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Asymmetric Price Adjustments in the Fuel Market

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Abstract

The purpose of the article is to verify a hypothesis about the asymmetric pass-through of crude oil prices to the selling prices of refinery products (unleaded 95 petrol and diesel oil). The distribution chain is considered at three levels: the European wholesale market, the domestic wholesale market and the domestic retail market. The error correction model with threshold cointegration proved to be an appropriate tool for making an empirical analysis based on the Polish data. As found, price transmission asymmetry in the fuel market is significant and its scale varies depending on the level of distribution. The only exception is the wholesale price transmission to the domestic refinery price. All conclusions are supported by the cumulative response functions. The analysis sheds new light on the price-setting processes in an imperfectly competitive fuel market of a medium-sized, non-oil producing European country in transition.

Keywords: threshold cointegration, threshold error correction model, asymmetric price adjustment, fuel price transmission

JEL Classification: C51, C52, D40, Q40

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1 Introduction

Oil companies are commonly believed to exploit crude oil price volatility in the markets to achieve extra profits at the cost of intermediate and final buyers. The mechanism that makes it possible is the asymmetric pass-through of crude oil prices to local selling prices of oil-based products, which means that the latter respond more readily to increases than to decreases of raw material prices (so-called rockets and feathers, see Bacon 1991).

There are probably four major reasons which may cause the asymmetry of fuel price adjustments: the strong market position of oil companies operating under imperfect competition, high search costs for consumers, refinery inventory management, and producers and/or retailers' engagement in tacit collusion (see Borenstein et al. 1997, Meyer and Von Cramon-Taubadel 2004, L'Oeillet and Lantz 2009).

The oligopolistic structure of the fuel market is considered the most important among the four, as it enables its participants to take advantage of their market position in the price setting process. As a result, oil companies transmit increases in raw material prices to the selling prices of refined products faster and more fully than when the prices are falling.

As refineries and fuel trading companies are legally bound to maintain stocks of crude oil and petroleum products, the inventory valuation method also significantly determines the price setting process. If a company uses the FIFO method (first in – first out), its prices of refinery products follow changes in raw material prices with a delay, because the already accumulated stock of products must go first. With the LIFO method (last in – first out), faster adjustments of prices are possible (see Frey and Manera 2007).

Another source of price asymmetry is the costs that final consumers have to incur to acquire information about fuel prices, which significantly hamper the information-seeking process and affect their decisions. Local fuel retailers skilfully exploit the situation and quickly increase their prices following rises in the wholesale prices of fuels, but are slow to reduce them when the latter are falling.

The asymmetric transmission of oil-based product prices is also induced by fuel companies' engagement in tacit collusion (see, for instance, Balke at al. 1998, Brown and Yücel 2000). A tacit agreement concluded by producers or retailers operating in the same area strengthens their market position and allows them to pursue pricing policy that offers extra profits at the expense of both intermediate and final buyers. A common element of these agreements that serves the purpose of identifying collusive companies that breach their rules is the provision of a minimum price; the identification of a lower price is a signal to seek and punish the culprit company (see Borenstein et al. 1997).

Whether price asymmetry in the fuel market really exists has been analysed in many studies (see, for instance, Bacon 1991, Wlazlowski 2003, Chen et al. 2005, Ewing et al. 2006, Al-Gudhea et al. 2007, Grasso, Manera 2007, L'Oeillet, Lantz 2009, Clerides 2010, Polemis and Fotis 2013). Their results are ambiguous and depend, for instance, on the particular country taken for analysis, the sample size, data type and frequency, and the econometric methods applied (a review giving special attention to the methods can be found in Frey and Manera (2007)).

The available analyses of asymmetric pricing use different variants of the threshold error correction model (TECM), namely an asymmetric ECM (see Bettendorf et al. 2003, Galeotti et al. 2003, Oladunjoye 2008, L'Oeillet and Lantz 2009, Clerides 2010), a threshold autoregressive ECM (see Godby et al. 2000, Douglas 2010, Bermingham and O'Brien 2011) which combines a threshold autoregressive model with a standard ECM, as well as ECM with threshold cointegration (see, for instance, Wlazlowski 2003, Chen et al. 2005, Hammoudeh et al. 2010). These three different variants of the TECM model have been compared by Grasso and Manera (2007). In multivariate analyses, the threshold vector error correction models have been used (see, for instance, Al-Gudhea et al. 2007). A separate group of studies are those based on high-frequency data and applying asymmetric GARCH models (see, for example, Radchenko 2005, Balaguer and Ripollés 2012).

In addition to the major hypothesis about asymmetric price adjustments, other hypotheses that have been verified concerned the relationship between the degree of fuel price asymmetry and crude oil price variability (see, for instance, Radchenko 2005), asymmetric fuel price responses to variations in the stock of refinery products (see Radchenko and Shapiro 2011, Kuper 2012), and the impact of market concentration on the asymmetric transmission of oil-based product prices (see, for instance, Oladunjoye 2008). It is worth noting that the asymmetric price effect has also been studied with the panel data from both micro and macroeconomic perspectives (see, for example, Wlazlowski et al. 2009, Faber 2011, Koltay 2012, Polemis and Fotis 2013).

The empirical studies into asymmetric price adjustments in the fuel market have used monthly data (see Manning 1991, Shin 1994, Reilly and Witt 1998, Galeotti et al. 2003, Kaufmann and Laskowski 2005, Grasso and Manera 2007, Deltas 2008, Honarvar 2009, Bermingham and O' Brien 2011), weekly data (see Duffy-Deno 1996, Borenstein et al. 1997, Godby et al. 2000, Bettendorf et al. 2003), as well as daily data (see Bachmeier and Griffin 2003, Faber 2011, Balaguer and Ripollés 2012). There is an evident lack of relationship between the frequency of time series used in the study and its final conclusions. Bachmeier and Griffin (2003) thesis that asymmetry identified based on lower frequency data is spurious and disappears with the level of aggregation decreasing in time is questionable. The absence of asymmetry has already been identified with daily data (see, for instance, Bachmeier and Griffin 2003), weekly data (see Godby et al. 2000), as well as with monthly data (see Shin 1994, Bermingham and O' Brien 2011). The same applies to testing for the presence of asymmetry.

