# Relation of Retail Gasoline and Diesel Prices in Croatia with Crude Oil Prices on World Markets

*Karol Szomolányi*
*University of Economics in Bratislava, Slovakia*
*Martin Lukáčik*
*University of Economics in Bratislava, Slovakia*
*Adriana Lukáčiková*
*University of Economics in Bratislava, Slovakia*

## Abstract

According to many studies, the transmission of oil prices to retail fuel prices is asymmetric. Fuel prices react faster if oil prices rise and more slowly if oil prices fall. We use the simple and dynamic asymmetry models, error correction models, threshold autoregressive cointegration, and an approach based on the adjustment cost function in the linear-exponential form to verify the hypothesis of asymmetric reactions of gasoline and diesel prices in Croatia. The analysis uses a weekly time series of Croatian fuel prices obtained from the European Commission Weekly Oil Bulletin and BRENT oil prices from the US Energy Information Administration. Different standard econometric procedures lead to different results. Nevertheless, the approach based on the linear-exponential lost function confirmed the price asymmetries in the Croatian market.

**Keywords:** asymmetry; retail gasoline prices; error correction model; threshold autoregressive cointegration; linear-exponential adjustment cost function; generalised method of moments; Croatia
**JEL classification:** C26; C51; Q41

**Paper type:** Research article
**Received:** 24 January 2023
**Accepted:** 28 April 2023

**DOI:** 10.54820/entrenova-2023-0005

**Acknowledgements:** The Grant Agency of Slovak Republic - VEGA, supports this paper by grant no. 1/0211/21, "Econometric Analysis of Macroeconomic Impacts of Pandemics in the World with Emphasis on the Development of EU Economies and Especially the Slovak Economy".

# Introduction

There is a common consumer complaint that retail fuel prices respond fast if crude oil prices rise but more slowly if crude oil prices fall. This asymmetric transition of input prices to output prices in the retail fuel market has been confirmed by many studies, beginning with Bacon (1991).

Among the first European studies dealing with asymmetric responses of retail prices was Lanza (1991), who confirmed asymmetric responses of retail prices to wholesale gasoline prices. In recent works, the authors confirmed asymmetric reactions in different European countries.

Apergis & Vouzavalis (2018) confirmed short-term asymmetric adjustment of retail gasoline prices to changes in crude oil prices on the Italian market and short- and long-term on the Spanish market. Torrado and Escribano (2020) confirmed the asymmetry in the Spanish and German markets. Bragoudakis et al. (2020) showed evidence of the asymmetric markup creation by Greek refineries in response to world crude oil price changes. This asymmetry is further transmitted to retailers and consumers. However, Bragoudakis and Sideris (2021) did not confirm asymmetric adjustments of gasoline prices to oil price changes in the Greek market after 2010. Genakos and Pagliero pointed out that consumers in isolated islands with less competition faced asymmetric responses of retail gasoline prices to unannounced and non-negligible increases in consumer taxes in 2010. Čipčić (2021), in research on reactions of retail fuel prices to changes in crude oil prices in Croatia, Czech Republic, Hungary, Slovenia, Slovak Republic, and Poland, confirmed asymmetries in the short period between 2009 and 2013 in 33.33% of the analysed cases. Szomolányi et al. (2020) confirmed asymmetric retail fuel price adjustment on crude oil price changes in Slovakia.

We adapted the paper structure to the breadth of methodological procedures with several diverse econometric models. We have created a section for each method containing the estimation results using European Commission Weekly Oil Bulletin (Croatian retail gasoline and diesel prices) and US Energy Information Administration (BRENT crude oil prices) data. We combined the discussion and conclusion in the final section.

# Simple Models of Asymmetry

We start with the simple model of asymmetry, similar to Tweeten & Quance (1969):

$$y_t = \beta_0 + \gamma_0^+ x_t^+ + \gamma_0^- x_t^- + u_t \quad (1)$$

where $y_t$ is regressand and the average weekly price of gasoline or diesel in time $t$; $x_t^+$ is the average weekly price of oil in time $t$ equals $x_t$ if its value has increased over the last period and zero otherwise and $x_t^-$ is the average weekly price of oil in time $t$ equals $x_t$ if its value has decreased over the last period and zero otherwise.

