Asymmetries in retail fuel prices in the European Union states

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This study estimates asymmetric transmission from crude oil prices to retail fuel prices in the European Union markets. Many methods have historically been used in similar research dealing with asymmetric output price responses. The choice of method, data frequency and range, the investigated country and other elements significantly influence the study results. This study focuses on selecting a process that corresponds to the theoretical starting points. Theoretical explanations of asymmetric price formation assume discretionary behaviour, which can be expressed by formulating adjustment costs in a linear exponential form. The specification of the output price reaction function and a systematic price bias caused by asymmetric price transmission can be derived from the formulation. Given the hypothesis of rational expectations of a price maker, the generalised method of moments is suitable for specification estimation. Because of the interconnectedness of different fuel markets in each country, system estimates can be applied using the generalised method of moments. Our results confirm price asymmetries at the retail level in all countries over the entire period for which data are available. The findings indicate that the focus should not be on whether retail price formation is asymmetric, but how significant price bias the asymmetry causes.

Keywords:
rockets and feathers, linear exponential adjustment cost function, generalised method of moments, price bias

Introduction

The current global focus has been to achieve carbon neutrality and a zero-emission economy in the short future; however, petroleum products remain essential economic commodities. Retail fuel prices are crucial for consumers' and firms' economic decision-making and planning.

According to many studies, beginning with Bacon (1991), retail fuel prices respond asymmetrically to changes in crude oil prices. Following an increase in crude oil prices, retail fuel prices tend to rise promptly, whereas if oil prices fall, fuel prices may decline slowly. This asymmetric retail petrol price adjustment has been termed the 'rockets and feathers' effect.

This evidence of asymmetric pricing aligns with consumer sentiments in some European countries and has attracted the attention of state competition authorities. Torrado–Escribano (2020) cited examples from Germany and Spain, where authorities intervened against petrol suppliers allegedly abusing a dominant market position.

Deltas–Polemis (2020) pointed out that the results depend on the design of the method used. The method of investigating asymmetry, the choice of the number of observations, the time frequency of the data and geographical and other specificities have an essential influence. The range of methods used is vast, including dummy variables, cointegration analysis, threshold autoregression models, estimation of multi-equation systems and regime-switching models. This study provides a detailed overview of the various methods used in the history of research into asymmetric price reactions.

An advanced formulation of theoretical starting points precedes the selection of an appropriate methodology. The literature review explains in detail four fundamental theories related to the examined asymmetry issue: oligopolistic coordination theory, the production and inventory cost of adjustment, search theory and the theory of strategic interactions. All four theories assume daily (or weekly) decision-making by a price maker who seeks to minimise the costs associated with discretionary behaviour.

The price maker faces non-linear adjustment price costs, which are higher if the input price falls and lower if the input price rises. Szomolanyi et al. (2022) used the linear exponential (LINEX) form of adjustment price costs. From the first-order condition of a firm minimising costs, it is possible to derive the econometric specification of reactions of fuel price changes to oil price changes. The specification makes it possible to estimate average weekly price biases caused by asymmetric discretionary reactions of the price maker.

This study will use the proposed approach to verify the asymmetric reactions of retail fuel prices in all European Union states. The superiority of the proposed approach lies in its consideration of the theoretical assumptions that price formation corresponds to discretionary decision-making. The approach is robust regarding data frequency (unlike other approaches, it ceases to be sensitive to it) and allows for simple and understandable geographical or temporal comparisons. The key question is no longer whether there is asymmetry but to what extent distortion occurs. This study is the first to estimate asymmetric fuel price responses across all European Union countries using this approach.

Literature review

In the literature review, we present an overview of various methods historically used to investigate asymmetric reactions of output prices, possible theoretical explanations for such behaviour and a summary of the results. In the overview of the results, we emphasise the earliest studies, recent research trends, primarily concerning the American retail fuel market, and the latest results on the European market.

Review of methods

According to Meyer–Cramon-Taubadel (2004), research into price asymmetries began with analysing price developments in agriculture. They consider Farrell's (1952) study on irreversible demand functions the first empirical work in this area. Dummy variables for price increases and decreases were used in their paper by Tweeten–Quance (1969). The product of the price and each of these dummy variables leads to the estimation of a pair of parameters, the equality of which is tested using the F test. Wolffram (1971), Houck (1977) and subsequently Ward (1982) modified this specification by using the products of dummy variables with price differences while incorporating the differences over several consecutive periods or focusing on their sums. For example, Karrenbrock (1991) and Duffy-Deno (1996) applied this methodology to fuel prices. Hahn (1990) attempted to generalise these approaches and proposed using the generalised switching model to analyse asymmetries.

Following the recognition of the non-stationarity of economic time series and the existence of cointegration, the methodology for investigating price asymmetries changed significantly. In the procedure developed by Engle–Granger (1987), the long-run relationship of non-stationary prices was first estimated. Once, the stationarity of the residuals was confirmed using the classic Dickey and Fuller test, an error correction model (ECM) incorporating asymmetries was estimated. Granger–Lee (1989) extended the ECM by incorporating lagged autoregressive terms. One of the first researchers to apply the ECM to fuel price asymmetry was Manning (1991), with a similar approach later adopted by Bettendorf et al. (2003). In the ECM, Cramon-Taubadel–Loy (1996) considered not only the separation of the correction term into positive and negative values (long-run asymmetry) but also the inclusion of dummy variable interactions with price differences and their lags in the short-term model component (short-term asymmetry). A different approach to estimating an ECM was proposed by Stock–Watson (1993), who combined the two-step procedure into a simultaneous estimation of the long-run relationship and the adjustment process. Manning (1991) compared both approaches. Enders–Granger (1998) modified the original procedure to consider and consistently estimate asymmetries in the long-run relationship. In their search for a unit root test for asymmetric adjustment, they utilised the threshold autoregressive model (TAR) proposed by Tong (1983). Balke–Fomby (1997) also examined asymmetries using the threshold autoregressive model within the cointegration framework.

In addition to the TAR model, Enders–Granger (1998) proposed the M-TAR model. Both have become popular methods for analysing price asymmetry. In the TAR model, positive and negative deviations from equilibrium are distinguished in the cointegration test. In the M-TAR model, positive and negative deviations of differences of deviations from equilibrium are distinguished. Additionally, Grasso–Manera (2007) used this model to analyse the fuel markets of several European countries.

Subsequently, regime-switching models began to be used to analyse asymmetries. Initially, deterministic models prevailed, where the threshold value depended on some characteristic related to the explanatory variables in the models, for example, the variability of the input price or the correction term in cointegration models. Grasso–Manera (2007) employed a deterministic model as an example of this approach. In contrast, Radchenko (2005) did not use deterministic models but instead adopted a specification where Markov chains govern the transition from one regime to another. Such a procedure is usually referred to as a Markov regime-switching model.