In this paper, the monthly data from January 2000 to March 2011 are used to verify a hypothesis that the crude oil prices in Poland are asymmetrically transmitted to the prices of refinery products charged at the different levels of the distribution chain.

The levels are analysed individually, because each of them is represented by a different group of agents that may be quite specific in terms of their market behaviour. Unlike the previous studies on European countries (see, for instance, Asplund et al. (2000), Galeotti et al. 2003, Lanza 1991, Reilly, Witt 1998, Valachy 2002) where price asymmetry analyses concerned two levels of commodity trading at the most, that is the domestic wholesale market frequently identified with the spot market for fuels and the retail market, the approach to the fuel price setting process proposed in this research is more detailed and contains one more level – the European wholesale market. This broadened perspective enables the verification of another potential source of asymmetry between the European wholesale price of a fuel and its local wholesale price, for which the former is the reference level.
Previous analysis of the price-setting process in the fuel market in Poland (see Leszkiewicz-Kędzior 2011) had two serious drawbacks. Firstly, it was carried out for two levels of distribution only: the wholesale trade (producer level) and the retail trade (consumer level). Therefore, an important stage of the fuel price-setting process (namely the European wholesale market) and its relationships with the domestic wholesale market were omitted, which did not allow for the analysis of specific to oil companies market behaviour. Secondly, in the inference process the standard cointegration analysis was used assuming *implicite* that price adjustments in the fuel market are symmetric. This study is devoid of these defects.
The inference is based on asymmetric threshold cointegration tests and ECM with threshold cointegration. The use of the univariate model is justified by the scope of the research that analyses the relation between pairs of variables at each price-setting stage. The ECM with threshold cointegration has been chosen as a research tool, because the asymmetric ECM and the threshold autoregressive ECM yield results which are deemed not fully satisfactory, considering the low power of the cointegration tests applied to variables with asymmetric adjustments to the long-run equilibrium trajectory (see, for instance, Pippenger and Goering 1993, Balke and Fomby 1997, Enders and Granger 1998, Enders and Siklos 2001). In order to estimate the long-run relationships a cointegration analysis was applied to the low frequency, monthly data.
The structure of the article is the following. Section 2 briefly describes the price transmission process in the fuel market, the error correction model with threshold cointegration dedicated to modelling asymmetric relationships, and the estimation strategy applied. In Section 3, the levels of fuel distribution chain are analysed, as well as the empirical results that largely confirm the initial hypothesis. Finally, in section 4, the main findings are summarised and compared with those obtained in other studies.

2 The error correction model with threshold cointegration

Crude oil is the primary raw material used by the refining industry and a change in its price is commonly treated as an impulse activating the price adjustment mechanism (the weak exogeneity of crude oil price has been confirmed in Asche et al. (2003)). However, the fuel price setting process is more complex than is usually thought and price transmission is specific to the level of distribution. At the first level, the reference price of crude oil (the Brent oil price quoted on the International Petroleum Exchange in London) is transmitted to fuel prices in the ARA market (Amsterdam-Rotterdam-Antwerp, the European wholesale market). Then the spot fuel prices quoted daily in the ARA market are converted in Poland into the domestic currency (zloty) to arrive at wholesale prices. Those are added charges that are mandatory in Poland, that is excise tax and fuel duty. The resulting prices are augmented by the retailer's mark-up and VAT and thereby the retail prices are set.

There are two general types of asymmetry that can be found at particular levels of distribution: one arising from the varying speed of price adjustments to the equilibrium trajectory (long-run asymmetry) and another from the different amounts and duration of short-run adjustments (short-run asymmetry). This hypothesis can be formalized through the threshold error correction model (TECM, see Enders and Granger 1998, Enders and Siklos 2001) that can be written in a compact form as:

$$\begin{aligned} \Delta y_{1t} \quad = \quad & \alpha^{+}\hat{\varepsilon}^{+}_{t-1} + \alpha^{-}\hat{\varepsilon}^{-}_{t-1} + \sum_{s=1}^{S_1}\gamma^{+}_{1s}\Delta y^{+}_{1,t-s} + \sum_{s=1}^{S_1}\gamma^{-}_{1s}\Delta y^{-}_{1,t-s} + \\ & + \sum_{m=2}^{M}\sum_{s=0}^{S_m}\gamma^{+}_{ms}\Delta y^{+}_{m,t-s} + \sum_{m=2}^{M}\sum_{s=0}^{S_m}\gamma^{-}_{ms}\Delta y^{-}_{m,t-s} + u_t, \end{aligned} \tag{1}$$

where $\hat{\varepsilon}_t$ stands for residuals from the first step of regression $y_{1t} = \beta_0 + \beta_2 y_{2t} + \ldots + \beta_m y_{mt} + \varepsilon_t$ ordered against threshold τ in such a way that

$$\hat{\varepsilon}^{+}_t = \begin{cases} \hat{\varepsilon}_t, & \hat{\varepsilon}_t > \tau \\ 0, & \hat{\varepsilon}_t \leq \tau \end{cases} \text{ and } \hat{\varepsilon}^{-}_t = \begin{cases} \hat{\varepsilon}_t, & \hat{\varepsilon}_t < \tau \\ 0, & \hat{\varepsilon}_t \geq \tau \end{cases}$$