We can continue with a model with another regressor (the price of another fuel $z_t$ – the gasoline price in the equation of diesel price and vice versa):

$$y_t = \beta_0 + \gamma_0^+ x_t^+ + \gamma_0^- x_t^- + \delta_0 z_t + u_t \quad (2)$$

Asymmetry in models (1) and (2) is present if the null hypothesis of $\gamma_0^+ = \gamma_0^-$ is rejected. The F test can test this linear hypothesis in the linear model.

We can also consider more dynamic models, similar to Karrenbrock (1991):

$$\Delta y_t = \beta_0 + \sum_{i=0}^{s} \gamma_i^+ \Delta x_{t-i}^+ + \sum_{i=0}^{q} \gamma_i^- \Delta x_{t-i}^- + u_t \quad (3)$$

where the cumulative effect of price variation can be tested with the hypothesis: $\sum_{i=0}^{s}\gamma_i^{+}=\sum_{i=0}^{q}\gamma_i^{-}$

Table 1 shows the coefficient estimates and asymmetry tests of the (1)-(3).

*Table 1*
Simple and Dynamic Models of Croatia's Fuel Prices Asymmetry

| Simple Models | $\gamma_0^+$ | $\gamma_0^-$ | $\delta_0$ | Symmetry |
|---|---|---|---|---|
| **gasoline model (1)** | 0.3840*** | 0.3953*** | --- | ***F* = 6.182**** |
| (std. err.) | (0.050) | (0.053) | --- | **[0.013]** |
| diesel model (1) | 0.3514*** | 0.3620*** | --- | *F* = 3.095* |
| (std. err.) | (0.064) | (0.069) | --- | [0.079] |
| **gasoline model (2)** | 0.1031** | 0.1089** | 0.5966*** | ***F* = 4.413**** |
| (std. err.) | (0.045) | (0.046) | (0.016) | **[0.036]** |
| diesel model (2) | 0.0670** | 0.0693** | 0.8083*** | *F* = 0.119 |
| (std. err.) | (0.030) | (0.032) | (0.185) | [0.731] |
| **Dynamic Models – 1 Lag** | **Symmetry** | **Dynamic Models – 2 Lags** | | **Symmetry** |
| gasoline model (3) | *F* = 1.001 | gasoline model (3) | | *F* = 0.424 |
| | [0.318] | | | [0.515] |
| diesel model (3) | *F* = 0.024 | diesel model (3) | | *F* = 0.915 |
| | [0.878] | | | [0.393] |
| **Dynamic Models – 3 Lags** | **Symmetry** | **Dynamic Models – 4 Lags** | | **Symmetry** |
| gasoline model (3) | *F* = 0.584 | gasoline model (3) | | *F* = 2.634 |
| | [0.445] | | | [0.105] |
| diesel model (3) | *F* = 0.342 | diesel model (3) | | *F* = 0.177 |
| | [0.559] | | | [0.674] |

*Note:* Three asterisks indicate statistical significance at the 1% significance level, two at the 5%. A bolded result means the rejection of symmetry. The probability values are in square brackets.
*Source:* Authors' calculations

## Error Correction Models

We continue with the auto-regressive distributed lag model of order one with two variables:

$$y_t=\beta_0+\beta_1 y_{t-1}+\gamma_0 x_t+\gamma_1 x_{t-1}+u_t \tag{4}$$

and then with three variables:

$$y_t=\beta_0+\beta_1 y_{t-1}+\gamma_0 x_t+\gamma_1 x_{t-1}+\delta_0 z_t+\delta_1 z_{t-1}+u_t \tag{5}$$

where $y_t$ is the average weekly price of gasoline or diesel in time $t$; $x_t$ is the average weekly price of oil in time $t$; $z_t$ is another relevant regressor in time $t$ (the price of another fuel); $u_t$ is a stochastic term in time $t$ and $\beta_0$, $\beta_1$, $\gamma_0$, $\gamma_1$, $\delta_0$, and $\delta_1$ are unknown parameters of this regression model.

