The Journal of Economic Asymmetries 28 (2023) e00326

Contents lists available at ScienceDirect

The Journal of Economic Asymmetries

journal homepage: www.elsevier.com/locate/jeca

Do petrol prices rise faster than they fall? Evidence from the UK retail and wholesale petrol sectors☆

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ARTICLE INFO

JEL classification:
C22
C32
D40
L16
Q41

Keywords:
Petrol prices
Crude oil prices
Asymmetries
Retail petrol sector
Wholesale fuel sector
UK

ABSTRACT

This study investigates the presence of price asymmetries in the UK retail and wholesale petrol sectors over the period of January 2020–July 2022. The scope of this research is to explore whether petrol prices rise faster than they fall according to changes in input costs, namely fuel and international crude oil prices for the retail and wholesale sector respectively. As the time sample considers the shocks of covid-19 restrictions and rising inflation, the presence of structural breaks is assumed which may contribute to asymmetric behaviour. The Autoregressive Distributive Lag (ARDL) approach is implemented in the pricing equation of the model by formulating four versions for each sector, according to the presence of asymmetries and price-cost margins. The results provide significant evidence of price asymmetries in the retail petrol sector; however, such asymmetries are less pronounced over high margin periods. The wholesale sector is found to be more flexible to changes in crude oil prices as asymmetries are less persistent throughout the sample. Therefore, consumers face rigid petrol prices because of retail firms' decisions, which should be the focus of policy makers.

1. Introduction

Global developments have caused international crude oil prices to fluctuate violently over the last years. During the beginning of the covid-19 pandemic, the price of crude oil dropped to $3.32 per barrel in April 2020, whilst it exceeded $120 per barrel in June 2022 because of surging global inflation and soaring energy prices.[1] This outcome is complemented by the increasing rate of financialization of the global oil market which has been contributing to high volatile prices over the years (Le Pen and Sévi, 2017). Such fluctuations affect the refinery and pump price levels significantly, thus introducing the concept of asymmetry and the question of whether wholesale and retail price adjustment is flexible to crude oil price dynamics. There are several studies in the literature arguing in favour of price rigidities in the oil markets, focusing on the decisions made by retail firms (Apergis et al., 2018; Bacon, 1991; Borenstein et al., 1997; Brown and Yucel, 2000). However, as the role of refineries is quite important in the oil distribution network, there are studies that also focus on the pricing decisions of the wholesale sector (Borenstein and Shepard, 2002; Hastings and Gilbert, 2005).

☆ This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
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[1] The spot price of Europe Brent was $14.24 in April 2020 and $127.4 in June 2022 per barrel. For more information, see the US Energy Information Administration (EIA) statistics.

https://doi.org/10.1016/j.jeca.2023.e00326
Received 26 January 2023; Received in revised form 10 July 2023; Accepted 7 August 2023
Available online 15 August 2023

The current study attempts to investigate those issues by considering the impact of international crude oil prices on the refining sector and subsequently, the effects of wholesale price on pump price levels. By adopting this approach, this paper departs from the assumption that crude oil prices exert a direct effect on pump prices but instead, it focuses on the fact that they are transmitted through the price setting of refining firms. Moreover, the price-cost margin in both sectors is taken into consideration to investigate whether price asymmetries are more pronounced over periods of high margins because of market power. The UK petrol sectors will be used as a case study given that there have been several papers studying those markets by following several approaches and obtaining various outcomes.

As there are mixed results presented for the UK petrol market dependent on various conditions (Bacon, 1991; Galeotti et al., 2003), the current approach employs weekly data over the period of January 2020–June 2022 to investigate the presence of price asymmetries in the UK wholesale and retail petrol sector.[2] Several papers use either weekly or monthly datasets to study price asymmetries given that high frequency data provide more accurate results (Godby et al., 2000; Bermingham and O'Brien, 2011; Kristoufek and Lunackova, 2015; Boroumand et al., 2016; Blair et al., 2017).[3] Moreover, the distribution network between refineries and petrol stations is taken into consideration to investigate how crude oil price levels affect wholesale prices and subsequently, how the retail prices respond to changes in the wholesale pricing decisions.

To this end, the empirical model consists of two major equations, one for the wholesale and one for the retail sector, where price changes are regressed against fluctuations in input costs and the level of demand. Moreover, price asymmetries are investigated under both normal and high price-cost margin periods to test whether wholesale and pump prices are subject to market power exploitation strategies (Deltas, 2008; Olayungbo and Ojeyinka, 2022; Valadkhani et al., 2021; Verlinda, 2008). The methodological approach to estimate the equations uses an Autoregressive Distributive Lag (ARDL) model in the presence of structural breaks to study the dynamics of wholesale and retail price fluctuations,[4,5]. The main scope of the model is to investigate whether downward price rigidities are evident in the UK petrol sectors and whether periods of high price-cost margins contribute to this outcome. Finally, as the time sample covers the span of the covid-19 pandemic and the recent spell of increasing inflation, structural breakpoints are considered in the estimation process to capture the effects and the significance of breaks on the dynamics of petrol prices.

This paper is organised as follows: Section 2 presents the literature review; Section 3 presents the methodological approach and data collection; Section 4 discusses the empirical findings; and section 5 offers a conclusion.

2. Literature review

Several studies attempt to investigate the dynamics of petrol prices and particularly, their response to market variants, such as input costs and market power exploitation. Bacon (1991) focused on the identification of such asymmetries as retail prices tend to adjust differently to changes in input costs. When such costs increase, retailers are quite flexible by increasing pump prices; however, when costs decrease, there is a strong downward price rigidity as they can acquire more profits for a short period. This asymmetric behaviour is known as "rockets and feathers".[6] Nevertheless, as competitors realise that they can enjoy more profits by lowering prices, the whole sector will eventually adjust to such fluctuations and restore equilibrium to the market. Manning (1991) also argues that petrol prices exert fast adjustment rates to changes in input costs, including oil prices. This outcome occurs mainly because there is a stable relationship between the level of excise duty, spot oil price and petrol price. To this end, the presence of structural distortions significantly influences the degree of market competition, thus shaping pricing decisions and the time of adjustment to changes in input costs (Brown & Yücel, 2002).

Borenstein and Shepard (2002) note that the presence of price rigidities in the wholesale sector is quite significant because of market power and the ability of refining firms to slow down their adjustment whenever crude oil prices fall. Delpachitra (2002) argues that the presence of market power in the refining sector is an important parameter of price stickiness because pump prices do not respond directly to changes in international crude oil prices. Instead, they respond to domestic wholesale prices and for this reason, they appear to exert a weak adjustment process. Hastings and Gilbert (2005) support this outcome and argue that refineries may have power over the price level due to vertical integration, which provides them the opportunity to compete both in wholesale and retail markets. Bragoudakis et al. (2020) also note that refineries set their price-cost margin according to changes in crude oil prices and then pass it through to retail firms and consumers. On the other hand, Kaufmann and Laskowski (2005) support that the US refining sector does not exhibit any price asymmetries and quickly adjusts to changes in international crude oil prices. Therefore, the degree of market

[2] One major setback in the current dataset is the inclusion of sectorial instead of firm-level data due to limitations across several variables. This means that price-cost margins can only be calculated for time periods and not for specific regions or locations.

[3] Eleftheriou et al. (2019) and Bragoudakis et al. (2020) employ daily datasets arguing that there are potential effects and improvements on daily price fluctuations in the petrol market. However, as there are restrictions in daily data, the best alternative for the current study was to use weekly data.

[4] Several studies use asymmetric error correction models or panel regression analysis according to the structure of the datasets (Boroumand et al., 2016; Kilian, 2010; Liu et al., 2010; Sen, 2003).

[5] Bai (1997) and Bai and Perron's (1998, 2003) breakpoint tests are used to check whether any breaks persist in the long-run equations. Subsequently, the extended Augmented Dickey-Fuller (ADF) unit root test proposed by Perron (1989, 1997) and the cointegration test developed by Gregory and Hansen (1996) are employed to thoroughly investigate the presence of breakpoints in the equations and thus, include them in the final ARDL formulation of the model.

[6] For more information, see Cook and Fosten (2019).

power may be a crucial determinant of sticky prices as refineries may choose to enjoy higher profits over a short period by slowing down price adjustment.