which is equivalent to a threshold autoregressive (TAR) model. It is assumed that $y_{mt} \sim I(1)$ and $\varepsilon_t \sim I(0)$, where $t = 1, ..., T$. Furthermore, the ordering of residuals according to

$$\hat{\varepsilon}^{+}_t = \begin{cases} \hat{\varepsilon}_t, & \Delta\hat{\varepsilon}_t > \tau \\ 0, & \Delta\hat{\varepsilon}_t \leq \tau \end{cases} \text{ and } \hat{\varepsilon}^{-}_t = \begin{cases} \hat{\varepsilon}_t, & \Delta\hat{\varepsilon}_t < \tau \\ 0, & \Delta\hat{\varepsilon}_t \geq \tau \end{cases}$$

constitutes a momentum threshold autoregressive (M-TAR) scheme and leads to a momentum threshold error correction model (M-TECM, see Caner and Hansen 2001, Enders and Granger 1998).

The parameters α^+ and α^- measure the speed at which the explained variable approaches the equilibrium trajectory. The speed varies depending on whether the variable is above or below the long-run trajectory. Increments of variables are defined as:

$$\Delta y^+_{m,t-s} = \begin{cases} y_{m,t-s} - y_{m,t-s-1}, & y_{m,t-s} - y_{m,t-s-1} > 0 \\ 0, & \text{otherwise} \end{cases}$$

$$\Delta y^-_{m,t-s} = \begin{cases} y_{m,t-s} - y_{m,t-s-1}, & y_{m,t-s} - y_{m,t-s-1} < 0 \\ 0, & \text{otherwise} \end{cases}$$

which allows the effect of asymmetric short-run adjustments to be analysed. Hypotheses $\alpha^+ = \alpha^-$, $\gamma^+_{ms} = \gamma^-_{ms}$ and $\sum_{s=0}^{S_m} \gamma^+_{ms} = \sum_{s=0}^{S_m} \gamma^-_{ms}$ are verified with the Wald test. The last hypothesis concerns a short-run cumulative response.

With the Chan (1993) procedure, a consistent estimate of the threshold τ can be obtained (see Enders and Siklos 2001). In the first step, $\hat{\varepsilon}_t$ residuals (or differences in residuals, $\Delta\hat{\varepsilon}_t$, when the M-TECM model is used) must be ordered ascendingly, with the cutting off of 15 percent of elements in the series which represent respectively the lowest and the highest values. In the second step, the remaining 70 percent of observations are used to estimate the parameters of the equation:

$$\Delta\hat{\varepsilon}_t = \rho_1 \hat{\varepsilon}^+_{t-1} + \rho_2 \hat{\varepsilon}^-_{t-1} + \sum_{s=1}^{S} \theta_s \Delta\hat{\varepsilon}_{t-s} + \mu_t, \tag{2}$$

where $\mu_t \sim IID\left(0, \sigma^2_\mu\right)$, assuming each time that the threshold value is a successive value in the ordered series. Ultimately, the consistent estimate of τ is a value minimizing the sum of residual squares. If the threshold value is set to zero, $\tau = 0$, the above model reduces to the asymmetric error correction model (see Granger and Lee 1989).

Equation (2) is also used to test a hypothesis stating that the error correction mechanism has a threshold effect (see Enders and Granger 1998, Enders and Siklos 2001). The $\rho_1 = \rho_2 = 0$ hypothesis is verified by means of Φ statistics with non-standard F-distribution; the $\rho_{\max} = 0$ hypothesis where $\rho_{\max} = \max\{\rho_1, \rho_2\}$ is tested by t-max statistics with t-Student distribution. Enders and Siklos (2001) have tabulated the critical values in the distributions of both statistics for an unknown threshold value and a predetermined threshold value ($\tau = 0$).

For any τ, $\rho_1 < 0$, $\rho_2 < 0$ and $(1 + \rho_1)(1 + \rho_2) < 1$ are necessary and sufficient conditions for residuals from the long-run relation to be stationary (see Petrucelli and Woolford 1984). When the error term ε_t is stationary, then the estimates of the ρ_1 and ρ_2 parameters obtained from the ordinary least squares method have asymptotic multivariate normal distribution (see Tong 1983, 1990).

With the following formulas (see Doornik and Hendry 1994, Hendry 1995):

$$MAL^+ = \left(1 - \gamma^+_{m0}\right) / \left|\alpha^+\right|, \tag{3a}$$

$$MAL^{-} = \left(1 - \gamma_{m0}^{-}\right) / \left|\alpha^{-}\right| \tag{3b}$$

the asymmetric mean adjustment lags (MAL) of a complete pass-through can be found. The lags vary depending on whether the variable is above (MAL^{+}) or below (MAL^{-}) the long-run trajectory.

3 Empirical analysis

The Polish fuel sector offers a wide range of liquid fuels: motor petrols (unleaded 95 and 98), diesel oil, heating oils (classified by density and sulphur content into light, medium and heavy) and LPG. In the research, the asymmetric price effect is studied for fuels that have the largest market shares, that is diesel oil and unleaded 95 petrol, using monthly time series from the period January 2000 – March 2011. The data have been transformed into real terms (adjusted for inflation) by means of the consumer price index with the base period of January 2000. All prices are given as indexes expressed in Polish zlotys, so the effects of exchange rate fluctuations have been eliminated. The net retail prices of both considered fuels are used, because the value-added tax is calculated ad valorem.
The research results clearly showed that all stochastic processes generating variables were integrated of order one (see Table 1).
To find out whether an asymmetric price effect occurs, in the first step the parameters of the long-run relationships were estimated, separately for each of the three levels of distribution:

the European wholesale market

$$ara_t^j = \beta_0 + \beta_1 brent_t + \varepsilon_t, \tag{4a}$$

the Polish wholesale market

$$wp_t^j = \beta_0 + \beta_1 ara_t^j + \beta_2 tax_t^j + \varepsilon_t, \tag{4b}$$

the Polish retail market

$$rp_t^j = \beta_0 + \beta_1 wp_t^j + \varepsilon_t, \tag{4c}$$

or, alternatively, omitting the different levels of distribution

$$rp_t^j = \beta_0 + \beta_1 brent_t + \varepsilon_t, \tag{4d}$$

where:
brent – the crude oil price,

Table 1: Order of integration

Variable	Symbol / transformation of the variable	ADF test statistics	KPSS test statistics
Hypothesis ADF: I(1) vs. I(2) KPSS: I(1) vs. I(2)			
ARA price of 95 petrol	Δara^{PB}	-9.825	0.029
Domestic wholesale price of 95 petrol	Δwp^{PB}	-9.743	0.022
Retail price of 95 petrol	Δrp^{PB}	-8.512	0.024
Charges on the wholesale price of 95 petrol	Δtax^{PB}	-9.306	0.134
ARA price of diesel oil	Δara^{ON}	-9.976	0.050
Domestic wholesale price of diesel oil	Δwp^{ON}	-10.357	0.049
Retail price of diesel oil	Δrp^{ON}	-7.500	0.052
Charges on the wholesale price of diesel oil	Δtax^{ON}	-10.940	0.169
Brent oil price	$\Delta brent$	-11.030	0.052
Hypothesis ADF: I(1) vs. I(0) KPSS: I(0) vs. I(1)			
ARA price of 95 petrol	ara^{PB}	-1.852	3.148
Domestic wholesale price of 95 petrol	wp^{PB}	-1.985	3.554
Retail price of 95 petrol	rp^{PB}	-1.663	3.094
Charges on the wholesale price of 95 petrol	tax^{PB}	-2.268	0.778
ARA price of diesel oil	ara^{ON}	-1.208	3.867
Domestic wholesale price of diesel oil	wp^{ON}	-1.019	4.524
Retail price of diesel oil	rp^{ON}	-1.421	4.658
Charges on the wholesale price of diesel oil	tax^{ON}	-2.814	1.670
Brent oil price	$brent$	-1.221	4.308

Δ stands for first difference. Inference at a level of significance of 0.05. The test equations included constant and dummy variables allowing for seasonal effects. The critical value in the ADF test was -2.86 (see, Davidson, MacKinnon, 1993) and 0.463 in the KPSS test (see Kwiatkowski *et al.*, 1992).

ara – the ARA fuel price,
wp – the domestic wholesale price of fuel,
tax – charges levied on the wholesale price (excise tax plus fuel duty),
rp – the fuel retail price,
and j denotes the type of fuel (unleaded 95 petrol or diesel oil).

Since net retail prices of fuels were used, VAT enters neither (4c) nor (4d).
The results in Table 2 provide solid arguments that all the considered equations define stable long-run relationships.
In the next step, the threshold cointegration hypotheses were tested for both types of fuels and price-setting stages (4a)-(4d), assuming that the process was TAR or

M-TAR and $\tau = 0$, or estimating the threshold value with the Chan's procedure (see Tables 3a and 3b).

The results of the threshold cointegration test, t-max, obtained for particular models at a significance level of 0.05 led to the rejection of the hypothesis stating that the variables are not cointegrated. An exception was the M-TAR model for the stage where a crude oil price is directly transmitted to a diesel oil retail price. However, an alternative test of the $\rho_1 = \rho_2 = 0$ hypothesis rejected it at $p = 0.01$ for all models, pointing to the threshold cointegration between the respective variables.

Table 2: Parameter estimates of the long-run relationships

Long-run parameters	Type of fuel	
	95 petrol	Diesel oil
crude oil price (brent) → ara price (ara)		
β_0	0.054 (6.031)	0.021 (2.495)
β_1	0.876 (35.067)	0.943 (39.596)
ara price (ara) → wholesale price (wp)		
β_0	0.017 (5.071)	-0.017 (-2.727)
β_1	0.399 (64.476)	0.495 (56.031)
β_2	0.416 (14.707)	0.471 (9.240)
wholesale price (wp) → retail price (rp)		
β_0	-0.006 (-1.542)	0.017 (5.655)
β_1	0.786 (34.310)	0.917 (66.277)
crude oil price (brent) → retail price (rp)		
β_0	0.052 (12.339)	0.059 (9.201)
β_1	0.262 (22.610)	0.447 (25.283)

Note: the brackets show the t-Student statistics.

The best model was selected on the basis of AIC and BIC information criteria (see bolded columns in Tables 3a and 3b). It is notable that the TAR model with a zero threshold value was not ranked among the best models regardless of the level of price transmission.

The optimal lag distribution in the threshold error correction models (1) was determined from the Akaike and Hannan-Quinn information criteria. It is worth noting that the decomposition of the impact of short-term increases and decreases in charges levied on the wholesale prices had to be given up because of steadily rising nominal taxes in the sample period, which means that the $\gamma_{30}^{+} = \gamma_{30}^{-}$ parameters were assumed to be equal.

Because the error correction parameter estimates were statistically significantly different from zero (excluding the parameters showing how fast the retail fuel prices adjust to the long-run trajectory following a decrease in the price of crude oil, see Table 4), applying a threshold error correction model to all relationships between prices was a rational solution. Further, the $|\alpha^{+}| < |\alpha^{-}|$ condition was met in all instances as expected, thus proving that fuel prices respond more readily to an upward impulse.

