Price Relationships Between Crude Oil And Retail Fuel In Ukraine

by

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Abstract

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This paper investigates the relationship between world crude oil prices, dollar-hrivnia exchange rate and fuel prices in the Ukraine. The research is based on two times per week data for the period from January 2007 till February 2009. Error-correction and threshold autoregression models are employed to investigate asymmetric price transmission on the Ukrainian petrol market. The results of the research conducted show the presence of the short-run asymmetry in the responses of fuel prices in the Ukraine to changes in the world crude oil price but fail to prove that the adjustment towards long-run equilibrium is asymmetric neither with respect to size nor change in the market margin.

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GLOSSARY

Asymmetry - is the absence of, or a violation of, a symmetry.

Chapter 1

INTRODUCTION

"In spite of the world oil prices decrease the Ukrainian prices for various types of fuel have increased on average by 12% during this month (February). Experts say that such process only starts to go at steady gate and by the end of February prices can increase by additional 8%. There are several reasons – from fiscal initiatives of the government to fluctuated exchange rates. Also sector experts think that oilmen simply don't want to loose profits. Domestic petroleum products as usual persistently ignore world tendencies." – Dmitriy Riasnoy "Delovaya Stolica (25.02.2009)". This newspaper article pushed me to write my thesis about the dependence of the Ukrainian retail prices for fuel on the world price of oil.

This paper will focus on the factors determining the dynamics of Ukrainian fuel prices. Examining price transmission on the Ukrainian gasoline market is important for several reasons. First, it can provide useful guidelines for policy makers. It is very often claimed in last months that fuel traders earn excess profits by buying oil on world market at relatively low prices, refining it and by selling fuel on the domestic market at relatively high prices. However, this might occur only if there were a very weak competition on the Ukrainian fuel market. The analysis of price transmission from the world to the Ukrainian fuel market is a useful tool for making inferences about competitive environment and efficiency of the fuel market.

In this work I provide a theoretical background and use econometrics to explain the response of the Ukrainian fuel market to fluctuations in the world price for oil. There are two basic components affecting the price on fuel in

Ukraine – world quotations (rates) for crude oil and the market exchange rate (not official rate of National Bank of Ukraine) for the US dollar. These ingredients have demonstrated the reverse dynamics of late. During July 2008 (when oil was bought for refining in September 2009) a barrel of Urals cost on average $134 and the average interbank exchange rate for the month was 4.63 hrn/USD the average retail price for A-95 on Ukrainian refueling stations was about 6.53 hrn/l. In turn during September 2008 (when oil was bought for refining in November 2008) the barrel of Urals cost on average $104 and the average exchange rate for month was 4.89 hrn/USD the average retail price for A-95 on Ukrainian refueling stations was about 6.06 hrn/l. So, as the world prices for oil expressed in Ukrainian currency decreased by 18.35% the Ukrainian price for fuel decreased only by 7.25%. Further, during November 2008 (when oil was bought for refining in February 2009) the barrel of Urals cost on average $57 and the average exchange rate for month was 6.25 hrn/USD the average retail price for A-95 on Ukrainian refueling stations was about 5.07 hrn/l. Again, as the world prices for oil expressed in Ukrainian currency decreased by 29.6% the Ukrainian price for fuel decreased only by 16.3%. Such decrease can be explained by refiners relying not on current prices but on prices the oil was bought two months earlier or by very weak competition on the Ukrainian fuel market.

We can compare this numbers with corresponding numbers for increasing phase of the world prices for crude oil. For example, looking on the period between April and June 2008, the world prices for crude oil expressed in Ukrainian currency increased by 13.9% and the Ukrainian price for fuel increased by almost 11%. So, one can argue that domestic prices for fuel react more rapidly to the world crude oil price increases than decreases and asymmetry in the price transmission is present on the Ukrainian market for petrol.

Other factors that influence the dynamic of retail prices for fuel are: market capacity or how much can be consumed (from $1.03 bln for December 2007 to $0.7 bln for December 2008 and $0.64 bln for January 2009 – so, traders can maintain their profits by two ways – increase price or reduce quality – the second way can be costly due to regulations of State Quality commission (DergSpogivStandard), so the priority is given for the first way), the level of competition in the industry which is very low, seasonal demand for fuel, government changes in import fees, etc. Of course, such factors can considerably influence the fuel prices, but in this work I fully concentrate only on two main factors: world quotations for crude oil and the official exchange rate for US dollar.