Moreover, Borenstein et al. (1997) highlight the importance of pricing decisions in the retail sector and particularly, their response to international crude oil price changes. Their main argument is that pump prices are quite asymmetric to such changes as they tend to rise faster than they fall. Atil et al. (2014) and Apergis et al. (2018) also reach the same conclusion for certain countries as there is strong evidence of asymmetry between crude oil and pump prices. However, the latter study diversifies the main findings as structural characteristics within economies result in different rates of price adjustment or no asymmetry at all. Angelopoulou and Gibson (2010) complement this line of reasoning by providing significant evidence of no asymmetric behaviour in the Greek petrol markets; nevertheless, structural characteristics such as market power greatly influence firms' pricing decisions and dictate competitive conduct across the markets. Ederington et al. (2021) also support this narrative as they argue that petrol prices react strongly to oil-specific demand shocks, but they are relatively weak to structural oil-supply shocks.[7]

For the UK economy, Galeotti et al. (2003) study both refining and pump price levels in the UK markets and conclude that asymmetries with crude oil price levels are quite evident as firms attempt to take advantage of prolonged periods of sticky prices until they start to fall because of competition. Wlazlowski (2001) also argues that asymmetries emerge due to production lag, inventory effects and the long-run presence of market power. Nagy Eltony (1998) and Reily and Witt (1998) support this outcome by showing that there is a strong asymmetric behaviour of retail petrol prices to changes in crude oil prices. However, Apergis and Vouzavalis (2018) find no significant evidence of asymmetries between crude oil and retail prices, thus suggesting that the UK petrol market has not been subject to significant price rigidities over recent years.

To this end, there is strong evidence that petrol prices are significantly affected by the pricing decisions of retailers and refineries. According to fluctuations in international crude oil prices, suppliers can exercise their power on the price level and boost their profitability in the short-term until such disturbances settle down and restore markets to their long-run state.

3. Methodology and data collection

The main objective of the study is based on the insights of Borenstein and Shepard (2002) and Borenstein et al. (1997) who argue that changes in international crude oil price exert a significant effect on both wholesale and retail petrol price levels. Their adjustment to such changes is asymmetric and particularly, they tend to respond faster to price increases than decreases, thus enhancing the argument of "rockets and feathers" (Bacon, 1991). Given that the ARDL approach is employed, the theoretical formulation of the dynamic behaviour of petrol prices and their response to changes in input costs is considered according to Verlinda (2008). The initial pricing equation is formulated as

$$p_t = a + \sum_{j=0}^{J+1} \beta_j w_{t-j} + \sum_{j=0}^{J+1} \gamma_j y_{t-j} + \sum_{k=1}^{K+1} \delta_j p_{t-k} + u_t \tag{1}$$

where p is the price level, w is the unit cost of inputs, y is the level of consumption and u is the error term which is assumed to be white noise. The formulation of the pricing equation allows for short-run fluctuations of the price level when there are changes in input costs and consumption levels. Moreover, as the model converges to a long-run state, prices will have to adjust to such changes and thus, it holds that $w_t = w_{t-1} = \ldots = w_{t-j} = \overline{w}$ and $y_t = y_{t-1} = \ldots = y_{t-j} = \overline{y}$, where $\overline{w}$ and $\overline{y}$ are the fixed values of w and y in equilibrium. The expected value of the pricing equation in long-run, conditional on the cost of inputs is given by

$$E(p_t | w_t = \overline{w}) = a + \sum_{j=0}^{J+1} \beta_j \overline{w} + \sum_{j=0}^{J+1} \gamma_j E(y_t | w_t = \overline{w}) + \sum_{k=1}^{K+1} \delta_j E(p_t | w_t = \overline{w}) \tag{2}$$

The level of consumption depends on the price level charged by the sector, so it is assumed that it is independent of changes in input costs. As consumers observe the final selling price, firms take into consideration fluctuations in the cost of inputs and pass them to the price level, so it holds that $E(y_t | w_t = \overline{w}) = \overline{y}$. Therefore, equation (2) is transformed into

$$E(p_t | w_t = \overline{w}) = \frac{a + \sum_{j=0}^{J+1} \gamma_j \overline{y} + \sum_{j=0}^{J+1} \beta_j \overline{w}}{1 - \sum_{k=1}^{K+1} \delta_j} = a' + \varphi \overline{y} + \psi \overline{w} \tag{3}$$

Equation (3) captures the long-run state of the pricing equation when price adjusts to changes in input costs and consumption is equal to its long-run value. According to the theoretical formulation of an ARDL model, φ shows the inverse elasticity of consumption with respect to the price level, whilst ψ expresses the responsiveness of the price level to changes in input costs. If the price-cost margin is defined by $\mu_t = p_t - w_t$, equation (3) is equivalent to

$$E(\mu_t | w_t = \overline{w}) = a' + \varphi \overline{y} + (\psi - 1) \overline{w} \tag{4}$$

Finally, when short-run fluctuations are considered in equation (1), according to which $\Delta p_t = p_t - p_{t-1}$, $\Delta w_t = w_t - w_{t-1}$ and $\Delta y_t =$

[7] See Ederington et al. (2019) for an extensive discussion on the role of asymmetries in petrol pricing decisions.

$y_t - y_{t-1}$, the short-run and long-run interactions amongst the model's parameters can be investigated by formulating the final version of the ARDL, which includes an error correction mechanism

$$\Delta p_t = \sum_{j=0}^{J} \beta_j^{'} \Delta w_{t-j} + \sum_{j=0}^{J} \gamma_j^{'} \Delta y_{t-j} + \sum_{k=1}^{K} \delta_j^{'} \Delta p_{t-k} + \\ + \lambda(p_{t-1} - \varphi y_{t-1} - \psi w_{t-1} - a^{'}) + u_t \tag{5}$$

Equation (5) captures the short-run and long-run relationship between the price level and the explanatory variables, when the number of lags in the model is defined. The coefficients $\beta_j^{'}$ and $\gamma_j^{'}$ show the short-run response of the price level to changes in input costs and consumption, while $\delta_j^{'}$ represent the effects of lagged price changes on the current value over the given period. The error correction mechanism shows the deviation of the pricing equation from its long-run relationship with the input costs and the level of demand, thus λ can be interpreted as the speed of adjustment to equilibrium. When the price level exceeds input costs by more than the long-run margin, it is expected that prices will start to fall by converging towards the value of those costs. If the demand curve is linear in the long-run and marginal costs are constant, it should be expected that ψ is equal to 1, thus suggesting a flexible price adjustment to changes in production costs.

Moreover, if price asymmetries are introduced in equation (5), an indicator function is included which is set equal to 1 when a certain condition is met; and zero otherwise. If it is assumed that demand is not subject to such asymmetries, the equation is transformed into

$$\Delta p_t = \sum_{j=0}^{J} \left(\beta_j^{'} + \beta_j^{'+} f\left(\Delta w_{t-j} > 0\right)\right) \Delta w_{t-j} \\ + \sum_{j=0}^{J} \gamma_j^{'} \Delta y_{t-j} + \sum_{k=1}^{K} \left(\delta_k^{'} + \delta_k^{'+} f(\Delta p_{t-k} > 0)\right) \Delta p_{t-k} + \\ + \lambda(p_{t-1} - \varphi y_{t-1} - \psi w_{t-1} - a^{'}) + u_t \tag{6}$$

where $\beta_j^{'+}$ and $\delta_k^{'+}$ account for positive asymmetries. This shows that whenever changes in the cost of inputs are followed by price changes subject to a degree of rigidity, the coefficients will be able to capture those effects and provide evidence of whether prices tend to rise faster than they fall. To this end, the empirical formulation of the model for the UK wholesale and retail petrol sectors is given by

$$\Delta pru_t = \sum_{j=0}^{J} \left(\beta_{1j} + b_{1j} mru\right) \Delta pwu_{t-j} + \sum_{j=0}^{J} \left(\beta_{2j} + b_{2j} mru\right) \Delta pwu_{t-j}^{+} + \sum_{j=0}^{J} \gamma_j \Delta y_{t-j} \\ + \sum_{k=1}^{K} (\delta_{1k} + d_{1k} mru) \Delta pru_{t-k} + \sum_{k=1}^{K} (\delta_{2k} + d_{2k} mru) \Delta pru_{t-k}^{+} \\ + \lambda_1 (pru_{t-1} - \varphi_1 y_{t-1} - \psi_1 pwu_{t-1} - \alpha_1) + \varepsilon_t \tag{7}$$