In addition to the single-equation models presented, several authors have analysed the behaviour and interconnections between the prices of different goods and other variables or identical variables from different markets using systems of equations. Each of these approaches can be applied in vector form. Schertz Willett et al. (1997) assumed a vector autoregression specification corresponding to the Ward (1982) model. Kirchgässner–Kübler (1992) used the vector ECM to analyse price asymmetries. Agüero (2007) applied the vector error correction regime-switching model, estimating it not only using the approach of Enders–Granger (1998), which assumes a known threshold value, but also using the method proposed by Hansen–Seo (2002), which allows for estimation in the case of an unknown cointegrating vector and threshold value. Bagnai–Mongeau Ospina (2018) employed multi-mode threshold models, while Torrado–Escribano (2020) used a double-threshold ECM to analyse asymmetry.

Review of theories

Borenstein et al. (1997) suggest possible explanations for the asymmetric response of petrol prices. A brief review is also provided by Brown–Yücel (2000), and Radchenko (2005), with another one proposed by Douglas–Herrera (2010):

(i) the oligopolistic coordination theory,
(ii) the production and inventory cost of adjustment,
(iii) the search theory, and
(iv) the theory of strategic interactions.

According to the oligopolistic coordination theory, when the crude oil price rises in an industry with a few dominant firms, each firm quickly raises its selling price to signal to its competitors that it is adhering to the tacit agreement by not cutting its margin. When the crude oil price falls, each firm is slow to lower its selling price to avoid signalling to its competitors that it is cutting its margin and no longer adhering to the tacit agreement.

Borenstein–Shepard (2002) argue that production and inventory adjustment costs contribute to the asymmetric response of petrol prices. Firms spread the adjustment over time because modifying production and inventory levels is costly. For example, a reduction in the price of crude oil will imply a long-run increase in petrol supply. However, adjustment costs rise with the absolute size of the adjustment per period. In this case, firms will spread the adjustment over time, gradually achieving the total quantity increase implied by the decline in cost.

With volatile prices of crude oil and retail fuel, consumers do not always have information on whether a change in the oil price or a shift in the pricing policy of a petrol station causes a fluctuation in retail prices. When oil prices are volatile, the cost to consumers of finding a cheaper fuel provider is high, leading to low demand elasticity. A retailer aware of this decrease in elasticity may temporarily increase margins, potentially resulting in a stronger price reaction to rising oil prices.

Douglas–Herrera (2010) established a detailed connection between asymmetric pricing and the New Keynesian theory of sticky prices. According to the authors, the theory of strategic interactions between firms and consumers can explain asymmetric retail petrol price reactions to crude oil price changes (e.g. Okun 1981). Price makers (including 'selfish' ones) seek to avoid antagonising a minority of consumers who tend to 'punish' firms for unjustified or insufficiently explained price increases (Rotemberg 2011). Generally, an increase in output price due to a rise in input price is more easily understood than an increase in output price caused by other or unknown shocks. Therefore, firms tend to use crude oil price increases as an opportunity to adjust retail fuel prices in response to additional unexpected costs or rising demand. As a result, substantial oil price increases impact fuel prices.

All four theoretical starting points assume discretionary retail fuel price setting, with fuel prices determined on a daily or weekly basis. In all cases, firms face price adjustment costs. Under the oligopolistic coordination theory, there is a risk that competitors may misinterpret price adjustments, rising too slowly and falling too quickly. In the second theory, adjustment costs stem from production and inventory constraints. The third theory highlights the opportunity cost of missed margins when consumers cannot effectively evaluate supply at a given time. In the final case, adjustment costs arise from the threat of punishment by a minority of consumers who evaluate the fairness or unfairness of price increases. This study verifies the asymmetric adjustment of retail fuel prices by estimating the reaction function derived from the non-linear form of the adjustment cost function. The derivation is presented in the Methods.

Review of results

Asymmetric price transmission is not exclusive to the fuel market. Peltzman (2000) analysed the formation of prices of 175 production and 77 consumer goods and found that, on average, two out of three markets exhibited positive asymmetry, where output prices rose more quickly than they fell following a change in input prices.

Bacon (1991) coined the term 'rockets and feathers' effect to describe the asymmetric adjustment of retail petrol prices. He tested and confirmed this hypothesis using a quadratic adjustment function and examined the relationship between retail petrol prices and costs in Great Britain from 1982 to 1989.

Most studies on asymmetric price reactions focus on the United States. According to Karrenbrock (1991), there was no time lag in the response of retail petrol prices to increases and decreases in wholesale prices during the period under review. However, retail price reactions to wholesale price increases were more immediate. Borenstein et al. (1997) also confirmed asymmetric responses of retail petrol prices to changes in oil prices.

Kang et al. (2019) demonstrated that the asymmetric behaviour of petrol prices is linked to economic police uncertainties. Bagnai–Mongeau Ospina (2018) investigated the asymmetry in retail petrol prices' responses to changes in crude oil price volatility. Their findings indicate a structural break in 2008, after which extreme observations played a significant role in shaping asymmetry.

Bumpass et al. (2019) investigated the short- and long-run relationship between retail petrol prices, spot petrol prices and the price of West Texas Intermediate crude oil within the petrol supply chain. They found mixed evidence of short-term asymmetric responses across all petrol retail supply chain stages. Their results assume a structural break in the relationship between crude oil and spot petrol after 17 October 2005, after which the direction of short-term asymmetry changed.

Sun et al. (2019) confirmed the asymmetric responses of retail petrol prices, with the level and volatility of oil prices having a positive effect on the price of petrol, contributing to asymmetries in the transmission of oil price shocks. However, the speeds of error correction and asymmetries decreased after the financial crisis.

Szomolanyi et al. (2022) examined petrol and diesel supply chain relationships at aggregate and local levels (regions, states, cities). We employed the formulation of the LINEX adjustment cost function. However, we only confirmed the asymmetric reactions of petrol and diesel retail prices at the aggregated and local levels. Contrary to previous studies (Bagnai–Mongeau Ospina 2018, Bumpass et al. 2019, Sun et al. 2019), we did not identify structural breaks in these relationships during the period under review.

One of the first studies on the European petrol market was conducted by Lanza (1991). The author analysed the reactions of wholesale and retail petrol prices in Germany and confirmed asymmetric responses of retail prices to changes in wholesale prices.

Apergis–Vouzavalis (2018) tested the short- and long-run asymmetric responses of retail petrol prices to changes in crude oil prices in the United States, United Kingdom, Spain, Italy and Greece between January 2006 and July 2016. Their results varied by country. Short-term asymmetry was confirmed in the Italian market. At the same time, short- and long-run asymmetry were evident in the Spanish market.