The results of the Wald tests lead to the following conclusions (see Table 5).

Table 3a: The results of the threshold cointegration tests for 95 petrol

Parameters Hypothesis Information criteria	Pattern of adjustment: TAR		M-TAR	
crude oil price (brent) → ara price (ara)				
τ	0	0.012	0	**-0.009**
ρ_1	-0.328 (-4.483)	-0.330 (-4.514)	-0.283 (-3.597)	**-0.244** (-3.349)
ρ_2	-0.269 (-2.917)	-0.266 (-2.880)	-0.332 (-3.926)	**-0.407** (-4.404)
θ_1	0.260 (3.086)	0.260 (3.083)	0.255 (2.998)	**0.250** (2.975)
$\rho_1 = \rho_2 = 0$	13.527 (0.000)	13.558 (0.000)	13.483 (0.000)	**14.574** (0.000)
AIC	-407.574	-407.627	-407.499	**-409.337**
BIC	-396.013	-396.066	-395.938	**-397.775**
ara price (ara) → wholesale price (wp)				
τ	0	**-0.011**	0	0.013
ρ_1	-0.347 **(-3.761)**	**-0.332 (-3.731)**	-0.373 (-3.994)	-0.225 (-1.587)
ρ_2	-0.384 (-3.864)	**-0.408 (-3.930)**	-0.382 (-3.990)	-0.420 (-5.585)
$\rho_1 = \rho_2 = 0$	14.539 (0.000)	**14.684 (0.000)**	15.933 (0.000)	16.857 (0.000)
AIC	-771.612	**-771.854**	-769.886	-771.386
BIC	-762.918	**-763.160**	-761.215	-762.715

Note: the critical values of the *t-max* test at a significance level of 0.05 are -2.11 and –2.14 for the TAR model with a zero threshold and -1.85 and -1.90 when the threshold value is unknown (for model variants without lags and with one lag, respectively); for the M-TAR model these are -2.02 and -2.03 in the first case and -1.90 and -1.94 in the second case (for model variants without lags and with one lag, as before), see Enders, Siklos (2001).

At the first level of the distribution chain (*brent* → *ara*) the error correction parameter estimates are significantly different, particularly in the case of unleaded 95 petrol. This means that the ARA prices adjust to the equilibrium trajectory at

Table 3a: The results of the threshold cointegration tests for 95 petrol

Parameters Hypothesis Information criteria	Pattern of adjustment			
	TAR		M-TAR	
wholesale price (wp) → retail price (rp)				
τ	0	0.026	0	**-0.015**
ρ_1	-0.527 (-5.775)	-0.579 (-5.947)	-0.500 (-5.848)	**-0.477** (-6.126)
ρ_2	-0.422 (-3.929)	-0.388 (-3.983)	-0.448 (-3.706)	**-0.519** (-3.205)
θ_1	0.300 (3.571)	0.301 (3.613)	0.297 (3.532)	**0.299** (3.534)
$\rho_1 = \rho_2 = 0$	22.377 (0.000)	23.393 (0.000)	22.056 (0.000)	**22.005** (0.000)
AIC	-662.007	-661.439	-661.517	**-663.544**
BIC	-650.445	-649.878	-649.955	**-651.982**
crude oil price (brent) → retail price (rp)				
τ	0	0.040	0	**0.008**
ρ_1	-0.299 (-3.664)	-0.266 (-2.913)	-0.229 (-2.848)	**-0.229** (-2.324)
ρ_2	-0.343 (-4.106)	-0.358 (-4.703)	-0.419 (-5.032)	**-0.368** (-5.099)
θ_1	0.236 (2.785)	0.237 (2.801)	0.245 (2.917)	**0.230** (2.721)
$\rho_1 = \rho_2 = 0$	14.198 (0.000)	14.489 (0.000)	15.846 (0.000)	**14.954** (0.000)
AIC	-609.309	-609.797	-610.573	**-612.048**
BIC	-597.748	-598.236	-599. 012	**-600.487**

Note: the critical values of the *t-max* test at a significance level of 0.05 are -2.11 and –2.14 for the TAR model with a zero threshold and -1.85 and -1.90 when the threshold value is unknown (for model variants without lags and with one lag, respectively); for the M-TAR model these are -2.02 and -2.03 in the first case and -1.90 and -1.94 in the second case (for model variants without lags and with one lag, as before), see Enders, Siklos (2001).

a speed that varies depending on whether crude oil price goes up or down. At the same time, the short-term response of the ARA prices to a change in the crude oil price is immediate (occurring in the same period) and its intensity is unrelated to the direction of the change.

At the second level of distribution where a fuel price quoted on the European market is transmitted to its wholesale price in Poland ($ara \rightarrow wp$), the reference price increases and decreases bring about a symmetric response, with the short-run pass-through of an impulse from the ARA market being lagged by one month. This finding can be explained as follows. Because the Orlen company has a dominant position in the market, the Lotos company and minor players have to abide by to the rules it sets. Additionally, because of the special characteristics of the Polish wholesale market for fuels domestic refineries set their prices within the range of the European