$$\Delta pwu_t = \sum_{j=0}^{J} \left(\xi_{1j} + h_{1j} mwu\right) \Delta pcr_{t-j} + \sum_{j=0}^{J} \left(\xi_{2j} + h_{2j} mwu\right) \Delta pcr_{t-j}^{+} + \sum_{j=0}^{J} \rho_j \Delta lu_{t-j} \\ + \sum_{k=1}^{K} (\theta_{1k} + r_{1k} mwu) \Delta pwu_{t-k} + \sum_{k=1}^{K} (\theta_{2k} + r_{2k} mwu) \Delta pwu_{t-k}^{+} \\ + \lambda_2 (pwu_{t-1} - \varphi_2 lu_{t-1} - \psi_2 w_{t-1} - a_2) + u_t \tag{8}$$

where Δ denotes first difference order, *pru* is the retail price charged by petrol stations, *pwu* is the wholesale price of refineries, *pcr* is the price of crude oil expressed by the Europe Brent Spot Price, *y* corresponds to petrol consumption denoted by the volume of sales, *lu* is the volume of deliveries to petrol stations by refineries, *mru* and *mwu* are the price-cost margins in the retail and wholesale sector respectively formulated as: $mru = pru - pwu/_{pwu}$ and $mwu = pwu - pcr/_{pcr}$,[8,9] and ε and u are random disturbances. Moreover, the superscript of "+" denotes that the variable is censored from below at zero, thus serving as a parameter of asymmetric behaviour (Deltas, 2008). Finally, λ_i reflect the speed of the model's adjustment to a long-run state depicted by the error correction mechanisms (ECM). This means that retail and wholesale prices converge towards a sustainable fixed state due to a mean reversion effect.

To this end, the empirical process follows the insights of Deltas (2008), under which the presence of price asymmetries and price-cost margins are considered in the estimation of equations (7) and (8) by using four different versions of the model. The first version is a symmetric formulation without taking into consideration price-cost margins; the second version is a symmetric formulation where price adjustment depends on the price-cost margins; the third version is an asymmetric formulation independent of price-cost

[8] The price-cost margins capture the gap between the price and cost levels in each sector. They are not correlated to the error term as their formulation is independent of the current period *T*.

[9] One of the limitations of this indicator is the exclusion of transportation costs and local market conditions. As this study focuses on the aggregate retail and wholesale petrol sectors, it is assumed that transportation costs are embodied in the wholesale price level, whilst local market conditions are partially reflected by the final retail price level.

margins; and the fourth version is an asymmetric formulation dependent on the price-cost margins of the retail and wholesale petrol sectors. This approach aims to investigate the presence of price asymmetries in the sectors and whether, they depend on the presence of price-cost margins over a long period of time. Therefore, versions 1, 2, and 3 are estimated to check the robustness of version 4's results and they focus on the parameters affecting asymmetric behaviour.

The implementation of the ARDL approach provides several advantages to the formulation of the current model. It can effectively take into consideration endogeneity issues by using lagged values of the dependent variable as regressors, which mitigates the problem of simultaneity bias and obtains consistent and efficient estimates. It also performs well with any sample sizes, which is particularly advantageous when dealing with time series data that may have limited observations. Finally, it enables the analysis of long-run equilibrium relationships as it provides insights into the dynamic adjustment process and the speed at which variables converge to their long-term equilibrium levels. Under this approach, both short-term and long-term fluctuations can be studied, allowing the use of several model formulations, including the addition of structural breaks across the sample. To this end, the ARDL approach is the most fitted for the delivery of the current model and its empirical insights.

The dataset comprises of weekly data for the UK retail and wholesale petrol sectors over the period 22/1/2020-6/7/2022, where the number of observations is set to 129 per variable, and it is obtained by the UK government, the Royal Automobile Club (RAC) foundation and the US Energy Information Administration (EIA) databases[10]. The main intention of the given sample is to study how the UK petrol sectors performed over a period of two severe shocks and whether, price asymmetries were evident to cost fluctuations.[11] Those periods refer to the covid-19 pandemic in March 2020 and the initiation of quantitative tightening by the Bank of England in March 2022.[12] Weekly datasets provide a relatively high accuracy of studying sticky prices in the market and thus, they improve the explanatory power of the underlying model.

To this end, structural breaks are introduced in equations (7) and (8) to investigate their presence and significance on price fluctuations. Each breakpoint dummy variable is equal to zero before the break date; and equal to one afterwards. The Bai (1997) and Bai and Perron (1998, 2003) multiple breakpoint tests are used to check the presence of breaks in the pricing equation of each sector.[13] A linear regression with T periods and m breaks producing j regimes is given by

$$y_t = X_t^{'}\beta + Z_t^{'}\delta + u_t \tag{9}$$

where X is a set of variables that do not vary across regimes and Z is a set of variables with regime specific coefficients. The break-date point is defined as the first date of the subsequent regime by setting $T_0 = 1$ and $T_{m+1} = T + 1$. The sequential procedure begins by considering the whole sample and a test of parameter consistency with an unknown break is performed. If the null hypothesis is rejected, the breakpoint is determined and thus, the sample is divided into two sub-samples. The same process is applied in each of those sub-samples until the null hypothesis is accepted.[14]

Subsequently, the extended ADF approach as developed by Perron (1989, 1997) is used to identify the presence of unit roots in the time series under the assumption that a known breakpoint persists. Two versions of the model are considered to treat the break dynamics: the Innovational Outliner (*IO*) and the Additive Outliner (*AO*). The former outliner assumes that the break follows the same dynamic path as the innovations, while the latter one assumes that breaks occur immediately. The null hypothesis assumes that the time series follow a unit root process with a known breakpoint against the alternative of a trend stationary series. Therefore, the following equations are given for the *IO* and the *AO* formulations respectively

$$y_t = \mu + \beta t + \theta DU_t(T_b) + \gamma DT_t(T_b) + \omega D_t(T_b) + a y_{t-1} + \sum_{i=1}^{K} a_i \Delta y_{t-i} + u_t \tag{10.1}$$

$$y_t = \mu + \beta t + \theta DU_t(T_b) + \gamma DT_t(T_b) + \psi(L) + \varepsilon_t \tag{10.2}$$

where $DU_t(T_b)$ *and* $DT_t(T_b)$ are an intercept and trend break dummy variables equal to zero for all dates prior to the break and equal to 1 thereafter, $D_t(T_b)$ is a one-time break dummy variable which is equal to one on the break date and zero otherwise, $\psi(L)$ is a lag

[10] Any error in the formulation of the dataset lies with the author.

[11] According to the U.S. Energy Information Administration (EIA) (2022), the UK economy is the second-largest producer of petroleum products and natural gas in OECD Europe. However, as production has been declining over the last years, the UK has become a net importer of crude oil after 2005. Moreover, government revenue from crude oil and natural gas production were £248 million over 2020–2021, showing that their contribution to the UK GDP is quite significant.

[12] The nominal interest rate set by the Bank of England could be an additional variable to the current model; however, as weekly price data are employed, that would require the use of a mixed data sampling (MIDAS) approach which would introduce several limitations to the investigation of price asymmetries.

[13] The Bai-Perron test (1998, 2003) is carried out by assuming L+1 vs L sequentially determined breaks in the long-run equation of each sector, whilst the Bai test (1997) assumes the presence of breaks in all recursively determined partitions of the equations.

[14] According to Bai (1997), breakpoints are re-estimated when they are obtained from a sub-sample containing more than one breaks.

polynomial capturing a stationary ARMA process and ε_t and u_t are *i.i.d.* innovations,[15,16].

The last step corresponds to the Gregory and Hansen (1996) cointegration test under which the ADF, Z_a and Z_t type tests are used to check the null hypothesis of no cointegration against the alternative of cointegration with a level or regime shift in the cointegrating vector. In particular, the level shift (C) and the regime shift (C/S) formulations are given by

$$y_t = a_0 + a_1 D_{1t} + \beta_0 X_t + u_t \tag{11.1}$$

$$y_t = a_0 + a_1 D_{1t} + \beta_0 X_t + \beta_1 D_{1t} X_t + u_t \tag{11.2}$$

where a_0 and a_1 are the intercept coefficients, β_0 and β_1 are the slope coefficients and D_{1t} is a time dummy variable equal to zero for all dates prior to the break and one thereafter. The three tests are given by

$$ADF^* = infADF(\tau) \tag{11.3}$$

$$Z_t^* = inf\ Z_t(\tau) \tag{11.4}$$

$$Z_a^* = inf\ Z_a(\tau) \tag{11.5}$$

They are calculated for each possible shift in equations (11.1) and (11.2) and ultimately, the smallest value is chosen for each test for every possible breakpoint.