Deltas–Polemis (2020) highlighted that differences in research methods, data frequency and length, inclusion or exclusion of taxes in prices and many other factors can significantly affect comparisons of studies on asymmetric fuel pricing. In their study, they utilised 20 years of data from 28 European Union countries – including the United Kingdom, which left the EU on January 31, 2020 – to demonstrate how the choice of data structure, temporal and country heterogeneity and sampling variation influence results. Torrado–Escribano (2020) confirmed asymmetric reactions of retail petrol prices to changes in crude oil prices in Spain and Germany but not in France from 2011 to 2017.

After the debt problems in Greece, many studies examined the impact of structural changes resulting from restrictive government policies aimed at improving the government's debt position on market structures. Bragoudakis et al. (2020) investigated the effects of crude oil price fluctuations on refinery margins and the impact of wholesale petrol price changes on petrol station margins in Greece. According to their findings, fuel sellers do not adjust their margins in response to changes in the price of refined fuel. Conversely, asymmetric behaviour is evident in refiners' markups with respect to changes in international oil prices, which then get passed on to retailers and consumers. Bragoudakis–Sideris (2021) did not confirm asymmetric adjustments of petrol prices to changes in oil prices in the period after 2010.

Genakos–Pagliero (2022) explored the relationship between market structure and asymmetric price adjustment. They focused on the responses of retail petrol prices in isolated Greek regions to an unannounced and non-negligible increase in consumption taxes in 2010. The results supported the hypothesis that consumers in markets with low competition experience greater price asymmetries.

Cipcic (2021) tested asymmetric reactions of petrol and diesel prices in selected post-communist countries, including Croatia, the Czech Republic, Hungary, Slovenia, Slovakia and Poland. She did not confirm asymmetry across all countries for the entire review period, from January 2005 to June 2013. According to the study's findings, asymmetric fuel price reactions were observed in some countries from January 2009 to June 2013.

Honarvar (2009) provided a detailed summary of previous empirical studies. In addition to their analysis, Torrado–Escribano (2020) summarised contemporary empirical studies. In their article, Deltas–Polemis (2020) categorised selected studies by model, country coverage and data frequency. These studies provide a comprehensive comparative analysis of the literature.

Methods

The theoretical justifications for asymmetric retail fuel price-making are consistent with the assumption that the seller minimises the adjustment cost function in a non-linear form in each period. The LINEX form of the adjustment cost function is

$$F\left[p_{it}, E_t\left(c_{t+1}\right)\right] = \frac{-\gamma_i\left[p_{it} - k_i E_t\left(c_{t+1}\right)\right] + \exp\left\{\gamma_i\left[p_{it} - k_i E_t\left(c_{t+1}\right)\right]\right\} - 1}{\gamma_i^2} \quad (1)$$

where c is the input price (crude oil), p is the output price (retail fuel), k is the technological coefficient and γ is the asymmetry coefficient. The indices i and t are the fuel type (petrol, diesel) in a given country and time period. The retail fuel price-making process is based on crude oil price expectations, with E denoting the expectation operator. $E_t(c_{t+1})$ is the crude oil price in period $t + 1$ expected by retailers in period t.

By applying l'Hôpital's rule twice, it can be shown that if the asymmetric coefficient γ_i is close to 0, equation (1) reduces to a quadratic form. A positive asymmetric reaction of output prices requires $\gamma_i < 0$.

The firm's problem is to choose the output price p_{it} to minimise the cost function (1). The first-order condition is

$$\frac{-1 + \exp\left\{\gamma_i\left[p_{it} - k_i E_t\left(c_{t+1}\right)\right]\right\}}{\gamma_i} = 0 \quad (2)$$

Notably, if γ_i tends to 0, applying l'Hôpital's rule yields the reaction function in a linear form:

$$\lim_{\gamma_i \to 0}\left(p_{it}\right) = k_i E_t\left(c_{t+1}\right) \quad (3)$$

By performing a second-order Taylor expansion of (2), solving for pit, replacing the expected values with actual ones (prior to the generalised method of moments estimation, generalised method of moments (GMM)), and taking the first differences of the relation, we obtain a non-linear specification of the reaction function:

$$\Delta p_{it} = k_i \Delta c_{t+1} - \frac{1}{2}\gamma_i \Delta\left[\left(p_{it} - k_i c_{t+1}\right)^2\right] + u_{it} \quad (4)$$

where Δ is the first difference operator and u_{it} is a stochastic term containing terms of the third and higher orders in the Taylor expansion (first difference). When $\gamma_i = 0$, the reaction function specification becomes linear, and output prices react symmetrically to changes in input prices.

The changes in input prices Δc_t follow a normally distributed process with zero mean and variance σ^2. Taking the first differences, expected values and logarithms of the first-order condition (2), and after rearranging terms, we derive the price bias in the form:

$$E\left(\Delta p_{it}\right) = -\frac{k_i^2 \gamma_i}{2}\sigma^2 \tag{5}$$

A non-zero price bias (5) is inconsistent with a linear cointegrating relationship between input and output prices. Price bias depends on oil price volatility, aligning with recent research (Kang et al. 2019, Bumpass et al. 2019), which suggests that oil price volatility affects the asymmetric formation of retail petrol prices.

The orthogonality conditions implied by the rational expectations hypothesis make the GMM a natural candidate for estimating specification (4). We assume that petrol and diesel markets are closely interconnected and subject to joint shocks. Several studies have examined the coupling of the oil and petrol markets (e.g. Liu et al. 2010). To validate this assumption, we incorporated it into our analysis. An approach based on the LINEX adjustment cost formulation enables the estimation of reaction functions for different fuel types within a single system. We computed Breusch–Pagan's (1980) χ^2-distributed LM statistics to test the correlation of error terms of equations as a means of confirming the coupling of oil and petrol markets.

Deltas–Polemis (2020) highlighted that various survey methods, frequency and many other factors can significantly affect the comparison of asymmetric fuel pricing studies. The ability to estimate a system of multiple price reaction equations in a single step facilitates cross-country comparisons of fuel price asymmetries.

Standard errors were computed using the Newey and West procedure. The most important feature of this procedure, as explained by Newey–West (1987), is its consistency in the presence of heteroscedasticity and autocorrelation of unknown forms.

We use the GMM to estimate the parameters of (4). The main idea behind GMM is that when we cannot solve the system of equations obtained from the sample moment conditions formulated according to the model, we can still obtain a parameter estimate that brings the sample moments as close as possible to orthogonality. Hansen (1982) addressed the statistical properties of the GMM.

The model is considered overidentified if the number of moment terms exceeds the number of estimated parameters. Hansen (1982) followed the procedure of Sargan (1958), who proposed the well-known test of overidentified instruments and applied it to a mathematically equivalent formulation of GMM estimators. He thus developed the J statistic, which we use to evaluate the deviation from orthogonality in the obtained parameter estimates. The J statistic is asymptotically distributed as an χ^2 variable with degrees of freedom equal to the number of overidentifying restrictions.

