Analysis of Asymmetry in Slovak Gasoline and Diesel Retail Market

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Abstract

In this paper we examine if Slovak retail gasoline and diesel prices respond more quickly when crude oil price rises rather than when it decreases. The error correction model with irreversible behaviour of explanatory variables is considered to be basic tool for the analysis of asymmetric retail price reaction of gasoline and diesel. The explanatory variable is divided into two variables, the positive and the negative differences implying a price increase and a price decrease. Due to the link between the gasoline and diesel markets, we assume a common co-integration relationship. Therefore, we also estimate vector error correction model in our analysis. The both model approaches reject expected asymmetry in the retail price reactions on crude oil changes.

Introduction

Numerous studies dealing with the transmission of crude oil prices to retail gasoline prices indicate that retail gasoline prices respond more quickly when crude oil price rises rather than when it decreases; e.g. Radchenko (2005) and Liu et al. (2010). Bacon (1991) called this asymmetric retail gasoline price adjustment as "rockets and feathers" effect. His study was followed by the paper of Borenstein et al. (1997) who provide strong evidence of asymmetry in the US market between 1986 and 1992 in different stages of the production and distribution of gasoline.

The commonly used methods in given empirical studies are error correction models (ECM) and vector autoregressive models (VAR); e.g. Radchenko (2005), Honarvar (2009) and Liu et al. (2010). Such approaches are also used in our paper, investigating the reactions of retail gasoline and diesel prices to changes in crude oil prices on the Slovak fuel market. The only Slovak study analysing the reaction of the gasoline prices based on the ECM model is from the authors of this paper Szomolányi et al (2011). However, weekly data gathered from an unofficial source from the only three-years period and the single equation error correction models without a possibility of trends

in co-integration relationships and without a testing of adjustment parameters (we test only short-run asymmetry) were used.

It is precisely because of the official and much more extensive database and the more complex used methodology (vector error correction model with Johansen co-integration test), we have returned to this interesting and important issue and implemented our analysis. It can help antitrust authorities detect potential abuses of fuel producers' monopoly position on the Slovak fuel market. In the case of asymmetry confirmation, we could try to calculate the asymmetry coefficient by which we could try to determine the total resources obtained by this monopolistic behaviour.

Methodology

We are interested in question, if a positive unit change of the oil price has an identical influence on the fuel price as a negative unit change. The error correction model with irreversible behaviour of explanatory variables is considered to be basic tool for the analysis of asymmetric price reaction of fuel. The reason is clear, originally non-stationary price variables are used as the first differences in this model, so it is easy to separate positive and negative values in explanatory variable.

A non-stationarity of variables is tested by unit root tests. We prefer the augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981). In the case of significant autocorrelation confirmed by a large number of lagged terms in Dickey-Fuller test equation we use also the Phillips-Perron (PP) unit root test (Phillips and Perron, 1988). The single-equation error correction model is essentially auto-regressive distributed lag model with rearranged terms. We can show it by the auto-regressive distributed lag model of order one with three variables:

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

where y_t is regressand – average weekly price of gasoline or diesel in time t; x_t is the key regressor – average weekly price of oil in time t; z_t is another relevant regressor in time t; u_t is a stochastic term in time t and β_i, γ_i and δ_i are unknown parameters of this regression model.

We can rewrite model (1) as the error correction (ECM) model (Engle and Granger, 1987):

$$\Delta y_t = \beta_0 + \gamma_0 \Delta x_t + \delta_0 \Delta z_t + (\beta_1 - 1) \left[y_{t-1} - \frac{(\gamma_0 + \gamma_1)}{1 - \beta_1} x_{t-1} - \frac{(\delta_0 + \delta_1)}{1 - \beta_1} z_{t-1} \right] + u_t \tag{2}$$

which contains the original (one period lagged) variables in the levels and their first differences, and allows us to explore both the long-run equilibrium relationship and its adjustment along with the short-run dynamics. If a positive unit change of the regressor has an identical influence on the regressand as a negative unit change, we do not have to distinguish between them and we can estimate the overall response with one parameter for one regressor, as in the reversible model (2). But this is exactly a restriction. If this restriction is not valid, the estimation results can be improved by specifying increases ($\Delta^+ x_t$) and decreases ($\Delta^- x_t$) of explanatory variable as separate variables and also by separating the positive and negative deviations from the long-run equilibrium relationship.