4. Results and discussion

The estimation process of the ARDL approach is implemented to investigate the significance of asymmetries in the UK retail and wholesale petrol sectors when the price-cost margin is considered. According to the interactions between the sectors and the dynamics of the international crude oil price level, the presence of asymmetries will reflect the strategic price settings of the sectors, contributing to the current empirical literature.

Table 1 shows the descriptive statistics of the parameters. The retail price level is on average equal to 1.31 pounds, while wholesale prices averaged 95 pence, thus reflecting a gap of 38%. Both indicators have also been increasing over this period by 0.49 and 0.34 pence respectively, showing that retail prices are more susceptible to upward pressure than wholesale prices. This argument is also complemented by the standard deviation of weekly changes of the retail price, equal to 1.60 pence, which is lower compared to the value of wholesale price changes. This means that the weekly retail price series “dampens” wholesale price changes, suggesting that retail prices are rigid, and they do not fully transmit short-run fluctuations in the wholesale price level (Deltas, 2008). Changes in the volume of retail sales and wholesale deliveries are negative on average because of the shock of the covid-19 pandemic and lockdown restrictions.

Table 1
Descriptive analysis of data.

Variables	Obs.	Mean	Std. Dev.	Min	Max
pru	129	131.28	20.72	104.86	191.55
Δ*pru*	128	0.49	1.60	−7.19	7.53
pwu	129	95.53	17.82	67.7	148.86
Δ*pwu*	128	0.34	3.06	−11.14	16.14
pcr	129	34.07	13.85	7.22	64.61
Δ*pcr*	128	0.19	2.13	−8.61	7.64
yu	129	41965.5	9275.5	9768	59061
Δ*yu*	128	−47.77	3882.6	−26896	15498
lu	129	42049.6	8938.6	14259	64234
Δ*lu*	128	−26.47	4019.6	−22538	8596
mru	129	0.13	0.02	0.06	0.23
mwu	129	2.18	1.20	0.90	8.64

Notes: Data are obtained for the period 22/1/2020-6/7/2022.

[15] According to Perron (1989), Perron and Vogelsang (1992a, 1992b), and Vogelsang and Perron (1998), there are four model specifications depending on the assumptions for the trend and break behaviour. In the current study, breaks in both trend and intercept are considered.

[16] The null hypothesis in equation (10.1) is evaluated by applying the *t*-statistic for each of the underlying parameters; whilst the estimation process for equation (10.2) follows two-steps. In the first step, the *OLS* estimator and the intercept, trend and break variables are used to detrend the series and then, the detrended series are used to test for a unit root.

Figs. 1 and 2 capture the dynamics of the price indicators over this period and they have been increasing significantly after October 2021 because of disruptions in global supply chains. The gap between wholesale and crude oil prices is higher than the one between retail and wholesale prices, but it has been narrowing down since April 2020; however, as the former ratio has been steadily falling, the latter follows more volatile changes with an upward trend. This means that when prices increase, their gap is more stretched than when they are decreasing. Figs. 3 and 4 also show that the price-cost margin in the retail sector follows this pattern, especially over the last months of the sample as there are significant changes both to the downside and the upside. Therefore, movements of the retail price level do not always follow the dynamics of wholesale prices as they appear to be increasing periodically, pointing towards the presence of response asymmetries.

To this end, the importance of the current period necessitates the investigation of structural breakpoints across the sample and whether, they exert a significant effect on the ARDL model. The tests introduced by Bai (1997) and Bai and Perron (1998, 2003) are used and the results are presented in Table 2. 3 and 5 breakpoints are suggested for the retail and the wholesale petrol sectors respectively by confirming the presence of several disturbances across the period. Moreover, the unit root tests presented in Table 3 suggest the presence of first order integration across several series of the study, especially when the innovation and additive outlier approaches are introduced, under which a breakpoint is assumed in each one of the series (Perron, 1989, 1997). Finally, the cointegration tests of Johansen and Juselius (1990) and Gregory and Hansen (1996) are presented in Table 4 and reject the null hypothesis of no cointegration amongst the variables of the model, thus supporting the presence of a long-run relationship both in the retail and the wholesale petrol sectors.

The empirical estimates for the UK retail petrol sector are presented in Table 5, where the four versions of equation (7) are implemented. The coefficient of Δpwu is positive in the fourth version of the model, suggesting a gradual adjustment between retail and wholesale prices in the presence of asymmetries.[17] Interactions between Δpru and its lagged values are positive and significant

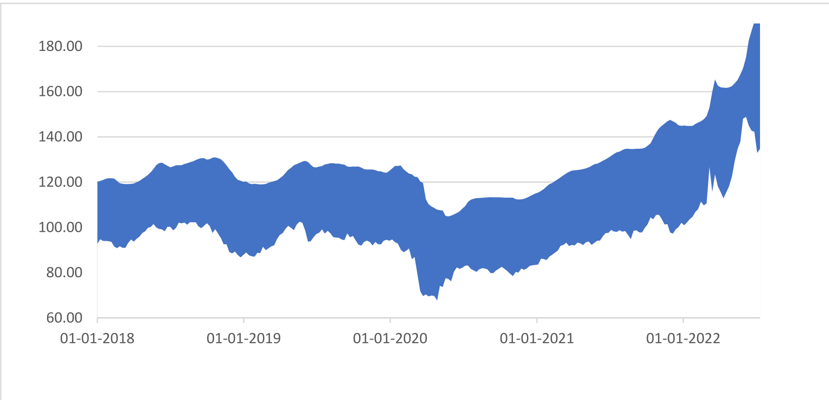

Fig. 1. Retail and wholesale petrol price fluctuations.
Notes: Data obtained by the RAC foundation database.

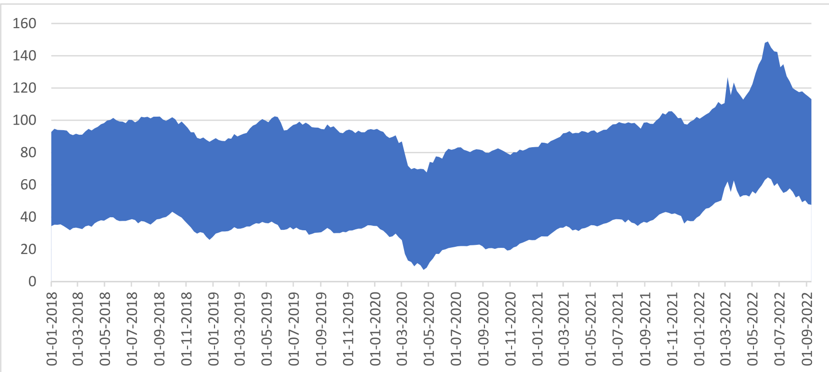

Fig. 2. Wholesale and Europe Brent Spot price fluctuations.
Notes: Data obtained by the RAC foundation and Energy Information Administration databases.

[17] The remaining versions of the model report insignificant results, showing no evidence of adjustment in the short run. This means that the presence of asymmetries and margins in the model boost the explanatory power of the regressors significantly.

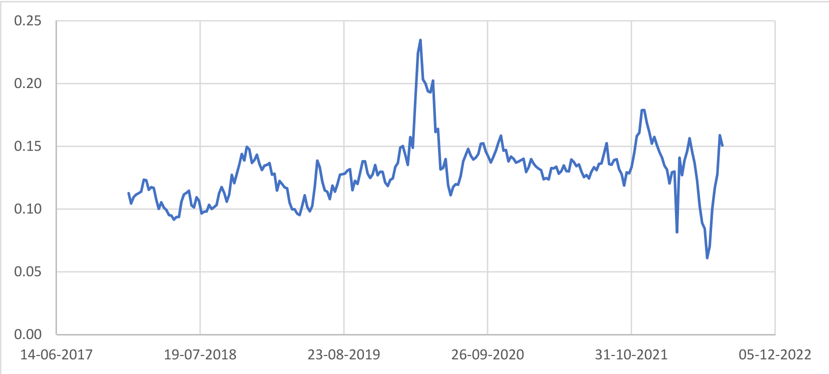

Fig. 3. Price-cost margin in the UK retail petrol sector.
Notes: The price-cost margin is denoted by the retail and the wholesale price levels in the market. Data obtained by the RAC foundation database.