We can rewrite model (4) as the error correction model (Engle & Granger, 1987):

$$\Delta y_t=\beta_0+\gamma_0\Delta x_t+(\beta_1-1)\left[y_{t-1}-\frac{(\gamma_0+\gamma_1)}{1-\beta_1}x_{t-1}\right]+u_t \tag{6}$$

and model (5) as the error correction (ECM) model:

$$\Delta y_t=\beta_0+\gamma_0\Delta x_t+\delta_0\Delta z_t+(\beta_1-1)\left[y_{t-1}-\frac{(\gamma_0+\gamma_1)}{1-\beta_1}x_{t-1}-\frac{(\delta_0+\delta_1)}{1-\beta_1}z_{t-1}\right]+u_t \tag{7}$$

which contains the original (one period-lagged) variables in the levels and their first differences. Suppose a positive unit change of the regressor has an identical influence on the regressand as a negative unit change. In that case, we do not have to distinguish between them. We can estimate the overall response with one parameter for one regressor, as in the reversible models (6) and (7). If this restriction is not valid, the estimation results can be improved by specifying increases ($\Delta^+x_t$ and $\Delta^+z_t$) and decreases ($\Delta^-x_t$ and ($\Delta^-z_t$) of the explanatory variables as separate variables and also by separating the positive and negative deviations from the long-run equilibrium relationship.

The asymmetric irreversible error correction model (Granger & Lee, 1989):

$$\Delta y_t = \beta_0 + \gamma_0^+ \Delta^+ x_t + \gamma_0^- \Delta^- x_t + \lambda^+ e_{t-1} \times D(e_{t-1} > 0) + \lambda^- e_{t-1} \times D(e_{t-1} \le 0) + u_t \quad (8)$$

where $e_{t-1} = y_{t-1} - \frac{(\gamma_0 + \gamma_1)}{1-\beta_1} x_{t-1}$ is one period-lagged deviation from the long-run equilibrium relationship; $D(e_{t-1} > 0)$ is a dummy variable that equals one if $e_{t-1} > 0$ and equals zero otherwise; $D(e_{t-1} \le 0)$ is a dummy variable that equals one if $e_{t-1} \le 0$ and equals zero otherwise; $\lambda^+$ and $\lambda^-$ are the corresponding adjustment parameters.
and then the asymmetric irreversible error correction (A - ECM) model:

$$\Delta y_t = \beta_0 + \gamma_0^+ \Delta^+ x_t + \gamma_0^- \Delta^- x_t + \delta_0 \Delta z_t + \lambda^+ e_{t-1} \times D(e_{t-1} > 0) + \lambda^- e_{t-1} \times D(e_{t-1} \le 0) + u_t \quad (9)$$

where $e_{t-1} = y_{t-1} - \frac{(\gamma_0 + \gamma_1)}{1-\beta_1} x_{t-1} - \frac{(\delta_0 + \delta_1)}{1-\beta_1} z_{t-1}$ is one period-lagged deviation from the long-run equilibrium relationship; $D(e_{t-1} > 0)$ is a dummy variable that equals one if $e_{t-1} > 0$ and equals zero otherwise; $D(e_{t-1} \le 0)$ is a dummy variable that equals one if $e_{t-1} \le 0$ and equals zero otherwise; $\lambda^+$ and $\lambda^-$ are the corresponding adjustment parameters, $\beta_0$, $\gamma_0^+$, $\gamma_0^-$, and $\delta_0$ are also parameters of this regression model.

*Table 2*
Error Correction Models of Croatia's Fuel Prices Asymmetry

| Cointegration Models | Engle-Granger | Cointegration Models | Engle-Granger |
|---|---|---|---|
| **gasoline model (4)** | **$\tau$ = -4.429*****| **gasoline model (5)** | **$\tau$ = -4.377***** |
| **gasoline model (4) + trend** | **$\tau$ = -5.832***** | **gasoline model (5) + trend** | **$\tau$ = -4.662**** |
| diesel model (4) | $\tau$ = -2.991 | diesel model (5) | $\tau$ = -2.939 |
| **diesel model (4) + trend** | **$\tau$ = -5.328***** | diesel model (5) + trend | $\tau$ = -3.253 |
| **Asymmetric ECM** | **LR Symmetry** | **SR Symmetry** | **Both Symmetries** |
| gasoline model (8) | $F$ = 0.738 | $F$ = 0.537 | $F$ = 1.268 |
| gasoline model (8) + trend | $F$ = 0.072 | $F$ = 1.711 | $F$ = 0.924 |
| gasoline model (9) | $F$ = 0.017 | $F$ = 3.232* | $F$ = 1.629 |
| gasoline model (9) + trend | $F$ = 0.006 | $F$ = 3.255* | $F$ = 1.704 |
| **diesel model (8) + trend** | $F$ = 0.926 | **$F$ = 5.199**** | $F$ = 2.665* |