The specific question that I want to address in this work is whether Ukrainian consumers can benefit from observing world prices for crude oil. There is a common assessment of experts that retail prices for benzine (petrol, gasoline) depend on the price of oil from which this benzine was produced, but not on the current market price of oil. The Ukrainian fuel market is a delayed reflection of the world market with some imperfection: with a decrease in the world prices we can hope only for some stabilization, but each increase in world prices results in increase for Ukrainian consumers but with some lag. In this work with the help of econometric methods I'll estimate the influence of a world price shock on Ukrainian price and the period that it takes to adjust to this shock. To my knowledge, research for asymmetric price transmission (APT) in gasoline market has not been done for Ukraine before.

So, this paper will focus on spatial market integration and asymmetry effects.

Spatial integration is a change in world price of oil causing a reaction in Ukrainian fuel price. Asymmetry effect is investigated for spatial integration that is whether the reaction of the Ukrainian fuel prices to changes in the World price for oil depends on whether this change is positive or negative.

The issue of asymmetric price transmission still has considerable economic interest in our days. First of all, it can point out on substantial problems in the economic theory for particular sector of economy. Also, price asymmetry has a significant meaning for policy implications. There is widespread believe that asymmetry arises from market power. So, empirical determining of asymmetry can be a motive for intervention by the government into price regulation in particular sector. Given all these we can state that problem of asymmetric price transmission is still very important.

The paper has the following structure. The introduction is followed by Chapter 2 where I analyze the existent literature concerning the problems of price transmission. Chapter 3 is dedicated to the data for investigation. Chapter 4 discusses methodological estimation of empirical model. Results and their implications are given in Chapter 5. Conclusions are posted in Chapter 6.

Chapter 2

LITERATURE REWIEV

In order to answer the raised questions we need to focus on asymmetric price transmission (APT).

The history of issue of APT is very long. The vast majority of studies that deal with this problem are devoted to agricultural sector. Many researches in this field are dealing with both theoretical and empirical investigation of the issue.

So, firstly I give the outlook of studies that are concerned with theoretical concepts of APT, even if they are taken from agricultural sector researches. And then, I cite the empirical literature dedicated to APT in gasoline market.

The theoretical literature of APT evolved with upgrading the methodology used. One of the first techniques was proposed by Tweeten and Quance (1969) to study supply functions. They use dummy variables that were constructed separately for increasing and decreasing parts of the input (exogeneous) price series. The judgment about asymmetry was made if coefficients for split input prices differ on the basis of standard F-test.

Then Wolfram (1971) suggests another method to split the input price variable. He introduced the sum of first differences split into negative and positive parts. He argues that Tweeten and Quance technique leads to incorrect estimate of the parameters because if asymmetry is present the output and input prices must drift apart. This leads to overestimation of constant term and biased estimates for coefficients representing increasing and decreasing parts of the input price series.

Houck (1977) claims that neither Tweeten and Quance nor Wolfram do not take into consideration that the first observation does not have independent explanatory power because monitored differential effects depend on changes from the previous value but do not depend on their levels. Houck's method take into account period to period changes and does not require implicit changes in coefficients for their comparison.

The Houck's approach was extended by Ward (1982), who proposed to include lags of the exogeneous variables. Based on such specification he found asymmetry in pricing of fresh vegetables in U.S.

The next huge step in evolution of methods for estimation of APT became the work of Engle and Granger (1987) in which they developed error-correction model (ECM). This model have received support for issue of APT in oil and gasoline relationship from the empirical work of von Cramon-Taubadel and Fahlbush (1996), who suggested to extend ECM by inclusion of error correction terms which should be split into negative and positive. Such extended version of ECM can be used for estimation of price transmission between cointegrated time series.

Balke and Fomby (1997) and Enders and Granger (1998) show that "tests for unit root and cointegration have some serious drawbacks in the presence of asymmetric adjustment" when ECM is used. They suggest a threshold cointegration approach introduced by Tong (1983) for model in which there is asymmetric adjustment to the long run equilibrium.

To sum up, Meyer and von Cramon-Taubadel (2002) survey the literature on asymmetric price transmission. They review the empirical implications of the methodological procedures discussed and state that "over all applications in the literature, symmetry is rejected in nearly one-half of all cases. Pre-cointegration methods based on first difference and threshold methods lead to considerably higher shares of rejection of symmetry (68 and 80%, respectively), while pre-cointegration methods based on the recursive summation of first differences and ECM-based methods lead to lower shares (23 and 45%, respectively)". They note that existing literature fails to make some comparison and analysis of the strength and weakness of the available methods. Also, they argue that data frequency should be at least weekly, because price transmission (which can take place within days of a week) requires data with a frequency that is higher than the frequency of the adjustment process.

During last two decades the problem of asymmetric price responses on gasoline market due to changes in crude oil prices has attracted a lot of attention. Below we can see the empirical studies in this field.