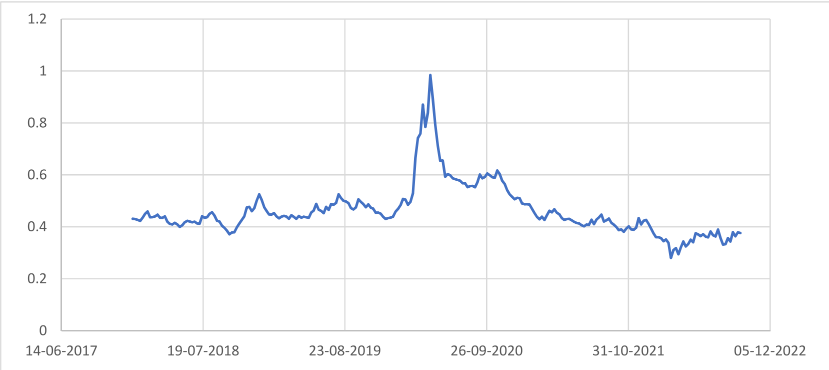

Fig. 4. Price-cost margin in the UK wholesale petrol sector.
Notes: The price-cost margin is given by the wholesale price level and the Spot Price of Europe Brent. Data obtained by the RAC foundation and Energy Information Administration databases.

Table 2
Breakpoint tests.

Sectors	Bai-Perron test (L+1 vs L sequentially determined breaks)	Bai test (breaks in all recursively determined partitions)
Retail sector	4/11/20, 9/3/22, 1/6/22	4/11/20, 9/3/22, 1/6/22
Wholesale sector	13/5/20, 14/7/21, 27/10/21, 9/3/22, 1/6/22	13/5/20, 14/7/21, 27/10/21, 9/3/22, 1/6/22

Notes: The Bai (1997) and Bai and Perron (1998, 2003) tests were run setting a 5% trimming percentage and 10 maximum levels at the 5% level of significance.

only in the first two versions of the model. This shows that fast adjustments do not experience any significant reversion in the short run. The inverse elasticity of consumption with respect to the retail price level is positive and smaller than one when it is significant, showing that higher demand for petrol tends to increase prices in the second week, while the effect dissipates afterwards. When the sector is operating under periods of high margins, any reversion in retail price changes is not pronounced, whilst they adjust faster to changes in wholesale prices, and they start to slow down over the second week (see Table 4).

Moreover, the coefficients of Δpwu^{+} are positive and significant, showing a faster response by the retail price to wholesale price increases than decreases. The lagged values confirm that such asymmetries persist over time, at least until the third week, and then dissipate. This outcome is also supported by the interactions between Δpru and the lags of $\Delta pr\,u^{+}$, showing that asymmetries in the retail price level initially increase, and then start to gradually fall at a slow rate. Over periods of high margins, it is found that asymmetries are less pronounced as they start to shrink over time. The results obtained by the fourth version provide a slightly better fit compared to the restricted versions of the model as more coefficients are statistically significant, thus improving the accuracy of the regression.

Table 3
Conventional and breakpoint unit root tests for the retail and wholesale sectors.

Variables	*ADF*	*PP*	*Innovation Outlier*	*Additive Outlier*	*Breakpoint (IO)*	*Breakpoint (AO)*
pru	−2.64 [0.26]	−2.42 [0.36]	−3.85 [0.61]	−3.80 [0.64]	9/3/22	23/2/22
Δpru	−5.21** [0.00]	−6.07** [0.00]	−7.79** [0.00]	−7.85** [0.00]	25/3/20	25/3/20
pwu	−4.96** [0.00]	−3.40 [0.05]	−7.20** [0.00]	−6.35** [0.00]	20/3/22	16/2/22
Δpwu	−11.90** [0.00]	−11.91** [0.00]	−13.90** [0.00]	−14.11** [0.00]	18/3/20	18/3/20
yu	−2.93 [0.15]	−2.93 [0.15]	−4.53 [0.22]	−4.80 [0.12]	22/4/20	29/4/20
Δyu	−8.26** [0.00]	−8.05** [0.00]	−12.14** [0.00]	−12.14** [0.00]	13/8/20	13/8/20
$mru * pru$	−4.62** [0.00]	−3.70* [0.02]	−5.87** [0.00]	−5.40* [0.02]	22/7/20	27/5/20
$mru * pwu$	−3.52* [0.04]	−3.55* [0.03]	−12.01** [0.00]	−11.16** [0.00]	15/4/20	15/4/20
pcr	−3.99* [0.01]	−3.90* [0.01]	−6.96** [0.00]	−6.81** [0.00]	15/4/20	15/4/20
lu	−3.14 [0.10]	−3.53* [0.04]	−5.54* [0.01]	−5.71* [0.01]	6/5/20	29/4/20
Δlu	−8.28** [0.00]	−7.97** [0.00]	−15.39** [0.00]	−15.65** [0.00]	25/3/20	25/3/20
$mwu * pwu$	−3.33 [0.06]	−3.54* [0.04]	−11.73** [0.00]	−10.96** [0.00]	15/4/20	15/4/20
$mwu * \Delta pwu$	−4.95** [0.00]	−10.93** [0.00]	−16.60** [0.00]	−16.71** [0.00]	15/4/20	15/4/20
$mwu * pcr$	−3.04 [0.12]	−3.39 [0.05]	−8.08** [0.00]	−7.82** [0.00]	15/4/20	15/4/20
$mwu * \Delta pcr$	−10.64** [0.00]	−10.63** [0.00]	−14.93** [0.00]	−15.10** [0.00]	15/4/20	15/4/20

Notes: ADF is the Augmented Dickey-Fuller test (Dickey and Fuller, 1979) and PP is the Phillips-Perron test (Phillips and Perron, 1988). The extended ADF test through innovation and additive outlier models are employed as proposed by Perron (1989,1997). The breakpoint is selected by using the Dickey-Fuller method and the lag length is selected based on Schwarz criterion. The values are *t*-statistic values. The values in brackets are *p*-values. Δ denotes first differences. The tests are conducted including a trend and intercept. Rejection of the null hypothesis suggests stationarity.
* Rejection of the null hypothesis at the 5% level of significance.
** Rejection of the null hypothesis at the 1% level of significance.

Table 4
Johansen and Gregory-Hansen cointegration tests.

Sectors	*Trace statistic*	*Max − Eigen statistic*	*ADF*	Z_t	Z_a	*Breakpoints*
Retail sector	66.65** [0.00]	33.55** [0.00]	−7.08** [0.00]	−7.41** [0.00]	−80.94* [0.04]	27/1/21
Wholesale sector	93.32** [0.00]	53.61** [0.00]	−7.04** [0.00]	−13.05** [0.00]	−148.84** [0.00]	20/10/21

Notes: The trace and the max-eigen statistics are calculated according to the methodology of Johansen and Juselius (1990). The ADF, Z_t and Z_a statistics are obtained by the approach of Gregory and Hansen (1996). The values in brackets are *p*-values.
* Rejection of the null hypothesis at the 5% level of significance.
** Rejection of the null hypothesis at the 1% level of significance.

Finally, the long run state of the model is captured by the error correction mechanism, which is similar across the four versions. The coefficients of the retail price index are always negative and lower than one, showing the rate at which, the model converges to its long run state.[18] The coefficients of the wholesale price index are positive and lower than one, capturing the long run effect on retail prices and particularly, the fact that any increase in *pwu* will eventually be passed to the retailers as the ratio of the coefficients of pwu_{t-1} to $pr\ u_{t-1}$ is close to one. According to Deltas (2008), petrol stations derive their profits from fluctuations in the wholesale price level, as they respond quicker to price increases than decreases. On the contrary, they tend to lose profits because of price rigidity when wholesale prices tend to increase, especially over the last months of the sample.

To this end, the results for the UK retail petrol sector suggest that price asymmetries persist, and they tend to increase faster than they fall as retailers slowly adjust to cuts in fuel prices (Bacon, 1991; Nagy Eltony, 1998; Galeotti et al., 2003; Manning, 1991; Reilly and Witt, 1998). However, periods of high margins do not provide evidence of significant market power exploitation as the sector overall tends to exert a more flexible rate of adjustment to changes in wholesale prices, thus contradicting the findings of some studies in the literature (Borenstein and Sephard, 2002; Wlazlowski, 2001; Hastings and Gilbert, 2005). The four versions of the model show the fitness of the data in equation (7) as they are statistically significant. The price-cost margin and the asymmetry effects are also significant, thus confirming their importance in the model and the price dynamics across the retail petrol sector. Additionally, the inclusion of structural breakpoints is significant, except for the first version, justifying their presence across the sample and adding value to the empirical findings. This shows that price stickiness and asymmetric behaviour depend on temporary shocks that occurred on certain dates as they affect the dynamics of both retail and wholesale prices.