As the model presented in specification (4) is forward-looking, we use the first differences of crude oil prices, led by one period, as the explanatory variable when estimating the parameters. As instruments, we preferred the one-period-lagged first differences of fuel prices and the first differences of crude oil prices. In some cases, we added the same instruments lagged by two or, at most, three periods. The final selection was verified for all estimates using the J statistic from the overidentifying restrictions test. The same sets of instruments were used for single-equation and system estimates within a specific country.

Data and results

The analysis uses weekly time series data on petrol (Eurosuper 95) and diesel prices in EU27 countries, gathered from the European Commission Weekly Oil Bulletin. The crude oil prices used in this research are daily spot BRENT oil prices, retrieved from the US Energy Information Administration website. Spot BRENT serves as the benchmark reference for oil prices in Europe.

European fuel prices are published in euros per 1,000 litres, while crude oil prices are expressed in dollars per barrel. To ensure consistency, all prices are converted into euros per 1,000 litres using the exchange rate time series obtained from the European Central Bank. Daily crude oil prices are averaged weekly.

Compared to other countries, retail fuel prices in Malta change much less frequently. Therefore, we excluded Malta's fuel prices from the analysis. The dataset contains data from 31 January 2005. However, fuel prices have been published for some countries since that period. The final data in the dataset are from 24 April 2023, i.e. the last Monday of that April.

Table 1 presents single-equation estimates of the reaction functions (4) for petrol and diesel prices. The two-equation system estimates for each country are shown in Table 2. In addition to the coefficient estimates (k_i, γ_i), the tables include bias estimates (5), the number of observations in each equation (*Nobs*) and corresponding *J*-stats in Table 1. Asterisks indicate the statistical significance of coefficients, with three asterisks denoting significance at 1% level. In Table 2, *J* and Breusch–Pagan statistics are shown in the last column. The results confirm a linkage between petrol and diesel markets in each country.

Figures 1 and 2 present maps with graded differences in the petrol and diesel bias values obtained in the single-equation estimates for better visual resolution.

Table 1

Asymmetric reactions of the EU fuel retail prices on the changes in BRENT crude oil spot prices (equation GMM by fuel and country)

Country	Gasoline equation				
	k	γ	J stat	Nobs	Bias
Austria	1.2776***	–0.0011***	1.6695	823	0.2132
Belgium	1.2918***	–0.0011***	0.1766	823	0.2119
Bulgaria	1.1447***	–0.0014***	0.1568	697	0.2156
Cyprus	1.1681***	–0.0012***	3.4239	826	0.1984
Czech Republic	1.0324***	–0.0011***	0.5012	820	0.1337
Germany	1.4279***	–0.0011***	7.4867	789	0.2607
Denmark	1.8213***	–0.0012***	0.7841	789	0.4770
Estonia	0.8364***	–0.0009***	4.4060	823	0.0740
Spain	0.9836***	–0.0009***	5.9851	785	0.1070
Finland	1.6969***	–0.0011***	7.9970	752	0.3680
France	1.4831***	–0.0011***	3.4275	826	0.2936
Greece	0.9794***	–0.0008***	4.3386	785	0.0882
Croatia	1.2369***	–0.0011***	1.6755	450	0.1912
Hungary	1.3973***	–0.0016***	0.7390	789	0.3665
Ireland	0.8608***	–0.0008***	2.3586	789	0.0660
Italy	1.3181***	–0.0009***	3.5349	785	0.1911
Lithuania	0.9780***	–0.0010***	6.3542	752	0.1074
Luxembourg	1.4037***	–0.0013***	0.5525	789	0.3071
Latvia	0.7847***	–0.0009***	1.3351	789	0.0657
Netherlands	0.9365***	–0.0007***	0.1808	826	0.0733
Poland	0.9678***	–0.0012***	5.1655	789	0.1327
Portugal	1.5339***	–0.0011***	6.9143	789	0.3026
Romania	0.6528***	–0.0010***	1.9702	666	0.0492
Sweden	1.3362***	–0.0009***	4.1261	789	0.1912
Slovenia	0.7901***	–0.0010***	1.6895	789	0.0747
Slovakia	1.2736***	–0.0011***	0.6337	826	0.2123

(Table continues on the next page.)

Continued.)

Country	Diesel equation				
	k	γ	J stat	Nobs	Bias
Austria	1.0878***	–0.0010***	0.7404	823	0.1370
Belgium	1.5758***	–0.0013***	4.5164	785	0.3735
Bulgaria	1.3570***	–0.0016***	0.2128	697	0.3337
Cyprus	1.2317***	–0.0012***	0.6210	826	0.2108
Czech Republic	1.2775***	–0.0011***	0.1334	820	0.2143
Germany	1.6280***	–0.0010***	4.9778	789	0.3115
Denmark	1.6837***	–0.0014***	2.0515	826	0.4474
Estonia	1.3294***	–0.0011***	4.6176	785	0.2292
Spain	1.1222***	–0.0011***	1.4003	823	0.1552
Finland	0.9346***	–0.0006***	3.6535	752	0.0615
France	0.4330***	–0.0007***	3.5578	789	0.0157
Greece	0.8610***	–0.0009***	0.8162	823	0.0748
Croatia	0.9544***	–0.0008***	4.0732	431	0.0799
Hungary	1.1501***	–0.0013***	0.2079	789	0.2052
Ireland	1.2715***	–0.0010***	4.0744	826	0.1825
Italy	1.2596***	–0.0009***	1.7749	785	0.1746
Lithuania	0.7261***	–0.0009***	0.0986	826	0.0546
Luxembourg	1.1125***	–0.0012***	1.0485	826	0.1735
Latvia	0.9603***	–0.0010***	0.8849	826	0.1109
Netherlands	1.3679***	–0.0010***	3.0750	789	0.2159
Poland	1.0780***	–0.0013***	2.2894	789	0.1720
Portugal	1.1108***	–0.0010***	0.4927	826	0.1485
Romania	1.0829***	–0.0012***	3.3594	635	0.1601
Sweden	1.3529***	–0.0007***	4.0426	752	0.1564
Slovenia	1.3497***	–0.0013***	1.5516	789	0.2663
Slovakia	1.2923***	–0.0013***	1.2980	826	0.2460

Note: *** denote statistical significance at 1% level.