The asymmetric form of this irreversible error correction (A-ECM) model (Granger and Lee, 1989) is:

$$\Delta y_t = \beta_0 + \gamma_0^+ \Delta^+ x_t + \gamma_0^- \Delta^- x_t + \delta_0 \Delta z_t + \lambda^+ e_{t-1} \times D(e_{t-1} > 0) + \lambda^- e_{t-1} \times D(e_{t-1} \leq 0) + u_t \tag{3}$$

where $e_{t-1} = y_{t-1} - \dfrac{(\gamma_0 + \gamma_1)}{1 - \beta_1} x_{t-1} - \dfrac{(\delta_0 + \delta_1)}{1 - \beta_1} z_{t-1}$ is one period lagged deviation from the long-run equilibrium relationship; $D(e_{t-1} > 0)$ is a dummy variable that equals 1 if $e_{t-1} > 0$ and equals 0 otherwise; $D(e_{t-1} \le 0)$ is a dummy variable that equals 1 if $e_{t-1} \le 0$ and equals 0 otherwise; λ^+ and λ^- are the corresponding adjustment parameters, β_0, γ_0^+, γ_0^- and δ_0 are also parameters of this regression model.

Model (2) is obtained from model (3) using restrictions $\lambda^+ = \lambda^-$ and $\gamma_0^+ = \gamma_0^-$. This linear hypothesis in the linear model can be tested by the F test. In the case of a more extensive dynamic structure of model (1), models (2) and (3) will also be more extensive and the test hypothesis will additionally include parameter comparisons for further lags.

Models (2) and (3) are some of the simplest types of error correction models, because their long-run equilibrium relationship does not contain any deterministic terms. When searching for the most appropriate specification of the model, it is necessary to analyse different versions of deterministic components as constant and trend in both the long-term equilibrium relationship as well as in the short-run dynamic part of the equation. This will bring us to the well-known five cases of the deterministic part of the model: no constant and no trend, restricted constant and no trend, unrestricted constant and no trend, unrestricted constant and restricted trend, unrestricted constant and unrestricted trend; among which we have to decide.

The single equation error correction models are usually estimated by a two-step Engle-Granger procedure (Engle and Granger, 1987) and the co-integration of variables is confirmed by ADF test of residuals from the first step. We can also use a one-step procedure to estimate ECM and Banerjee, Dolado and Mestre method (Banerjee et al., 1998) to verify the co-integration of variables – or more precisely – the co-integration is verified by bounds testing (Pesaran et al., 2001). After the validation of co-integration, we form the asymmetric ECM and test the appropriate restrictions. In the asymmetric ECM, we do not re-estimate co-integration relationship, which is included in the variable representing the deviation from equilibrium.

We expect that there are two co-integrating relationships between crude oil price and one each the retail fuel price for gasoline and for diesel, either individually or jointly; therefore we are looking for a long-term equilibrium relationship between the price of oil and the retail price of fuel with the help of the vector error correction model (VECM).

Similarly, as the single-equation error correction model is an auto-regressive model, so the vector error correction model is a vector auto-regressive model. We can show it by the vector auto-regressive model of order two:

$$\mathbf{y_t} = \mathbf{\Phi D_t} + \mathbf{\Pi_1 y_{t-1}} + \mathbf{\Pi_2 y_{t-2}} + \mathbf{u_t} \qquad (4)$$

where $\mathbf{y_t}$ is the vector of variables in time t; $\mathbf{D_t}$ is the matrix of deterministic terms (constant, trend, …) in time t; $\mathbf{u_t}$ is the vector of stochastic terms in time t and $\mathbf{\Phi}$, $\mathbf{\Pi_1}$ and $\mathbf{\Pi_2}$ are the matrices of unknown parameters of this model.