Table 6 presents the findings of equation (8) reflecting the conditions in the wholesale petrol sector. The coefficients of Δpwr and its lagged values are negative, indicating that fast adjustments experience some mean reversion. Changes in the spot price of Europe Brent

[18] On average, the model corrects about 10% of the error per week and thus, it is expected to reach its long run state over the tenth week.

Table 5
Estimates of the short-run and long-run dynamics in the petrol retail sector.

Variables	*Approach* 1: *Symmetric response*	*Approach* 2: *Symmetric response and margin effects*	*Approach* 3: *Asymmetric response*	*Approach* 4: *Asymmetric response and margin effects*
$\Delta pru(-1)$	0.24** [0.00]	1.32** [0.00]	−0.18 [0.11]	−0.49 [0.34]
$\Delta pru(-2)$	–	–	−0.10 [0.33]	–
Δpwu	0.01 [0.87]	0.07 [0.32]	0.06 [0.12]	0.65* [0.01]
$\Delta pwu(-1)$	−0.04 [0.21]	0.05 [0.46]	−0.15**[0.00]	0.47 [0.08]
$\Delta pwu(-2)$	0.01 [0.62]	0.08 [0.34]	0.12* [0.01]	−0.39 [0.10]
Δyu	−0.01* [0.01]	0.01 [0.86]	−0.01 [0.18]	−0.01 [0.34]
$\Delta yu(-1)$	0.01* [0.01]	0.01** [0.00]	0.01** [0.00]	0.01* [0.01]
$\Delta yu(-2)$	−0.01 [0.25]	0.01 [0.36]	0.01 [0.92]	0.01 [0.94]
$mru * \Delta pru(-1)$	–	−7.46** [0.00]	–	−3.77 [0.32]
$mru * \Delta pru(-2)$	–	−0.41 [0.35]	–	0.08 [0.86]
$mru * \Delta pwu$	–	−0.48 [0.34]	–	2.44* [0.03]
$mru * \Delta pwu(-1)$	–	−0.83 [0.14]	–	−3.19* [0.04]
$mru * \Delta pwu(-2)$	–	−0.54 [0.86]	–	3.34* [0.02]
$pru(-1)$	−0.18** [0.00]	−0.18** [0.00]	−0.15** [0.00]	−0.10* [0.01]
$pwu(-1)$	0.12** [0.00]	0.09** [0.00]	0.12** [0.00]	0.08** [0.00]
$yu(-1)$	−0.01* [0.01]	−0.01 [0.51]	−0.01 [0.61]	−0.01 [0.15]
Asymmetric response to positive changes				
$\Delta pru(-1)$	–	–	0.84** [0.00]	−1.22 [0.18]
$\Delta pru(-2)$	–	–	−0.21 [0.21]	2.33** [0.00]
Δpwu	–	–	0.12* [0.03]	0.63* [0.01]
$\Delta pwu(-1)$	–	–	0.15** [0.00]	−0.20 [0.47]
$\Delta pwu(-2)$	–	–	−0.20** [0.00]	0.77** [0.00]
$mru * \Delta pru(-1)$	–	–	–	8.87 [0.11]
$mru * \Delta pru(-2)$	–	–	–	−8.39** [0.00]
$mru * \Delta pwu$	–	–	–	−3.22* [0.04]
$mru * \Delta pwu(-1)$	–	–	–	1.45 [0.39]
$mru * \Delta pwu(-2)$	–	–	–	−7.27** [0.00]
No of obs.	126	126	126	126
R^2	0.69	0.75	0.79	0.87
$F-stat$	15.51** [0.00]	14.98** [0.00]	18.19** [0.00]	20.44** [0.00]
Significance of breakpoint dummies	8.35 [0.21]	20.37** [0.00]	15.41* [0.01]	20.81** [0.00]
Significance of margins	–	23.76** [0.00]	–	56.29** [0.00]
Significance of asymmetries	–	–	50.04** [0.00]	86.73** [0.00]

Notes: The model was estimated following the Autoregressive Distributed Lag (ARDL) methodology and the lag order was selected by using the Akaike information criterion (AIC). The breakpoints were selected according to the results of the Bai (1997), Bai and Perron (1998, 2003) and Gregory and Hansen (1996) tests. The values in brackets are *p*-values.
* Rejection of the null hypothesis at the 5% level of significance.
** Rejection of the null hypothesis at the 1% level of significance.

oil have a positive effect on Δpwr, suggesting a gradual adjustment process as well. The inverse elasticity of fuel deliveries to changes in the wholesale price level depict a positive effect, where positive changes in demand for refined fuel tend to increase wholesale prices.[19] Over periods of high margins, wholesale petrol prices adjust quickly to changes in Δpcr and any reversion is more pronounced. This means that refineries do not experience any significant degree of price stickiness as they do not exploit their power in the market.

Moreover, the coefficients of Δpcr^{+} and Δpwr^{+} are insignificant, suggesting that asymmetries in the sector are not evident and thus, wholesale prices flexibly adjust to changes in crude oil prices overall. Similar results are obtained over periods of high margins as asymmetries are less pronounced, showing that the wholesale petrol sector quickly adjusts to fluctuations in crude oil prices (Kaufmann and Laskowski, 2005)[20]. The long run estimates provide similar results as the retail sector, suggesting that any increase in *pcr* will eventually be reflected by the refineries on their price level, which ultimately is passed to retailers. The robustness of the results is also checked in Tables 7 and 8 when the Robust Least Squares estimator is implemented across the four versions of the model. This technique provides similar results as the ARDL approach, thus enhancing the structure of the model even further and the importance of the underlying parameters to the dynamics of the retail and wholesale petrol prices.

Those findings complement the studies of Galleoti et al. (2003) and Bragoudakis et al. (2020) who argue that refineries set their markups according to international crude oil prices, and they pass them to retailers eventually. This mechanism suggests that an investigation between retail and crude oil prices may be incomplete as it ignores the wholesale sector which may provide important insights. In the case of the UK petrol sectors, it is found that even if asymmetries are pronounced over the sample period, spells of high

[19] UK crude oil imports increased by 2% in 2021, showing that the UK economy is a net importer dependent on international markets (EIA, 2022). On the other hand, it is a net exporter of motor petrol and fuel oil as UK refineries produce more volume than it is domestically consumed.
[20] Peltzman (2000) also argues that market power is not a significant contributor to price asymmetries as firms are more focused on input price volatility and the presence of asymmetric menu costs.

Table 6
Estimates of the short-run and long-run dynamics in the wholesale sector.