Figure 1

EU country maps of retail prices of petrol biases
(single-equation GMM estimates)

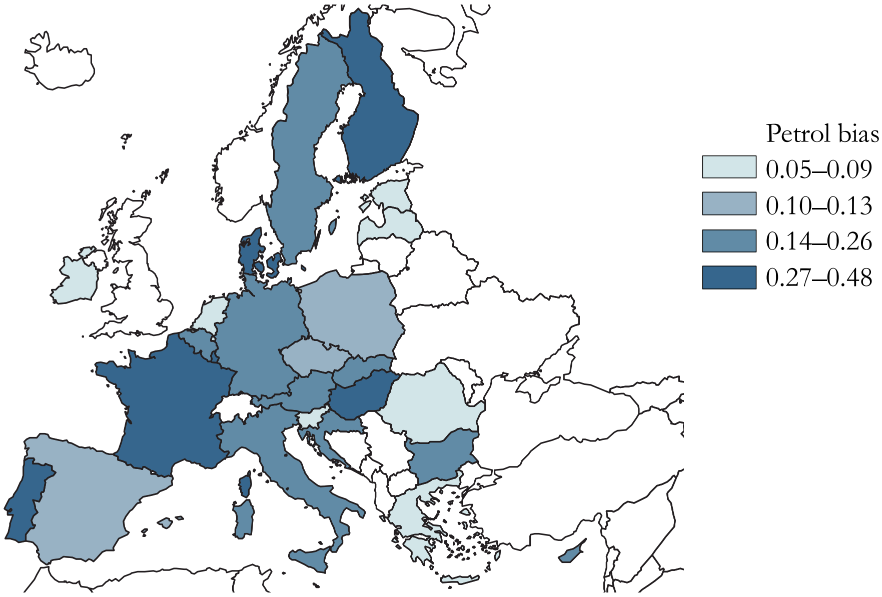


Figure 2

EU country maps of retail prices of diesel biases
(single-equation GMM estimates)

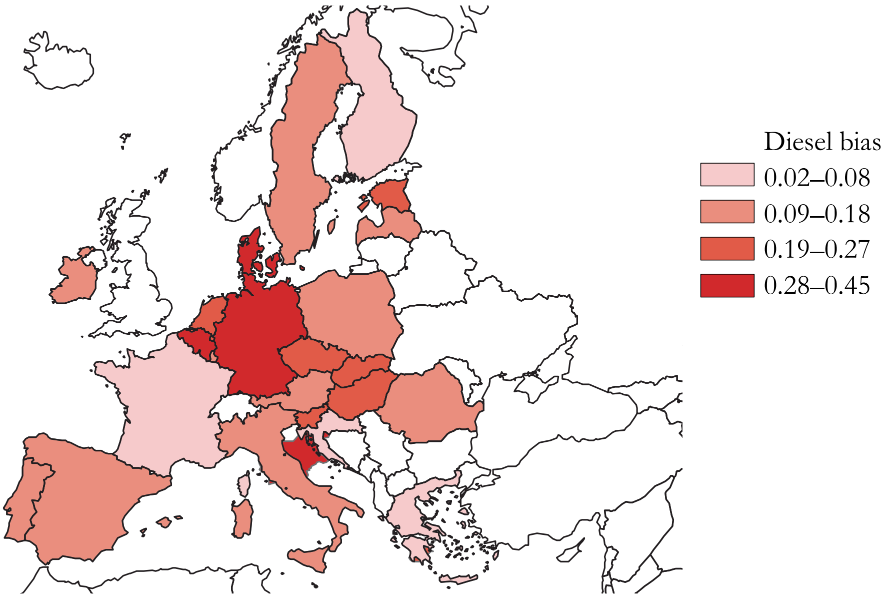


Table 2

Asymmetric reactions of the EU fuel retail prices on the changes in BRENT crude oil spot prices (two equations GMM by country)

Country	Gasoline equation			
	k	γ	Nobs	Bias
Austria	0.8009***	–0.0009***	785	0.0647
Belgium	1.1063***	–0.0010***	785	0.1414
Bulgaria	1.2010***	–0.0015***	697	0.2440
Cyprus	1.3672***	–0.0014***	789	0.3011
Czech Republic	0.5416***	–0.0009***	820	0.0295
Germany	1.8488***	–0.0013***	789	0.5193
Denmark	1.5292***	–0.0011***	789	0.2915
Estonia	0.8765***	–0.0009***	823	0.0830
Spain	0.8955***	–0.0010***	823	0.0888
Finland	1.3053***	–0.0009***	789	0.1866
France	1.7812***	–0.0013***	826	0.4729
Greece	1.3279***	–0.0009***	785	0.1877
Croatia	1.3172***	–0.0011***	450	0.2158
Hungary	1.3689***	–0.0016***	789	0.3390
Ireland	1.0544***	–0.0008***	789	0.1032
Italy	0.6420***	–0.0007***	823	0.0343
Lithuania	0.5503***	–0.0009***	752	0.0305
Luxembourg	1.5057***	–0.0014***	789	0.3796
Latvia	0.9066***	–0.0010***	789	0.0977
Netherlands	1.2057***	–0.0008***	789	0.1440
Poland	0.9034***	–0.0012***	789	0.1121
Portugal	1.5590***	–0.0011***	789	0.3088
Romania	1.6840***	–0.0018***	697	0.6104
Sweden	1.3258***	–0.0009***	789	0.1792
Slovenia	0.9100***	–0.0011***	789	0.1053
Slovakia	1.0341***	–0.0010***	789	0.1285

(Table continues on the next page.)

Continued.)

Country	Diesel equation				System	
	k	γ	Nobs	Bias	J stat	BP
Austria	0.9376***	–0.0009***	785	0.0941	0.0032	562.00
Belgium	1.6814***	–0.0015***	785	0.4915	0.0066	189.90
Bulgaria	1.3054***	–0.0015***	697	0.3009	0.0004	484.53
Cyprus	1.3222***	–0.0013***	826	0.2565	0.0027	444.70
Czech Republic	1.0551***	–0.0010***	820	0.1320	0.0021	444.41
Germany	1.6446***	–0.0011***	789	0.3314	0.0079	145.11
Denmark	1.7393***	–0.0013***	789	0.4596	0.0046	253.89
Estonia	1.6323***	–0.0016***	785	0.4836	0.0053	253.89
Spain	1.0431***	–0.0010***	823	0.1287	0.0016	513.85
Finland	0.9381***	–0.0006***	752	0.0658	0.0120	89.69
France	1.0223***	–0.0009***	789	0.1150	0.0020	85.98
Greece	0.8127***	–0.0008***	823	0.0643	0.0052	295.87
Croatia	0.8497***	–0.0007***	431	0.0567	0.0064	160.52
Hungary	0.9625***	–0.0011***	789	0.1222	0.0012	177.22
Ireland	1.2402***	–0.0010***	826	0.1721	0.0061	431.65
Italy	1.2911***	–0.0010***	823	0.1912	0.0003	376.98
Lithuania	0.7786***	–0.0009***	826	0.0654	0.0018	312.52
Luxembourg	1.2031***	–0.0013***	789	0.2209	0.0018	146.41
Latvia	0.8075***	–0.0010***	789	0.0751	0.0050	428.41
Netherlands	1.3086***	–0.0010***	789	0.1967	0.0090	234.91
Poland	1.2421***	–0.0013***	789	0.2405	0.0054	404.56
Portugal	1.6009***	–0.0014***	789	0.4243	0.0081	367.55
Romania	1.6335***	–0.0016***	697	0.4845	0.0012	479.68
Sweden	1.3572***	–0.0007***	752	0.1570	0.0074	444.17
Slovenia	1.4826***	–0.0013***	789	0.3417	0.0034	200.99
Slovakia	1.2797***	–0.0013***	789	0.2399	0.0044	269.99

Note: *** denote statistical significance at 1% level.