*Note:* Three asterisks indicate statistical significance at the 1% significance level, two at the 5%. A bolded Engle-Granger test result means the rejection of symmetric cointegration. A bolded F test results mean the rejection of long-run (LR), short-run (SR) or both symmetries.
*Source:* Authors' calculations

Models (6) and (7) are obtained from models (8) and (9) using restrictions $\lambda^+ = \lambda^-$ and $\gamma_0^+ = \gamma_0^-$. In cases where models (4) and (5) have a more extensive dynamic structure, models (8) and (9) will also be more extensive. The test hypothesis will additionally include parameter comparisons for other lags.

Table 2 shows the coefficient estimates and asymmetry tests of the (4)-(9).

## Threshold Autoregressive Cointegration

Engle & Granger's (1987) approach is based on a symmetric long-run relationship. A different solution to the problem than Granger & Lee (1989) was proposed by Enders & Granger (1998), who introduced Threshold Autoregressive Cointegration. If the adjustment to the long-run equilibrium is asymmetric, the cointegration test is misspecified. To overcome the problem, Enders & Siklos (2001) replace the standard augmented Dickey-Fuller test equation with the following threshold autoregressive process:

$$\Delta e_t = I_t \rho_1 e_{t-1} + (1 - I_t)\rho_2 e_{t-1} + \varepsilon_t \quad (10)$$

where $e_t$ is the deviation from the long-run equilibrium relationship (residual).

If the errors are serially correlated, equation (10) can be augmented with the lagged differences of $e_t$ as in the standard augmented Dickey-Fuller test.

Indicator function $I_t$ is defined to depend on the lagged values of the residuals, according to the following scheme:

$I_t$ equals one if $e_{t-1} > 0$ and equals zero otherwise (11)

alternatively, it is defined to depend on the lagged values of the first differences of residuals:

$I_t$ equals one if $\Delta e_{t-1} > 0$ and equals zero otherwise (12)

The relationships (10) and (11) are called TAR cointegration. In contrast, the relationships (10) and (12) are known as momentum TAR (or M-TAR) cointegration. In M-TAR models, the threshold is placed on the variation of $e_{t-1}$ rather than on $e_{t-1}$.

The null hypothesis $\rho_1 = \rho_2 = 0$ of no cointegration can be tested through an F test. The adjustment is symmetric for nonzero $\rho_1 = \rho_2$; thus, the Engle-Granger approach is a special case of (10) and (11).

*Table 3*

TAR and M-TAR Models of Croatia's Fuel Prices Asymmetry

| TAR Models | $\rho_1 = \rho_2 = 0$ | $\rho_1 = \rho_2$ | M-TAR Models | $\rho_1 = \rho_2 = 0$ | $\rho_1 = \rho_2$ |
|---|---|---|---|---|---|
| gasoline | **F = 7.010*** ** | F = 0.462 | gasoline | **F = 5.842*** ** | F = 0.558 |
| gasol. + trend | **F = 12.10*** ** | F = 0.105 | gasol. + trend | **F = 8.887*** ** | F = 0.280 |
| diesel | **F = 4.560** ** | F = 0.006 | diesel | F = 1.896 | F = 0.614 |
| diesel + trend | **F = 5.349*** ** | F = 0.055 | diesel + trend | **F = 4.621** ** | F = 0.015 |
| Cross Models | | | Cross Models | | |
| gasoline | **F = 5.679*** ** | F = 0.001 | **gasoline** | **F = 10.06*** ** | **F = 8.255*** ** |
| gasol. + trend | **F = 6.955*** ** | F = 0.016 | **gasol. + trend** | **F = 9.203*** ** | **F = 6.423** ** |
| diesel | **F = 4.292** ** | F = 2.133 | diesel | F = 3.010* | F = 0.549 |
| diesel + trend | **F = 3.737** ** | F = 0.097 | diesel + trend | **F = 4.389** ** | F = 0.327 |