Variables	*Approach* 1: *Symmetric response*	*Approach* 2: *Symmetric response and margin effects*	*Approach* 3: *Asymmetric response*	*Approach* 4: *Asymmetric response and margin effects*
$\Delta pwu(-1)$	−0.24** [0.00]	−0.95** [0.00]	−0.23 [0.15]	−0.62** [0.00]
$\Delta pwu(-2)$	–	−0.61** [0.00]	−0.31 [0.09]	−0.41** [0.00]
Δpcr	0.18** [0.00]	0.80** [0.00]	0.22** [0.00]	0.83** [0.00]
$\Delta pcr(-1)$	0.12** [0.00]	0.81** [0.00]	0.13* [0.02]	0.52** [0.00]
$\Delta pcr(-2)$	0.07* [0.02]	0.51** [0.00]	0.16* [0.01]	0.29** [0.00]
Δlu	−0.05* [0.01]	0.01 [0.11]	−0.04 [0.06]	0.01** [0.00]
$\Delta lu(-1)$	−0.01 [0.35]	0.01 [0.65]	−0.01 [0.74]	−0.01** [0.00]
$\Delta lu(-2)$	−0.01 [0.34]	0.01* [0.03]	−0.01 [0.63]	0.01 [0.89]
$mrw * \Delta pwu(-1)$	–	−0.01* [0.01]	–	−0.01** [0.00]
$mrw * \Delta pwu(-2)$	–	−0.01 [0.11]	–	−0.01 [0.79]
$mwu * \Delta pcr$	–	0.08** [0.00]	–	0.09** [0.00]
$mwu * \Delta pcr(-1)$	–	0.10** [0.00]	–	0.09** [0.00]
$mwu * \Delta pcr(-2)$	–	0.06** [0.00]	–	0.03** [0.00]
$pwu(-1)$	−0.38** [0.00]	−0.01 [0.62]	−0.41** [0.00]	−0.03** [0.00]
$pcr(-1)$	0.11** [0.00]	0.01 [0.15]	0.10** [0.00]	0.13** [0.00]
$lu(-1)$	0.01 [0.53]	0.01 [0.35]	0.01 [0.09]	0.11** [0.00]
Asymmetric response to positive changes				
$\Delta pwu(-1)$	–	–	0.04 [0.85]	−0.04 [0.51]
$\Delta pwu(-2)$	–	–	0.57* [0.02]	0.03 [0.49]
Δpcr	–	–	−0.08 [0.34]	−0.01 [0.80]
$\Delta pcr(-1)$	–	–	0.01 [0.87]	0.03 [0.24]
$\Delta pcr(-2)$	–	–	−0.16 [0.10]	0.04 [0.22]
$mwu * \Delta pwu(-1)$	–	–	–	0.02** [0.00]
$mwu * \Delta pwu(-2)$	–	–	–	0.01 [0.63]
$mwu * \Delta pcr$	–	–	–	−0.04** [0.00]
$mwu * \Delta pcr(-1)$	–	–	–	−0.01 [0.95]
$mwu * \Delta pcr(-2)$	–	–	–	−0.01 [0.60]
No of obs.	126	126	126	126
R^2	0.62	0.96	0.65	0.98
$F-stat$	11.54** [0.00]	150.34** [0.00]	8.69** [0.00]	204.47** [0.00]
Significance of breakpoint dummies	40.29** [0.00]	9.70 [0.13]	40.85** [0.00]	40.11** [0.00]
Significance of margins	–	160.33** [0.00]	–	205.84** [0.00]
Significance of asymmetries	–	–	6.02 [0.30]	104.64** [0.00]

Notes: The model was estimated following the Autoregressive Distributed Lag (ARDL) methodology and the lag order was selected by using the Akaike information criterion (AIC). The breakpoints were selected according to the results of the Bai (1997), Bai and Perron (1998, 2003) and Gregory and Hansen (1996) tests. The values in brackets are *p*-values.
* Rejection of the null hypothesis at the 5% level of significance.
** Rejection of the null hypothesis at the 1% level of significance.

price-cost margins do not boost those asymmetries significantly. This may be a result of the retail sector's response to consumer behaviour. As consumers observe that prices at petrol stations increase, they search for the cheapest alternative. However, as they realise that pump prices increase due to market-wide shocks, these prices are adjusted to fully reflect any increase in wholesale prices. This happens because when consumers reduce their search intensity, retailers have more incentives to keep their prices sticky and increase their profits. Moreover, as consumers expect that petrol prices will increase in the near future, they currently increase petrol consumption to benefit from lower prices. Fig. 5 shows that after the initial shock of covid-19 in March 2020, the volume of petrol sales increased prior to an increase in retail price, thus supporting the retailers' strategic decisions of slow price adjustments.

On the other hand, refineries are more flexible to changes in international crude oil prices as asymmetries are statistically insignificant or very weak over high margin periods. This shows that wholesale prices adjust quicker to crude oil price changes and thus, periods of asymmetries are less pronounced compared to the retail sector. This finding is an important addition to the literature as it supports the inclusion of the wholesale petrol sector in retail analysis because its exclusion would probably point to positive asymmetries between retail and crude oil prices. Therefore, it would not capture the flexible behaviour of the wholesale segment, leading to a biased investigation of the UK petrol markets.

5. Conclusion and policy implications

This study investigated the presence of response asymmetries across the UK retail and wholesale petrol sectors when the price-cost margin is used as a determinant of pricing decisions. Given that the underlying period includes the shocks of lockdown restrictions and rising inflation in the UK economy, the presence of structural breaks is also considered in the model. The empirical process estimates equations (7) and (8) under four versions, accounting for the presence of margins and asymmetries (Deltas, 2008). The results show that the retail petrol sector experiences significant price asymmetries over the sample period, denoting that prices rise faster than they fall as pump stations attempt to increase their profits. Such asymmetries are also affected by temporary shocks occurring in the

Table 7
Robustness results for the petrol retail sector.

Variables	*Approach* 1: *Symmetric response*	*Approach* 2: *Symmetric response and margin effects*	*Approach* 3: *Asymmetric response*	*Approach* 4: *Asymmetric response and margin effects*
Δpwu	0.01 [0.08]	0.19** [0.00]	−0.02 [0.14]	0.04 [0.46]
$\Delta pwu(-1)$	−0.06** [0.00]	−0.19** [0.00]	0.01 [0.73]	0.92** [0.00]
$\Delta pwu(-2)$	−0.05** [0.00]	0.30** [0.00]	−0.08** [0.00]	−1.14** [0.00]
Δyu	−0.01** [0.00]	−0.01** [0.00]	−0.01 [0.78]	−0.01 [0.74]
$\Delta yu(-1)$	0.01* [0.01]	−0.01 [0.98]	−0.01 [0.76]	0.01 [0.05]
$\Delta yu(-2)$	0.01** [0.00]	0.01 [0.28]	0.01* [0.03]	−0.01 [0.65]
$mru * \Delta pru(-1)$	–	1.79** [0.00]	–	−0.55 [0.06]
$mru * \Delta pru(-2)$	–	−0.35* [0.02]	–	0.79** [0.00]
$mru * \Delta pwu$	–	−1.05** [0.00]	–	0.68 [0.21]
$mru * \Delta pwu(-1)$	–	1.02** [0.00]	–	−5.84** [0.00]
$mru * \Delta pwu(-2)$	–	−2.39** [0.00]	–	7.83** [0.00]
$pru(-1)$	−0.10** [0.00]	−0.08** [0.00]	−0.06** [0.00]	−0.04** [0.00]
$pwu(-1)$	0.13** [0.00]	0.11** [0.00]	0.08** [0.00]	0.06** [0.00]
$yu(-1)$	−0.01** [0.00]	−0.01** [0.00]	−0.01* [0.02]	−0.01** [0.00]
Asymmetric response to positive changes				
$\Delta pru(-1)$	–	–	0.69** [0.00]	1.21** [0.00]
$\Delta pru(-2)$	–	–	−0.18** [0.00]	0.24 [0.42]
Δpwu	–	–	0.09** [0.00]	0.23* [0.04]
$\Delta pwu(-1)$	–	–	−0.07** [0.00]	−0.85** [0.00]
$\Delta pwu(-2)$	–	–	0.12** [0.00]	1.49** [0.00]
$mru * \Delta pru(-1)$	–	–	–	−4.92** [0.00]
$mru * \Delta pru(-2)$	–	–	–	−3.27 [0.15]
$mru * \Delta pwu$	–	–	–	−2.89** [0.00]
$mru * \Delta pwu(-1)$	–	–	–	4.58** [0.00]
$mru * \Delta pwu(-2)$	–	–	–	−10.49** [0.00]
No of obs.	126	126	126	126
R^2	0.51	0.61	0.62	0.57
$F-stat$	14.21** [0.00]	13.33** [0.00]	15.85** [0.00]	19.27** [0.00]
Significance of breakpoint dummies	6.15 [0.33]	18.86** [0.00]	16.03** [0.00]	18.56** [0.00]
Significance of margins	–	27.27** [0.00]	–	38.45** [0.00]
Significance of asymmetries	–	–	38.57** [0.00]	65.77** [0.00]

Notes: The estimation technique is the Robust Least Squares (RLS) and the lag order was selected by using the Akaike information criterion (AIC). The breakpoints were selected according to the results of the Bai (1997), Bai and Perron (1998, 2003) and Gregory and Hansen (1996) tests. The values in brackets are *p*-values.
* Rejection of the null hypothesis at the 5% level of significance.
** Rejection of the null hypothesis at the 1% level of significance.

economy; however, the findings of the model show that they are less pronounced throughout periods of high price-cost margins.

On the other hand, the wholesale sector shows flexibility to changes in international crude oil prices. The price setting of refineries quickly adjusts to such changes and high margin periods do not reflect any persistent rigidities in the dynamics of the wholesale price level. Consequently, refineries adjust their prices relatively fast to changes in crude oil prices, suggesting that asymmetries are not evident. This means that consumers face systematic price rigidities mostly because of retail decisions, which could have deteriorating effects on their disposable income and their purchasing power overall. This is an important observation made by this study as the exclusion of the refining fuel sector could lead to the presence of asymmetries between petrol and crude oil prices, entirely neglecting the flexible decisions of the wholesale segment.