All the estimates are statistically significant at 1% level. In all cases, the asymmetric coefficients are less than 0, confirming the asymmetric price reactions. The price biases, measured in euros per 1,000 litres, differ from country to country.

The average price bias, without accounting for differences in sales volumes across countries, is approximately 21 cents per 1,000 litres of petrol and 22 cents per 1,000 litres of diesel. According to the results, customers in Romania, Germany, Denmark, Portugal, Belgium and Luxembourg experience the most asymmetric reactions to retail fuel prices, while the smallest asymmetries are observed in Lithuania, Austria, the Czech Republic, Latvia, Spain, Italy, Greece and Finland.

Figures 3 and 4 present maps with graded differences in petrol and diesel bias values, derived from the multiple-equation estimates, to provide a clearer visual representation.

Figure 3

EU country maps of retail prices of petrol biases
(multiple-equation GMM estimates)

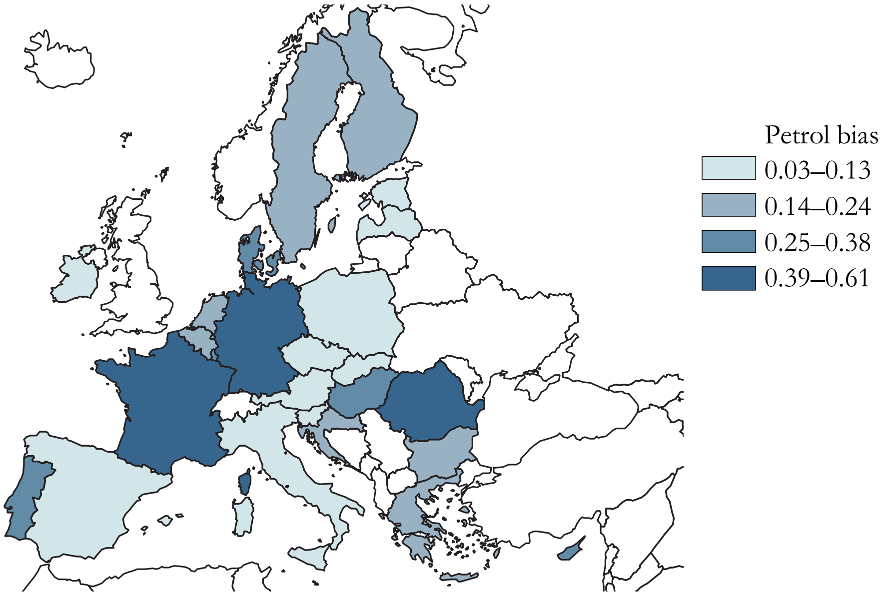
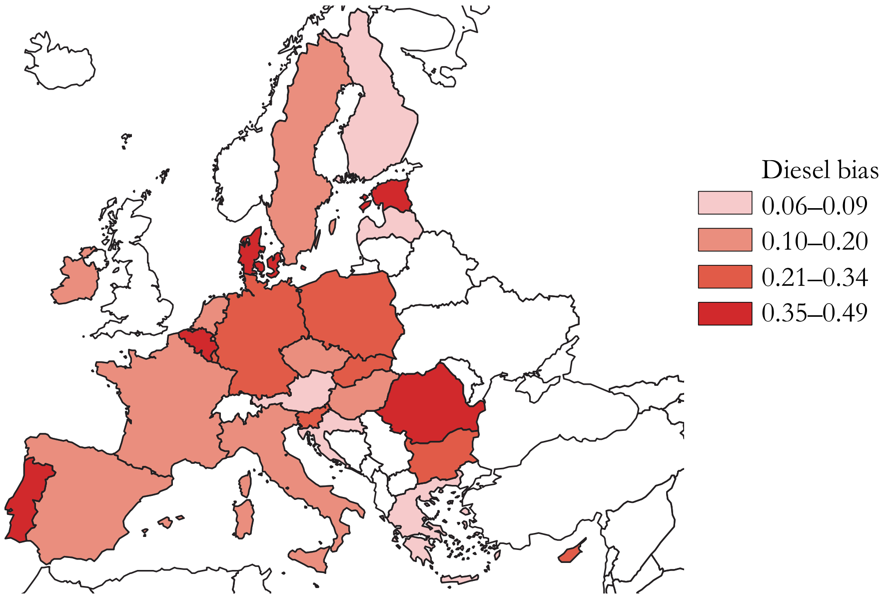


Figure 4

EU country maps of retail prices of diesel biases
(multiple-equation GMM estimates)



The asymmetric reactions of petrol and diesel prices differ significantly across many countries. For example, in Estonia, the diesel price bias is up to 48 cents per 1,000 litres compared to the petrol price bias of approximately 8 cents per 1,000 litres. Other countries where we estimate the price bias of diesel to be significantly higher than that of petrol include Belgium, Slovenia, Denmark and Italy. Conversely, there is a relatively high price bias for petrol in France, Hungary, Germany, Croatia and Luxembourg.

Conclusion

The hypothesis of asymmetric price transmission in petroleum product markets assumes that retail fuel prices adjust more quickly when oil prices increase and more slowly when they decrease. Deltas–Polemis (2020) highlighted that differences in research methods, data length and frequency and other research characteristics can significantly influence conclusions regarding the asymmetric response of retail fuel prices to changes in crude oil prices. In the literature review, we observe a wide range of methods historically used to examine asymmetric output price reactions, including the use of dummy variables, cointegration analysis, threshold autoregression models, multi-equation systems estimation and regime-switching models.

A well-developed theoretical foundation is essential before selecting an appropriate methodology. All theoretical explanations in the literature review assume discretionary pricing, which can be mathematically formulated using a LINEX adjustment cost function. From the function's form, one can derive the specification of the reaction function of retail output prices to changes in input prices and the average price bias resulting from asymmetric price formation. Given the hypothesis of rational expectations, the GMM is suitable for estimating the reaction function of retail fuel prices. In a highly interconnected market for different fuels, such as diesel and petrol, a key advantage of the GMM is its applicability in estimating multi-equation systems.