We can rewrite model (4) as the vector error correction (VECM) model of order one:

$$\Delta \mathbf{y_t} = \mathbf{\Phi D_t} + \left(\mathbf{\Pi_1} + \mathbf{\Pi_2} - \mathbf{I} \right) \mathbf{y_{t-1}} - \mathbf{\Pi_2} \Delta \mathbf{y_{t-1}} + \mathbf{u_t} = \mathbf{\Phi D_t} + \mathbf{\alpha \beta}^T \mathbf{y_{t-1}} + \mathbf{\Phi_1} \Delta \mathbf{y_{t-1}} + \mathbf{u_t} \qquad (5)$$

which contains the original (one period lagged) variables in the levels and their first differences, and allows us to explore both the long-run equilibrium relationship and its adjustment along with the short-run dynamics. The matrix $\mathbf{\beta}$ is called a co-integration matrix with co-integration vectors as columns and the matrix $\mathbf{\alpha}$ is called a loading

matrix. Again, it is necessary to analyse different versions of deterministic components $\mathbf{\Phi D_t}$ – the five cases mentioned above.

The asymmetric form of this irreversible vector error correction (A-VECM) model is:

$$\Delta \mathbf{y_t} = \mathbf{\Phi D_t} + \boldsymbol{\alpha}^+ \left[\boldsymbol{\beta}^T \mathbf{y_{t-1}} \times D\left(\boldsymbol{\beta}^T \mathbf{y_{t-1}} > \mathbf{0}\right)\right] + \boldsymbol{\alpha}^- \left[\boldsymbol{\beta}^T \mathbf{y_{t-1}} \times D\left(\boldsymbol{\beta}^T \mathbf{y_{t-1}} \leq \mathbf{0}\right)\right] + \mathbf{\Phi_1^+} \Delta^+ \mathbf{y_{t-1}} + \mathbf{\Phi_1^-} \Delta^- \mathbf{y_{t-1}} + \mathbf{u_t} \quad (6)$$

where $\boldsymbol{\beta}^T \mathbf{y_{t-1}}$ is the vector of one period lagged deviations from the long-run equilibrium relationships; $D(\boldsymbol{\beta}^T \mathbf{y_{t-1}} > \mathbf{0})$ is the vector of a dummy variable that equals $\mathbf{1}$ if $\boldsymbol{\beta}^T \mathbf{y_{t-1}} > \mathbf{0}$ and equals $\mathbf{0}$ otherwise; $D(\boldsymbol{\beta}^T \mathbf{y_{t-1}} \leq \mathbf{0})$ is a dummy variable that equals $\mathbf{1}$ if $\boldsymbol{\beta}^T \mathbf{y_{t-1}} \leq \mathbf{0}$ and equals $\mathbf{0}$ otherwise; $\boldsymbol{\alpha}^+$ and $\boldsymbol{\alpha}^-$ are the loading matrices of corresponding adjustment parameters and $\mathbf{\Phi_1}^+$ and $\mathbf{\Phi_1}^-$ are also matrices with some pairs of the asymmetric parameters of this model. The multiplication operation in square brackets of model (6) does not represent a matrix product, but the product of elements in the same positions in corresponding vectors.

The test of co-integration in VECM is realized by Johansen's procedure (Johansen, 1988) by the lambda trace statistics depending on the specification of the deterministic components of model (5). After the validation of co-integration, we form the asymmetric VECM and test the appropriate restrictions. In the asymmetric VECM, we do not re-estimate co-integration relationships, which are included in the variables representing the deviations from equilibrium.

Data and Tax Legislation

Data of retail gasoline and diesel prices on Slovak market are gathered from the Statistical office of the Slovak Republic. The spot prices for crude oil and petroleum products are gathered from the U.S. Energy Information Administration – the agency responsible for collecting, analysing, and disseminating energy information. Since we only have the weekly retail gasoline and diesel prices data, we can only use the weekly Europe Brent Spot Price FOB Dollars per Barrel for the analysis.

The weekly retail gasoline and diesel prices data are in euros, so we need to recalculate the crude oil prices from dollars to euros. We converted the daily oil prices in dollars by the euro exchange rate in dollars and then aggregated them into weekly averages. All data is since the first week of 2009 till the second week of 2019, so we have 524 observations available.