*Note:* Three asterisks indicate statistical significance at the 1% significance level, two at the 5%, and one at the 10%. A bolded F test result represents the rejection of null hypothesis.
*Source:* Authors' calculations

In the case of the rejection of null hypothesis in (10), the analysed variables are cointegrated, and the asymmetric ECM representation can be written as:

$$\Delta y_t = \lambda_{up} e_{t-1}^{up} + \lambda_{down} e_{t-1}^{down} + \sum_{i=0}^{p} \gamma_i \Delta x_{t-i} + \sum_{i=0}^{r} \delta_i \Delta z_{t-i} + \sum_{i=1}^{s} \alpha_i \Delta y_{t-i} + u_t \quad (13)$$

where $e_{t-1}^{up} = I_t e_{t-1}$, $e_{t-1}^{down} = (1 - I_t) e_{t-1}$. When ρ1 is less than ρ2, the increases tend to persist, whereas the decreases tend to revert quickly toward equilibrium.

Table 3 shows the coefficient estimates and asymmetry tests of the (10)-(13).

## Adjustment Cost Function in Linear-Exponential Form

From the linear-exponential cost function, it is possible to derive price response functions for a given fuel and a given country represented by an econometric system of equations in the form (Szomolányi et al. 2020 and 2022):

$$\Delta p_t = k \Delta c_t - \frac{1}{2} \gamma \Delta \left[ \left( p_t - k c_t \right)^2 \right] + u_t \quad (14)$$

where Δ denotes the first difference operator, $p_t$ is the output (gasoline or diesel) price, $c_t$ is the input (crude oil) price, $u_t$ is a stochastic term, $k$ is the technology coefficient, and γ is the asymmetry coefficient. If the output price reactions are excessive when the input price rises and mild when the input price falls, then the negative value of the asymmetry coefficient γ is assumed. When γ = 0, the reaction function specification is linear, and the output prices react on the input price changes symmetrically.

The changes in the input prices $\Delta c_t$ are a normally distributed process with zero mean and variance $\sigma^2$. The estimates of the average price biases are (Szomolányi et al. 2020 and 2022):

$$E(\Delta p_t) = -\frac{k^2 \gamma}{2} \sigma^2 \quad (15)$$

The orthogonality conditions implied by the rational expectation hypothesis make the GMM a natural candidate to estimate the (14). Standard errors have been computed using the Newey-West procedure. The most important feature of the procedure explained by Newey & West (1987) is its consistency in the presence of both heteroskedasticity and the autocorrelation of unknown forms.

Table 4 shows the coefficient estimates of the (14) and the bias estimate (15).

*Table 4*
Results of the Linear-Exponential Adjustment Cost Function Approach

| GMM Models | k | γ | J | Bias |
|---|---|---|---|---|
| **gasoline** | 1.5789*** | –0.0012*** | 0.521 | **0.3145** |
| (std.err.) | (0.186) | (0.0001) | [0.470] | |
| **diesel** | 1.4698*** | –0.0009*** | 0.00001 | **0.2122** |
| (std.err.) | (0.392) | (0.0002) | [0.997] | |

*Note:* Three asterisks indicate statistical significance at the 1% significance level. A bolded J test result means the rejection of orthogonality. The probability values are in square brackets.
*Source:* Authors' calculations

## Conclusion

As Deltas and Polemis (2020) argue, testing asymmetric price transition depends a lot on the design of the model. Different standard econometric procedures used in our paper, such as the simple asymmetry model, error correction model, and threshold

autoregression, also lead to different results. Nevertheless, the approach based on the linear-exponential lost function confirmed the price asymmetries in both Slovak (Szomolányi et al. 2020) and Croatian markets.

In the case of simple asymmetry models, asymmetry was indicated for gasoline prices in the simple model depending on oil price increases and decreases, but also in the model when we added the price of diesel. On the other hand, diesel prices in simple models did not show any asymmetry.

The Engle-Granger procedure showed the existence of cointegration between variables in all gasoline price models but only in the diesel price trend model without additional explanatory variables. Therefore, we only constructed an asymmetric irreversible error correction model for these cases. This time, no asymmetry was evident in any gasoline model, and only short-term asymmetry was observed in the diesel price model.