Table 3b: The results of the threshold cointegration tests for diesel oil

Parameters Hypothesis Information criteria	Pattern of adjustment			
	TAR		M-TAR	
crude oil price (brent) → ara price (ara)				
τ	0	-0.051	0	**-0.074**
ρ_2	-0.324 (-4.362)	-0.328 (-4.521)	-0.262 (-3.810)	**-0.232** (-3.903)
θ_1	-0.146 (-1.610)	-0.127 (-1.350)	-0.235 (-2.180)	**-0.602** (-2.592)
$\rho_1 = \rho_2 = 0$	10.81 (0.000)	11.133 (0.000)	9.634 (0.000)	**10.976** (0.000)
AIC	-407.187	-409.099	-408.334	**-410.69**
BIC	-392.773	-394.685	-399.663	**-402.019**
ara price (ara) → wholesale price (wp)				
τ	0	**-0.045**	0	0.008
ρ_1	-0.311 (-4.113)	**-0.212** (-3.576)	-0.311 (-4.417)	-0.422 (-5.296)
ρ_2	-0.136 (-1.663)	**-0.376** (-2.252)	-0.091 (-1.033)	-0.064 (-0.880)
$\rho_1 = \rho_2 = 0$	9.84 (0.000)	**8.93** (0.000)	10.287 (0.000)	14.409 (0.000)
AIC	-713.619	**-717.86**	-710.816	-712.002
BIC	-704.926	**-709.189**	-702.145	-703.308
wholesale price (wp) → retail price (rp)				
τ	0	**-0.024**	0	-0.006
ρ_1	-0.452 (-4.938)	**-0.432** (-5.108)	-0.462 (-4.975)	-0.425 (-4.904)
ρ_2	-0.448 (-3.676)	**-0.506** (-3.473)	-0.438 (-3.642)	-0.523 (-3.794)
$\rho_1 = \rho_2 = 0$	18.949 (0.000)	**19.074** (0.000)	19.007 (0.000)	19.221 (0.000)
AIC	-666.976	**-667.173**	-661.298	-661.635
BIC	-658.282	**-658.479**	-652.627	-652.964
crude oil price (brent) → retail price (rp)				
τ	0	-0.054	0	**0.041**
ρ_1	-0.214 (-2.959)	-0.234 (-3.471)	-0.177 (-2.639)	**0.01** -0.088
ρ_2	-0.195 (-2.560)	-0.161 (-1.938)	-0.269 (-3.299)	**-0.274** (-4.769)
$\rho_1 = \rho_2 = 0$	7.656 -0.001	7.901 -0.001	8.924 0	**11.373** 0
AIC	-518.179	-518.624	-518.181	**-522.488**
BIC	-509.485	-509.931	-509.51	**-513.817**

Note: see comments to table 3a.

Table 4: Parameter estimates of the threshold ECM models

Model parameters	Type of fuel	
	95 petrol	Diesel oil
crude oil price (brent) → ara price (ara)		
α^+	-0.157 (-2.201)	-0.298 (-5.372)
α^-	-0.412 (-4.267)	-0.571 (-2.721)
γ_{20}^+	0.920 (12.355)	0.746 (11.670)
γ_{20}^-	1.060 (15.768)	0.659 (10.963)
wholesale price (wp) → retail price (rp)		
α^+	-0.179 (-2.418)	-0.221 (-3.391)
α^-	-0.388 (-3.689)	-0.418 (-4.521)
γ_{20}^+	0.615 (11.796)	0.601 (17.165)
γ_{20}^-	0.335 (7.972)	0.455 (13.184)
γ_{21}^+	0.226 (4.325)	0.160 (3.895)
γ_{21}^-	0.301 (5.323)	0.251 (5.358)
γ_{22}^+	0.001 (0.021)	–
γ_{22}^-	0.124 (2.740)	–
γ_{23}^+	0.033 (0.704)	–
γ_{23}^-	0.137 (3.292)	–

Note: the brackets show the t-Student statistics.

wholesale prices (converted into zlotys) to make the import of fuels unprofitable. Asymmetric price transmission can also be found between the wholesale price and the retail price of both considered fuels ($wp \to rp$). The research results show asymmetry in the speed the prices adjust to the long-run equilibrium trajectory, as well as in the magnitude and duration of the response. Trying to compensate for wholesale price increases, retailers significantly raise their prices in the same period, but their direct response to wholesale price decreases is not only weaker, but also extended in time (see Figure 1). These practices are possible due to low price elasticity of the demand for fuels. Interestingly, in the case of diesel oil short-run adjustments do not exceed two periods (the lags were statistically insignificant after $s = 2$). An analysis of the direct

Table 4: Parameter estimates of the threshold ECM models

Model parameters	Type of fuel	
	95 petrol	Diesel oil
ara price (*ara*) $\rightarrow$ *wholesale price* (*wp*)		
α^+	-0.283 (-3.329)	-0.194 (-3.528)
α^-	-0.329 (-3.080)	-0.338 (-2.181)
γ_{20}^+	0.359 (18.357)	0.451 (17.529)
γ_{20}^-	0.348 (21.733)	0.411 (16.788)
γ_{21}^+	0.053 (2.729)	0.034 (1.254)
γ_{21}^-	0.049 (2.907)	0.057 (2.281)
γ_{30}	0.406 (8.340)	0.212 (2.582)
crude oil price (*brent*) $\rightarrow$ *retail price* (*rp*)		
α^+	-0.069 (-0.859)	-0.035 (-0.446)
α^-	-0.237 (-4.114)	-0.160 (-4.391)
γ_{20}^+	0.206 (6.132)	0.221 (6.651)
γ_{20}^-	0.165 (5.734)	0.115 (3.910)
γ_{21}^+	0.177 (5.332)	0.067 (2.049)
γ_{21}^-	0.143 (4.502)	0.162 (4.569)
γ_{22}^+	-0.018 (-0.569)	–
γ_{22}^-	0.068 (2.232)	–

Note: the brackets show the t-Student statistics.

relationship between the crude oil price and the fuel retail price ($brent \rightarrow rp$) has also found asymmetric price transmission. The results support the hypothesis that the latter price responds more readily when a crude oil price goes up than when it goes down (see Figure 2). Moreover, the adjustment of the retail price of a fuel to the equilibrium trajectory is statistically insignificant when the crude oil price is falling, which means that retailers following an asymmetric pricing policy mainly respond to increases in crude oil price, while decreases induce a very weak response from them. The above conclusions are supported by cumulative response functions to upward and