We estimated the reaction functions of retail petrol and diesel prices to changes in crude oil prices in 27 European Union countries, excluding Malta. In all countries, the interconnectedness of the petrol and diesel markets and the asymmetric formation of prices were confirmed. According to our estimates, in all 26 countries, retail prices react more sensitively to increases in crude oil prices than to decreases. Asymmetric pricing causes a systematic price bias that varies by country. Our estimates indicate that the average European price bias is 21 cents per 1,000 litres for petrol and 22 cents per 1,000 litres for diesel. We estimate the most significant price bias in the petrol market in Romania and the diesel market in Belgium.

Unlike other studies on motor fuel price asymmetries in EU countries, our findings confirm price asymmetries at the retail level in all countries over the entire period for which data are available. According to the results, the question is not whether retail price formation is asymmetric but how significant the resulting price bias is.

The size of the price bias caused by asymmetric reactions in retail petrol and diesel pricing varies across many countries. The systematic petrol price bias is more pronounced than the diesel price bias in France, Hungary, Germany, Croatia and Luxembourg. In contrast, the diesel price bias is greater in Belgium, Slovenia, Denmark and Italy.

Unlike the findings of Torrado–Escribano (2020), our results, based on the entire data sample, including the Covid-19 period, do not confirm the relatively stronger asymmetric responses of retail petrol prices in Spain and Germany compared to those in France. Germany has the second-largest average petrol bias after Romania (61 and 52 cents per 1,000 litres) among the countries studied, followed by France (47 cents per 1,000 litres). Conversely, Spain, where we estimate an average petrol price bias of 9 cents per 1,000 litres, is among the countries with the least asymmetric reactions.

The Greek retail petrol market has been the subject of many studies since the debt crisis (Bragoudakis et al. 2020, Bragoudakis–Sideris 2021, Genakos–Pagliero 2022). According to our estimate, asymmetric retail petrol pricing in Greece produces a bias of approximately 19 cents per 1,000 litres, which is slightly below the European average. In contrast to Cipcic (2021), we estimate asymmetric retail petrol and diesel price responses in Central European post-communist countries using the entire range of data.

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REFERENCES

APERGIS, N.–VOUZAVALIS, G. (2018): Asymmetric pass through of oil prices to gasoline prices: evidence from a new country sample *Energy Policy* 114: 519–528. https://doi.org/10.1016/j.enpol.2017.12.046

BACON, R. W. (1991): Rockets and feathers: the asymmetric speed of adjustment of UK Retail gasoline prices to cost changes *Energy Economics* 13 (3): 211–218. https://doi.org/10.1016/0140-9883(91)90022-R

BAGNAI, A.–MONGEAU OSPINA, C. A. M. (2018): Asymmetries, outliers and structural stability in the US gasoline market *Energy Economics* 69: 250–260. https://doi.org/10.1016/j.eneco.2017.11.014

BALKE, N. S.–FOMBY, T. B. (1997): Threshold cointegration *International Economic Review* 38 (3): 627–645. https://doi.org/10.2307/2527284

BETTENDORF, L.–VAN DER GEEST, S. A.–VARKEVISSER, M. (2003): Price asymmetry in the Dutch retail gasoline market *Energy Economics* 25 (6): 669–689. https://doi.org/10.1016/S0140-9883(03)00035-5

Borenstein, S.–Cameron, A. C.–Gilbert, R. J. (1997): Do gasoline prices respond asymmetrically to crude oil price changes? *The Quarterly Journal of Economics* 112 (1): 305–339. https://doi.org/10.1162/003355397555118

Borenstein, S.–Shepard, A. (2002): Sticky prices, inventories, and market power in wholesale gasoline markets *The RAND Journal of Economics* 33 (1): 116–139. https://www.jstor.org/stable/2696378

Bragoudakis, Z.–Degiannakis, S.–Filis, G. (2020): Oil and pump prices: testing their asymmetric relationship in a robust way *Energy Economics* 88: 104755. https://doi.org/10.1016/j.eneco.2020.104755

Bragoudakis, Z.–Sideris, D. (2021): Asymmetric price adjustment and the effects of structural reforms and low demand in the gasoline market: the case of Greece *Journal of Applied Economics* 24 (1): 504–522. https://doi.org/10.1080/15140326.2021.1922188

Breusch, T. S.–Pagan, A. R. (1980): The lagrange multiplier test and its applications to model specification in econometrics *The Review of Economic Studies* 47 (1): 239–253. https://doi.org/10.2307/2297111

Bumpass, D.–Douglas, C.–Ginn, V.–Tuttle, M. H. (2019): Testing for short and long-run asymmetric responses and structural breaks in the retail gasoline supply chain *Energy Economics* 83: 311–318. https://doi.org/10.1016/j.eneco.2019.07.021

Cipcic, M. L. (2021): The impact of oil prices on petroleum product prices in central east european markets. In: *Proceedings of 10th international scientific symposium region entrepreneurship and development* pp. 174–188. Osijek, June 2021, Studio HS internet d.o.o., Osijek, Croatia.

Cramon-Taubadel, S.–Loy, J-P. (1996): Price asymmetry in the international wheat market: comment *Canadian Journal of Agricultural Economics/Revue Canadienne D'Agroeconomie* 44 (3): 311–317. https://doi.org/10.1111/j.1744-7976.1996.tb00153.x

Deltas, G.–Polemis, M. (2020): Estimating retail gasoline price dynamics: the effects of sample characteristics and research design *Energy Economics* 92: 104976. https://doi.org/10.1016/j.eneco.2020.104976

Douglas, C.–Herrera, A. M. (2010): Why are gasoline prices sticky? A test of alternative models of price adjustment *Journal of Applied Econometrics* 25 (6): 903–928. https://doi.org/10.1002/jae.1115

Duffy-Deno, K. T. (1996): Retail price asymmetries in local gasoline markets *Energy Economics* 18 (1–2): 81–92. https://doi.org/10.1016/0140-9883(95)00051-8

Enders, W.–Granger, C. W. J. (1998): Unit-root tests and asymmetric adjustment with an example using the term structure of interest rates *Journal of Business & Economic Statistics* 16 (3): 304–311. https://doi.org/10.2307/1392506

Engle, R. F.–Granger, C. W. J. (1987): Co-integration and error correction: representation, estimation, and testing *Econometrica* 55 (2): 251–276. https://doi.org/10.2307/1913236

Farrell, M. J. (1952): Irreversible demand functions *Econometrica* 20 (2): 171–186. https://doi.org/10.2307/1907846

Genakos, C.–Pagliero, M. (2022): Competition and pass-through: evidence from isolated markets *American Economic Journal: Applied Economics* 14 (4): 35–57. https://doi.org/10.1257/app.20200863