Moreover, the presence of asymmetries does not imply that refineries and pump stations exploit their power in the market systematically as they are less pronounced over high margin periods. Therefore, the focus of policy makers should be to protect consumers over periods of persistent asymmetries in the retail segment of the sector. This means that anti-trust policies could investigate the degree of concentration in the market and conclude whether price rigidities can be prevented. In the case of the UK markets, where some firms are vertically integrated, policies should focus on both wholesale and retail sectors and investigate the main reasons of such asymmetries. However, a direct intervention into the competitive interactions of firms may not be efficient as market power exploitation is not a major contributor to price asymmetries. According to Peltzman (2000), market power is not correlated with asymmetries between refined fuel and crude oil, meaning that government intervention in the retail and wholesale petrol markets may reduce economic efficiency. If policy makers attempt to directly eliminate asymmetries through tax changes or inventory manipulation, this may have a negative effect on firms by experiencing a disruption in their economic activities and ultimately, such disruptions may be transferred to consumers via higher prices (Apergis & Vouzavalis, 2018).

To this end, as price rigidities are less evident over high margin periods, policy makers should examine the importance of market concentration and whether mergers and acquisitions reduce economic efficiency overall. When consumers pay higher prices than they should do, surplus is transferred towards firms by increasing their profits, which is an outcome that enhances income inequality. Consequently, firms that keep their prices rigid for the longest period enjoy an advantage over their competitors, they can boost their

Table 8
Robustness results for the wholesale sector.

Variables	*Approach 1: Symmetric response*	*Approach 2: Symmetric response and margin effects*	*Approach 3: Asymmetric response*	*Approach 4: Asymmetric response and margin effects*
Δpcr	0.15** [0.00]	0.83** [0.00]	0.26** [0.00]	0.80** [0.00]
$\Delta pcr(-1)$	0.14** [0.00]	0.11 [0.63]	0.17** [0.00]	0.01 [0.66]
$\Delta pcr(-2)$	0.05* [0.05]	−0.01 [0.10]	0.05 [0.25]	−0.03 [0.07]
Δlu	−0.04* [0.01]	−0.01 [0.30]	−0.03* [0.03]	0.01* [0.02]
$\Delta lu(-1)$	−0.03 [0.05]	−0.01 [0.07]	−0.02 [0.13]	−0.01** [0.00]
$\Delta lu(-2)$	−0.03* [0.03]	−0.01 [0.52]	0.01 [0.80]	0.01 [0.19]
$mrw * \Delta pwu(-1)$	–	0.01** [0.00]	–	−0.01** [0.00]
$mrw * \Delta pwu(-2)$	–	−0.01** [0.00]	–	−0.01 [0.89]
$mwu * \Delta pcr$	–	0.10** [0.00]	–	0.09** [0.00]
$mwu * \Delta pcr(-1)$	–	−0.01** [0.00]	–	0.02** [0.00]
$mwu * \Delta pcr(-2)$	–	0.01** [0.00]	–	−0.01 [0.73]
$pwu(-1)$	−0.10** [0.00]	−0.01* [0.02]	−0.06 [0.07]	−0.05** [0.00]
$pcr(-1)$	0.04* [0.01]	0.01* [0.04]	0.01 [0.70]	0.03** [0.00]
$lu(-1)$	0.03** [0.00]	0.01 [0.10]	0.02* [0.02]	0.01** [0.00]
Asymmetric response to positive changes				
$\Delta pwu(-1)$	–	–	−0.56** [0.00]	−0.01 [0.93]
$\Delta pwu(-2)$	–	–	0.31** [0.00]	0.06 [0.12]
Δpcr	–	–	−0.17* [0.01]	0.01 [0.84]
$\Delta pcr(-1)$	–	–	0.04 [0.53]	0.01 [0.81]
$\Delta pcr(-2)$	–	–	−0.07 [0.33]	0.01 [0.82]
$mwu * \Delta pwu(-1)$	–	–	–	0.03** [0.00]
$mwu * \Delta pwu(-2)$	–	–	–	0.01 [0.13]
$mwu * \Delta pcr$	–	–	–	−0.01 [0.36]
$mwu * \Delta pcr(-1)$	–	–	–	−0.06** [0.00]
$mwu * \Delta pcr(-2)$	–	–	–	−0.02* [0.03]
No of obs.	126	126	126	126
R^2	0.47	0.77	0.54	0.80
$F-stat$	15.27** [0.00]	59.23** [0.00]	17.95** [0.00]	73.33** [0.00]
Significance of breakpoint dummies	21.24** [0.00]	7.03 [0.21]	25.92** [0.00]	31.28** [0.00]
Significance of margins	–	92.38** [0.00]	–	118.66** [0.00]
Significance of asymmetries	–	–	21.32** [0.00]	63.74** [0.00]

Notes: The estimation technique is the Robust Least Squares (RLS) and the lag order was selected by using the Akaike information criterion (AIC). The breakpoints were selected according to the results of the Bai (1997), Bai and Perron (1998, 2003) and Gregory and Hansen (1996) tests. The values in brackets are *p*-values.
* Rejection of the null hypothesis at the 5% level of significance.
** Rejection of the null hypothesis at the 1% level of significance.

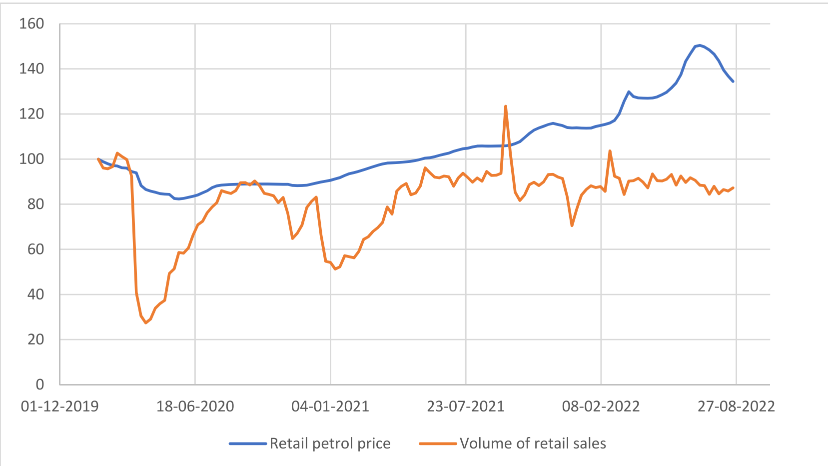

Fig. 5. Retail petrol price and volume of petrol sales indexes.
Notes: Data obtained by the RAC foundation the UK government databases.

investment and expand their activities in various markets, such as renewable energy markets. This means that their revenue streams will increase and ultimately, they may acquire more power and price control in the sector. For this reason, policy makers should identify such practices and act accordingly, rather than impose universal regulations across the market by affecting every participant firm.

The findings of this study significantly contribute to the pricing decisions of the UK retail and wholesale petrol sectors through the implementation of an ARDL approach under the presence of structural breaks. The use of weekly data also allows the model to identify breakpoints over the time sample and the results suggest that this assumption boosts the explanatory power of the model significantly. However, the main weakness of this model is the exclusion of individual refining firms and pump stations across the UK, which could provide a better interpretation of asymmetric behaviour. Under this approach, the factor of location would be an important addition in the model, as remote pump stations may have more incentives to keep their prices high for a longer period, thus capturing market power exploitation. As the current analysis stands, that factor cannot be considered in the model as pricing decisions are aggregated across the sector. Moreover, the investigation of pricing decisions made by vertically integrated firms could also enhance this outcome as many refineries are multi-product firms and the conditions of other fuel markets, such as diesel and kerosene, may influence their price-cost margin. Further research could implement the current ARDL model to account for individual firm characteristics and thus, provide a more accurate depiction of the UK petrol markets.

CRediT authorship contribution statement

Chrysovalantis Amountzias: I hereby declare that I, Chrysovalantis Amountzias, am the sole author of this research paper and that confirm sole responsibility for the following: study conception and design, data collection, Formal analysis, and interpretation of results, and manuscript preparation. I am also the corresponding author who will take primary responsibility for communication with the journal during the manuscript submission, peer review, and publication process.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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