Figure 1
The Weekly Crude Oil Price and the Retail Fuel Price for Gasoline and for Diesel
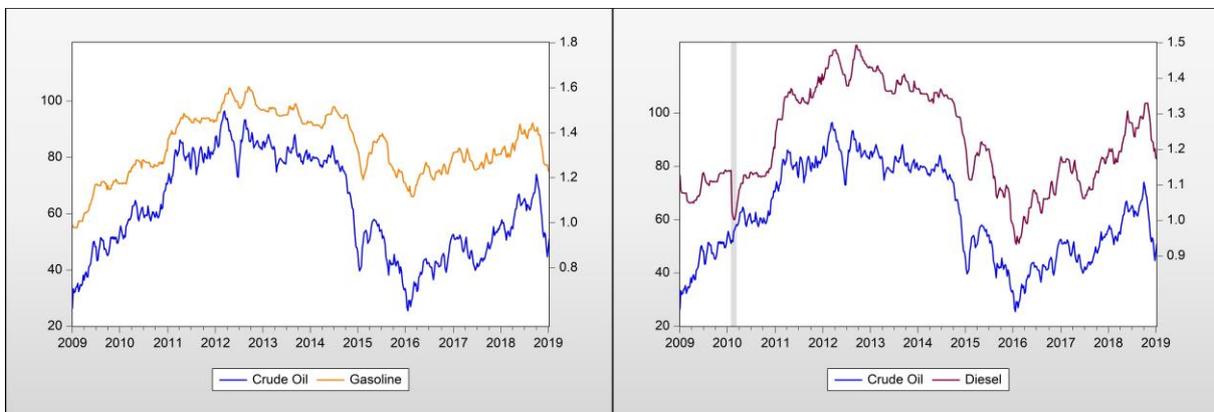
Source: Authors' illustration

Liu et al. (2010) notice that taxes and levies make up a significant proportion of retail fuel prices and any changes in government taxes and levies can therefore have a significant impact on retail diesel and petrol prices. During the analysis period, there was no significant change in the consumption taxes, except February 2010, when almost a quarter of the consumption taxes on diesel fell down. In other cases, only the classification and categorization of fuels (due to the biofuel), without significant intervention to tax rates (no more than 2 %), occurred in legislative change. The impact of the tax change of the consumption tax on diesel can be clearly seen also on the chart of the retail price for diesel.

Results and Discussion

The unit root tests of the analysed time series confirmed the non-stationarity of price variables. As a result, the condition for using Engle-Granger procedure is fulfilled. The key results of estimations and tests of single equation model are shown in the Table 1 and the Table 2. The selected parameters, their standard deviations, the test statistics and their critical values of the best model without trend and model with restricted trend as representatives of different deterministic schemes in co-integration modelling are sufficient to support our used methodology and conclusions. These models have been selected from a wide range of models with the most appropriate characteristics (no autocorrelation and precisely defined dynamics).

Table 1
The Results of Estimations and Tests of Single Equation Model for Gasoline Prices

Gasoline prices	Model without trend	Model with restricted trend
Co-integrating Equation		
crude oil	0.0071	0.0079
standard deviation	0.0006	0.0002
trend	-	0.0003
standard deviation	-	0.00002
Engle-Granger test		
ADF of residuals	-4.0812	-6.2863
critical value	-3.33	-3.74
Error Correction Model		
adjustment parameter	-0.0354	-0.0588
standard deviation	0.0072	0.0073
Bounds test		
F statistics	7.9594	10.2219
critical value I(1)	4.16	5.15
Asymmetric Error Correction Model		
irreversibility test	1.2148	1.6612
critical value	3.0135	3.0132

Note: The significant value of each statistical test is 5 %. The null hypothesis is rejected if the test statistics is greater than the critical value of bounds test and test of irreversibility and less than the critical value of ADF test.
Source: Authors' work

The results of all tests confirm the justification for use co-integration equation for modelling the long run relationships between pairs of prices. Likewise, it seems appropriate to include the trend into the long run relationships for both prices. However, the answer to the key issue of price asymmetry is negative in both cases. According to the results from single equation models, Slovak retail fuel prices don't respond more quickly when crude oil price rises rather than when it decreases.