Table 5: The Wald test results

Null hypothesis	Type of fuel	
	95 petrol	Diesel oil
crude oil price (brent) → ara price (ara)		
$\alpha^+ = \alpha^-$	4.229 (0.042)	1.579 (0.211)
$\gamma_{20}^+ = \gamma_{20}^-$	1.826 (0.179)	0.982 (0.324)
ara price (ara) → wholesale price (wp)		
$\alpha^+ = \alpha^-$	0.101 (0.751)	0.769 (0.382)
$\gamma_{20}^+ = \gamma_{20}^-$	0.138 (0.710)	1.023 (0.314)
$\gamma_{21}^+ = \gamma_{21}^-$	0.019 (0.892)	0.322 (0.571)
$\sum_{s=0}^{S_2} \gamma_{2s}^+ = \sum_{s=0}^{S_2} \gamma_{2s}^-$	0.384 (0.537)	0.244 (0.623)
wholesale price (wp) → retail price (rp)		
$\alpha^+ = \alpha^-$	3.522 (0.063)	3.400 (0.068)
$\gamma_{20}^+ = \gamma_{20}^-$	13.545 (0.000)	7.380 (0.008)
$\gamma_{21}^+ = \gamma_{21}^-$	0.926 (0.338)	2.118 (0.148)
$\gamma_{22}^+ = \gamma_{22}^-$	2.598 (0.110)	–
$\gamma_{23}^+ = \gamma_{23}^-$	1.963 (0.164)	–
$\sum_{s=0}^{S_2} \gamma_{2s}^+ = \sum_{s=0}^{S_2} \gamma_{2s}^-$	0.137 (0.712)	0.911 (0.342)
crude oil price (brent) → retail price (rp)		
$\alpha^+ = \alpha^-$	2.936 (0.089)	2.286 (0.133)
$\gamma_{20}^+ = \gamma_{20}^-$	0.622 (0.432)	4.523 (0.035)
$\gamma_{21}^+ = \gamma_{21}^-$	0.404 (0.526)	3.298 (0.072)
$\gamma_{22}^+ = \gamma_{22}^-$	2.857 (0.093)	–
$\sum_{s=0}^{S_2} \gamma_{2s}^+ = \sum_{s=0}^{S_2} \gamma_{2s}^-$	0.079 (0.779)	0.064 (0.800)

Note: the brackets show the t-Student statistics.

downward impulses, which were determined for each level of distribution (see Figures 3-6). It should be noted, however, that the results are limited to point estimates only. The estimation of probability intervals by bootstrap methods could definitely shed

Figure 1: Short-term response of unleaded 95 petrol retail price (left) and diesel oil retail price (right) to changes in their wholesale prices

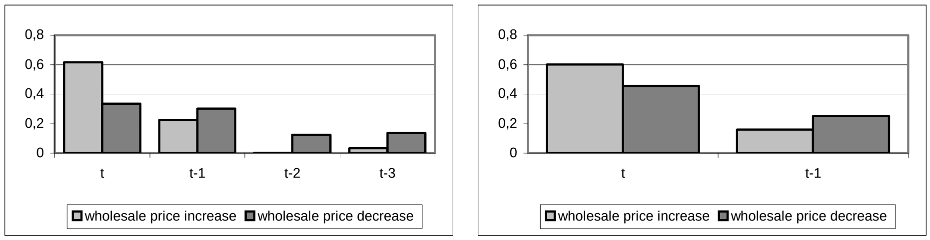
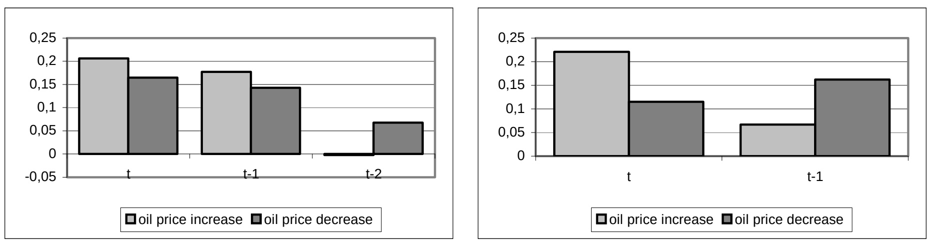


Figure 2: Short-term response of unleaded 95 petrol retail price (left) and diesel oil retail price (right) to a change in crude oil price



more light on the analysed problem. The relation between the European wholesale price and the Polish wholesale price of fuels is the only one that is symmetric – at all other levels of distribution the responses are asymmetric. The largest differences are found between the retail price of unleaded 95 petrol and of diesel oil responding to their rising and falling wholesale prices (0.26 p.p. and 0.15 p.p., respectively). The analysis of the direct relationship between the crude oil price and the fuel retail price ($brent \rightarrow rp$) shows the asymmetric price effect to be present at all times (see Figure 6).

The mean lag measuring the amount of time that prices need to adjust fully to the long-run equilibrium trajectory indicates that at each level of distribution upward price adjustments are effected in less time than those directed downward (see Table 6). The fastest to return to the equilibrium trajectory are fuel prices in the ARA market, as impulse transmission is complete within one month. At the second and third levels of the distribution chain, price adjustments induced by upward and downward impulses do not take longer than two and three months, respectively. The total times for a crude oil price decrease to pass through to the retail prices of unleaded 95 petrol and diesel oil are, respectively, 11.5 months and 22.3 months, while for a crude oil price increase these are 3.5 months and 5.5 months. It confirms that retailers pursuing an asymmetric pricing policy respond to increases in crude oil prices much more strongly.