Threshold Autoregressive Models indicated no asymmetry, and Momentum Threshold Autoregressive Models show asymmetry in gasoline price models with trendless and trended diesel price explanatory variables.

Finally, we also checked the asymmetry using the linear-exponential adjustment cost function approach proposed by Szomolányi et al. (2020) for Slovakia and replicated for the US cities in Szomolányi et al. (2022). As a result, we confirmed asymmetry for both fuel prices, and we calculated bias values, which are 0.3145 for gasoline and 0.2122 for diesel.

Our results contradict Čipčić's (2021), who did not confirm asymmetric retail gasoline and diesel reactions on crude oil changes in Croatia.

# References


1. 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
2. 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
3. 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
4. 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
5. Čipčić, M. L. (2021). The Impact of Oil Prices on Petroleum Product Prices in Central East European Markets. *Proceedings of 10th International Scientific Symposium Region Entrepreneurship and Development*, 174-188.
6. 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
7. 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), Article 3. https://doi.org/10.2307/1392506
8. Enders, W., & Siklos, P. L. (2001). Cointegration and Threshold Adjustment. *Journal of Business & Economic Statistics, 19*(2), Article 2. https://doi.org/10.1198/073500101316970395
9. Engle, R. F., & Granger, C. W. J. (1987). Cointegration and Error Correction: Representation, Estimation, and Testing. *Econometrica, 55*(2), Article 2. https://doi.org/10.2307/1913236
10. 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

11. 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
12. Karrenbrock, J. D. (1991). The Behaviour of Retail Gasoline Prices: Symmetric or Not? *Federal Reserve Bank of St. Louis Review, 73*(4), 19-29.
13. Lanza, A. (1991). *Speed of Adjustment and Market Structure: A Study of the Gasoline Market in Germany*. The Oxford Institute for Energy.
14. 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
15. Szomolányi, K., Lukáčik, M., & Lukáčiková, A. (2020). Asymmetric Retail Gasoline and Diesel Price Reactions in Slovak Market. *Ekonomický časopis, 68*(2), 115-133.
16. Szomolányi, K., Lukáčik, M., & Lukáčiková, A. (2022). Asymmetric Reactions of Retail Gasoline Prices on the Changes in Crude Oil Prices in Chosen US Cities. *ENTRENOVA - ENTerprise REsearch InNOVAtion*, *8*(1), 9-15. https://doi.org/10.54820/entrenova-2022-0002
17. Torrado, M., & Escribano, Á. (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
18. Tweeten, L. G., & Quance, C. L. (1969). Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches. *American Journal of Agricultural Economics, 51*(2), Article 2. https://doi.org/10.2307/1237584

## About the authors

Karol Szomolányi was born in Bojnice in the Slovak Republic (formerly Czechoslovakia) in 1976. He is an associated operations research and econometrics professor at the University of Economics in Bratislava, Faculty of Economic Informatics, Department of Operations Research and Econometrics. He is a member of the Slovak Society for Operations Research. He deals with macroeconomic analysis and econometrics. His areas of interest are accurate business cycle models and dynamic stochastic macroeconomic models and their use for developing countries of Eastern Europe. The author can be contacted at **karol.szomolanyi@euba.sk.**

Martin Lukáčik was born in Žilina in the Slovak Republic (formerly Czechoslovakia) in 1974. He is an associated operations research and econometrics professor at the University of Economics in Bratislava, Faculty of Economic Informatics, Department of Operations Research and Econometrics. He is a president of the Slovak Society for Operations Research. He deals with the econometric methods in macroeconomic framework and time series econometrics. His areas of interest are VAR models used in macroeconomics and forecasting methods. The author can be contacted at **martin.lukacik@euba.sk**

Adriana Lukáčiková was born in Gelnica in the Slovak Republic (formerly Czechoslovakia) in 1971. She is an assistant professor of operations research and econometrics at the University of Economics in Bratislava, Faculty of Economic Informatics, Department of Operations Research and Econometrics. She is a member of the Slovak Society for Operations Research. She deals with the computable general equilibrium models and econometrics. Her area of interest is the econometric modelling of the national economy. The author can be contacted at **adriana.lukacikova@euba.sk**