Table 2
The Results of Estimations and Tests of Single Equation Model for Diesel Prices

Diesel prices	Model without trend	Model with restricted trend
Co-integrating Equation		
crude oil	**0.0039**	**0.0086**
standard deviation	0.0013	**0.0004**
trend	-	**0.0002**
standard deviation	-	**0.00005**
Engle-Granger test		
ADF of residuals	**-4.7419**	**-5.8968**
critical value	-4.10	**-3.74**
Error Correction Model		
adjustment parameter	**-0.0473**	**-0.0510**
standard deviation	0.0098	**0.0109**
Bounds test		
F statistics	**5.8182**	**10.7645**
critical value I(1)	3.87	**5.15**
Asymmetric Error Correction Model		
irreversibility test	**1.0275**	**0.8300**
critical value	**2.3895**	**2. 3895**

Note: The significant value of each statistical test is 5 %. The null hypothesis is rejected if the test statistics is greater than the critical value of bounds test and test of irreversibility and less than the critical value of ADF test.
Source: Authors' work

As the gasoline and diesel markets are linked, we have also used vector error correction models in our analysis. The results of the analysis are in the Table 3.

Table 3
The Results of Estimations and Tests of Vector Error Correction Model

VECM	Gasoline	Diesel	VECM test statistics	
	Co-integrating equations		**Residual Portmanteau Test**	
oil	**0.0076**	**0.0087**	Lag(1) 1.9908	**---**
std. dev.	0.0004	0.0004	Lag(2) 10.2979	**χ²(10) = 18.307**
trend	**0.0002**	**0.0002**	Lag(3) 21.2660	**χ²(19) = 30.144**
std. dev.	0.00005	0.00005	Lag(4) 27.7830	**χ²(28) = 41.337**
	Error Correction		**Lag Exclusion Wald Test**	
adj. gasoline	**-0.0752**	**-0.0346**	**Lag(1) 124.807**	**χ²(12) = 21.026**
std. dev.	0.0120	0.0119	Lag(2) 14.3612	**χ²(12) = 21.026**
adj. diesel	**-0.0358**	**-0.0729**	Lag(3) 13.6213	**χ²(12) = 21.026**
std. dev.	0.0111	0.0109	Lag(4) 11.3476	**χ²(12) = 21.026**
VECM – test for weak exogeneity of crude oil price			**Trace statistics**	**Critical value**
restriction test **1.1946**		χ²(2) = 5.9915	CE(0) 91.9573	**42.9153**
A-VECM test statistics			**CE(1) 27.2200**	**25.8721**
irreversibility test		**8.1016**	CE(2) 5.8493	**12.5180**
critical value		**14.0671**	**Test indicates 2 coint. eqn(s)**	

Note: The significant value of each statistical test is 5 %. The null hypothesis is rejected if the test statistics is greater than the critical value.
Source: Authors' work

When looking for a final vector error correction model, we considered the lag exclusion test and the residual portmanteau test as a help in finding appropriate lag. The Johansen test with its lambda trace statistics indicates two co-integration

equations, so we normalized model to create one co-integrating equation for gasoline and the other for diesel. According to the proper test we did not reject the weak exogeneity of crude oil prices. The equilibrium relations for Slovak gasoline and diesel prices cannot influence the crude oil prices.

Our results from the vector error correction models are the same as the results from the single error correction models. Slovak retail fuel prices don't respond more quickly when crude oil price rises rather than when it decreases.

Conclusion

The aim of the analysis is to verify that the gasoline or diesel price adjustments is not the same when crude oil prices are falling on world markets than if they are rising. We used the irreversible model with the correction term as the single equation model as well as the vector model for the analysis and tested the asymmetry of the reaction by comparing the parameters for these variables corresponding to the increase and the decrease in the price of crude oil on the world markets. The result of the testing did not reject the hypothesis that the reaction of gasoline and diesel prices is the same in the case of the increase and the decrease in the crude oil prices. So, the price asymmetry analysed using classical tools has not been confirmed in Slovak gasoline and diesel retail market.

Douglas and Herrera (2010) argue that asymmetry retail fuel price creation hypothesis results from a theory of strategic interactions between firm and its consumers. The theory justifies a price rigidity assumption used in New Keynesian models of business cycles. Rejecting the hypothesis, we reject the New Keynesian price rigidity assumptions based on the theory of strategic interaction between firm and its consumers. This result is important for Slovak economic policy makers.

The limitation of our study is that a price asymmetry may take shorter time than a week and the weekly frequency of the used data needs not to catch it. Since Slovak price fuel market data with lower frequency are not published, we will effort to suggest a methodology solving the data frequency problem.

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