Figure 3: Cumulative response functions of the European wholesale price of unleaded 95 petrol (left) and diesel oil (right) to a unit impulse from crude oil price

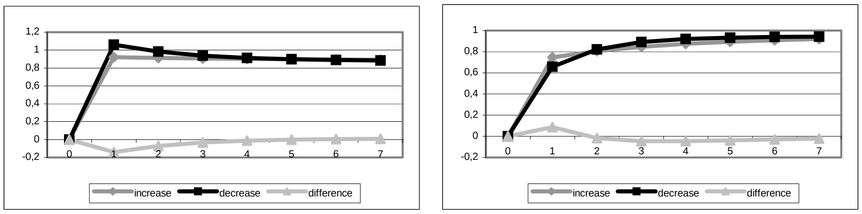


Figure 4: Cumulative response functions of the domestic wholesale price of unleaded 95 petrol (left) and diesel oil (right) to a unit impulse from the ARA wholesale price

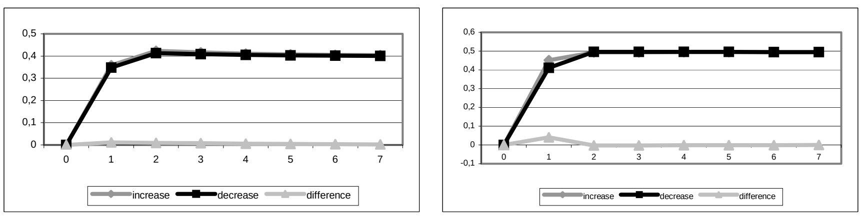


Figure 5: Cumulative response functions of the retail prices of unleaded 95 petrol (left) and diesel (right) to a unit impulse from their wholesale prices

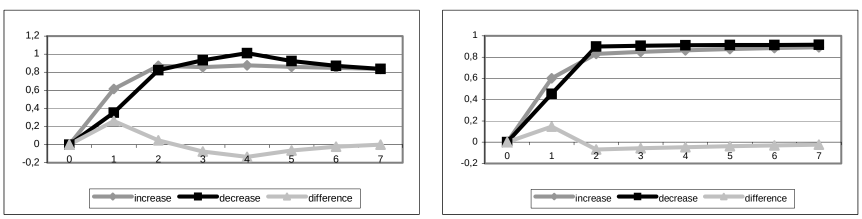


Figure 6: Cumulative response functions of the retail prices of unleaded 95 petrol (left) and diesel oil (right) to a unit impulse from crude oil price

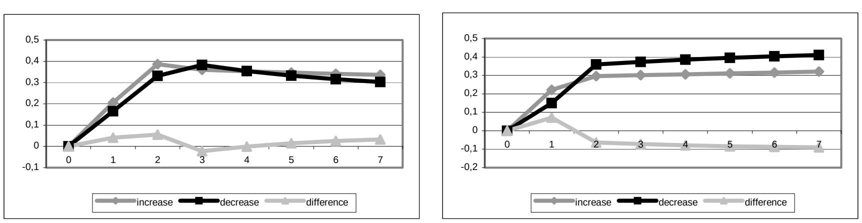


Table 6: Mean adjustment lags of a complete pass-through by level of the distribution chain

Mean adjustment lag (MAL)	Type of fuel	
	95 petrol	Diesel oil
crude oil price ($brent$) $\rightarrow$ *ara price* (ara)		
MAL^{+}	0.510	0.852
MAL^{-}	0.146	0.597
ara price (ara) $\rightarrow$ *wholesale price* (wp)		
MAL^{+}	2.265	2.830
MAL^{-}	1.982	1.743
wholesale price (wp) $\rightarrow$ *retail price* (rp)		
MAL^{+}	2.151	1.805
MAL^{-}	1.714	1.304
crude oil price ($brent$) $\rightarrow$ *retail price* (rp)		
MAL^{+}	11.507	22.257
MAL^{-}	3.523	5.531

4 Conclusions

The threshold error correction model used in this research allowed the price transmission mechanisms to be decomposed into short- and long-run effects and the asymmetric mean adjustment lags of a complete pass-through to be determined, thus considerably expanding the knowledge of these processes. The hypotheses about the presence of asymmetric price adjustments were tested for two main types of fuels and for particular levels of distribution. This approach proved that the scale of price transmission asymmetry varies depending on the level of distribution.

The direct relationship between the crude oil price and the retail prices of fuels, that is without the intermediate levels was also analysed. The widespread opinion that retail prices respond more readily to crude oil price increases than to its decreases has been confirmed.

According to the results, asymmetric price transmission can be expected already at the first level of the distribution chain (in the European market), where crude oil prices become fuel prices quoted in the ARA market. The special characteristics of the Polish wholesale market and the risk that the oil-based products will be imported directly from abroad discourage domestic oil companies from exploiting their market position to generate extra profits and make them follow the reference prices (almost) symmetrically. On the contrary, significant asymmetric price transmission can be observed between the wholesale prices and the retail prices of both analysed fuels, though.

Similar studies on the Polish fuel market and other markets in the CEE countries have not been performed so far. The existing analyses of the EU member states (see Wlazlowski et al. 2009, Clerides 2010) use different samples, data frequencies, levels of distribution and econometric methods, so comparing their results with our findings is

not a straightforward task. Clerides (2010) has reached similar conclusions to ours for unleaded gasoline, but somewhat different for diesel oil (identifying weak asymmetry in the reverse direction), probably because of adopting a simple asymmetric error correction model where the threshold value was not estimated but set to zero.
The threshold error correction model that was used in this study to analyse the different levels of the fuel distribution chain offers a new perspective on the price-setting processes in an imperfectly competitive fuel market of a medium-sized, non-oil producing country in transition.

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