GRANGER, C. W. J.–LEE, T. H. (1989): Investigation of production, sales and inventory relationships using multicointegration and non-symmetric error correction models *Journal of Applied Econometrics* 4 (S1): 145–159. https://doi.org/10.1002/jae.3950040508
GRASSO, M.–MANERA, M. (2007): Asymmetric error correction models for the oil–gasoline price relationship *Energy Policy* 35 (1): 156–177. https://doi.org/10.1016/j.enpol.2005.10.016
HAHN, W. F. (1990): Price transmission asymmetry in pork and beef markets *Journal of Agricultural Economics Research* 42 (4): 21–30. https://doi.org/10.22004/AG.ECON.139044
HANSEN, B. E.–SEO, B. (2002): Testing for two-regime threshold cointegration in vector error-correction models *Journal of Econometrics* 110 (2): 293–318. https://doi.org/10.1016/S0304-4076(02)00097-0
HANSEN, L. P. (1982): Large sample properties of generalized method of moments estimators *Econometrica* 50 (4): 1029–1054. https://doi.org/10.2307/1912775
HONARVAR, A. (2009): Asymmetry in retail gasoline and crude oil price movements in the United States: an application of hidden cointegration technique *Energy Economics* 31 (3): 395–402. https://doi.org/10.1016/j.eneco.2009.01.010
HOUCK, J. P. (1977): An approach to specifying and estimating nonreversible functions *American Journal of Agricultural Economics* 59 (3): 570–572. https://doi.org/10.2307/1239663
KANG, W.–DE GRACIA, F. P.–RATTI, R. A. (2019): The asymmetric response of gasoline prices to oil price shocks and policy uncertainty *Energy Economics* 77: 66–79. https://doi.org/10.1016/j.eneco.2018.09.007
KARRENBROCK, J. D. (1991): The behavior of retail gasoline prices: symmetric or not? *Federal Reserve Bank of St. Louis Review* 73 (4): 19–29. https://doi.org/10.20955/r.73.19-29
KIRCHGÄSSNER, G.–KÜBLER, K. (1992): Symmetric or asymmetric price adjustments in the oil market: an empirical analysis of the relations between international and domestic prices in the Federal Republic of Germany, 1972–1989 *Energy Economics* 14 (3): 171–185. https://doi.org/10.1016/0140-9883(92)90010-B
LANZA, A. (1991): *Speed of adjustment and market structure: a study of the gasoline market in Germany* Oxford Institute for Energy Studies EE, Energy Economics 14. Oxford.
LIU, M-H.–MARGARITIS, D.–TOURANI-RAD, A. (2010): Is there an asymmetry in the response of diesel and petrol prices to crude oil price changes? Evidence from New Zealand *Energy Economics* 32 (4): 926–932. https://doi.org/10.1016/j.eneco.2009.12.008
MANNING, D. N. (1991): Petrol prices, oil price rises and oil price falls: some evidence for the UK since 1972 *Applied Economics* 23 (9): 1535–1541. https://doi.org/10.1080/00036849100000206
MEYER, J.–CRAMON-TAUBADEL, S. (2004): Asymmetric price transmission: a survey *Journal of Agricultural Economics* 55 (3): 581–611. https://doi.org/10.1111/j.1477-9552.2004.tb00116.x
NEWEY, W. K.–WEST, K. D. (1987): A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix *Econometrica* 55 (3): 703–708. https://doi.org/10.2307/1913610
OKUN, A. M. (1981): *Prices and quantities: a macroeconomic analysis* Brookings Institution, Washington, D.C.
PELTZMAN, S. (2000): Prices rise faster than they fall *Journal of Political Economy* 108 (3): 466–502. https://doi.org/10.1086/262126

Radchenko, S. (2005): Oil price volatility and the asymmetric response of gasoline prices to oil price increases and decreases *Energy Economics* 27 (5): 708–730. https://doi.org/10.1016/j.eneco.2005.06.001

Rotemberg, J. J. (2011): Fair pricing *Journal of the European Economic Association* 9 (5): 952–981. https://doi.org/10.1111/j.1542-4774.2011.01036.x

Sargan, J. D. (1958): The estimation of economic relationships using instrumental variables *Econometrica* 26 (3): 393–415. https://doi.org/10.2307/1907619

Willett, S. L.–Hansmire, M. R.–Bernard, J. C. (1997): Asymmetric price response behavior of Red Delicious apples *Agribusiness* 13 (6): 649–658. https://doi.org/10.1002/(SICI)1520-6297(199711/12)13:6<649::AID-AGR9>3.0.CO;2-3

Stock, J. H.–Watson, M. W. (1993): A simple estimator of cointegrating vectors in higher order integrated systems *Econometrica* 61 (4): 783–820. https://doi.org/10.2307/2951763

Sun, Y.–Zhang, X.–Hong, Y.–Wang, S. (2019): Asymmetric pass-through of oil prices to gasoline prices with interval time series modelling *Energy Economics* 78: 165–173. https://doi.org/10.1016/j.eneco.2018.10.027

Szomolanyi, K.–Lukacik, M.–Lukacikova, A. (2022): Estimation of asymmetric responses of U.S. Retail fuel prices to changes in input prices based on a linear exponential adjustment cost approach *Central European Journal of Operations Research* 30 (2): 757–779. https://doi.org/10.1007/s10100-021-00783-0

Tong, H. (1983): *Threshold models in non-linear time series analysis* Vol. 21. Lecture Notes in Statistics, Springer, New York. https://doi.org/10.1007/978-1-4684-7888-4

Torrado, M.–Escribano, A. (2020): European gasoline markets: price transmission asymmetries in mean and variance *Applied Economics* 52 (42): 4621–4638. https://doi.org/10.1080/00036846.2020.1739224

Tweeten, L. G.–Quance, C. L. (1969): Positivistic measures of aggregate supply elasticities: some new approaches *American Journal of Agricultural Economics* 51 (2): 342–352. https://doi.org/10.2307/1237584

Ward, R. W. (1982): Asymmetry in retail, wholesale, and shipping point pricing for fresh vegetables *American Journal of Agricultural Economics* 64 (2): 205–212. https://doi.org/10.2307/1241124

Wolffram, R. (1971): Positivistic measures of aggregate supply elasticities: some new approaches – some critical notes *American Journal of Agricultural Economics* 53 (2): 356–359. https://doi.org/10.2307/1237462

INTERNET SOURCES

Agüero, J. M. (2007): *Asymmetric price adjustment and behaviour under risk: evidence from peruvian agricultural markets* University of Wisconsin-Madison, Department of Agricultural and Applied Economics. https://faculty.ucr.edu/~jorgea/research/asymm.pdf (downloaded: April 2024)

Brown, S. P. A.–Yücel, M. K. (2000): Gasoline and crude oil prices: Why the asymmetry? *Federal Reserve Bank of Dallas Economic and Financial Review* Q3: 23–29. https://www.dallasfed.org/~/media/documents/research/efr/2000/efr0003b.pdf (downloaded: April 2024)