One of the first attempts to analyze relationships between gasoline and oil prices was made by Sumner (1989). Using Wolfram's segmentation in first differences of explanatory variables he employs Engel-Granger specification for U.K. data over the period 1981-1989. He found both long-run relationship and persistent asymmetry in retail fuel price response to changes in crude oil price. Also, Bacon (1991) and Reilly and Witt (1998) conduct a research on U.K. gasoline market. Both find the evidence for asymmetric relationship and use in estimation the dollar-pound exchange rate. Reilly and Witt (1998) emphasize that part of asymmetry can be explained by the exchange rate fluctuations. Contrary, Karrembock (1991) using distributed lags model fail to find evidence for asymmetry using 1983 – 1990 monthly data. More recently, Wlazlowski (2001) examines the relationship between crude oil prices, the dollar-pound exchange rate and petrol prices in the UK over the period 1982-2001. He employed asymmetric ECM, threshold autoregressive model (TAR) and momentum TAR, all of which give the evidence of asymmetry for UK petrol market. Both sort-run responses and adjustment towards long-run equilibrium exhibit asymmetry with larger effect of oil prices increases than decreases.

Switching to the U.S. gasoline market, one of the first and most influential papers in this field is the study of Borenstein, Cameron and Gilbert (1992), further BCG. They empirically confirmed the common belief that retail gasoline prices respond more quickly to increases in crude oil prices than to decreases. They investigated price transmission on different points of distributional chain using bivariate error-correction models and found that most significant asymmetry appears in the response of retail prices to wholesale price changes, indicating that refiners who set wholesale prices are not the source of the asymmetry which means that retail sellers have short-run power on this market. The analysis was made for United States using 1986-1990 weekly data at various points of production and distributional chain.

Balke et al. (1998) argued that BCG used comprehensive model to find an asymmetry (applying error correction specification they does not include long-run restriction). They find that evidence for asymmetry depends on the specification whether to use levels or first differences when initial data is stationary. They test both specifications and find evidence for asymmetry using error-correction specification, model in levels indicates a small asymmetry only in a few cases. It was established that upstream crude oil prices Granger-cause downstream petroleum prices at all stages of the distribution chain. Balke et al. (1998) concluded that model with first differences fits the data better than the levels model, suggesting that asymmetry depends on the rate of change in prices.

Bachmeier and Griffin (2003) also disprove the results of BCG. They find no evidence for asymmetry using standard Engel-Granger procedure for daily US data over the period 1985-1998. Even using specification proposed by BCG they discover that daily data gives little evidence for asymmetry in price responses, resulting in the conclusion about efficiency of US spot gasoline market.

Godby et al. (2000) analyzes Canadian gasoline market using weekly data for thirteen cities from 1990 to 1996. Using the TAR model they fail to find asymmetric response of fuel prices to changes in oil prices.

Asche F, Gjolberg O, Volker (2001) used in their analysis monthly data for period from January 1992 to November 2000 for North West Europe. They discuss the assumption about weak exogeneity of crude oil price that it is not *a priori* obvious which variable should be chosen as exogeneous. Using multivariate Johanson test they found that crude oil price is weakly exogenous for fuel products, implying that relationships can be tested by single equation model. It was proved that crude oil price influences the dynamics of refined products' prices in the long-run, but not wise versa. Also, fuel prices do influence the crude oil price in the short-run. They concluded that North West European market is a supply driven market integration.

There are several reasons for asymmetry to arise. BCG, Balke et al. (1998), Radchenko (2005) propose several explanations which can be tested: market power of producers or distributors, consumer search costs, inventory management, refinery adjustment costs and accounting practices. But the objective of this paper is an identification of asymmetry in Ukrainian gasoline market, and determining the factors that lead to asymmetry (if it will be discovered) is left for further research.

This paper also moves beyond studies that focus only on the world oil price as the main determinant of fuel prices and examines the effect of exchange rate. Also the research is based on higher frequency data (two times per week) than it was done before (almost monthly or weekly data) that allows to capture short-run responses in price transmission.

C h a p t e r 3

DATA DESCRIPTION

The analysis relies on average two-times per week price for different sorts of fuel (A-76, A-92, A-95, DT) sold on Ukrainian refuelling stations and reported by UPECO (United Petroleum Consultants) for period from January 2007 to February 2009. There are 202 observations in this time series. World prices for oil are obtained from www.finance.urwealthy.com/ on the basis of NYMEX rates for Brent crude oil. The prices are reported on working day basis (Monday-Friday), so they should be adjusted. Though, Ukraine is imported 98% of Russian crude oil of Urals type we still can use prices of publicly traded benchmarks. Urals is a mix of oil extracted in Hanty-Mansiysk autonomous region and oil produced in Tatarstan. Urals is highly sulfurous oil and, so, is of lower quality than WTI or Brent. That is why Russian oil is priced via a mechanism called benchmark pricing which links local prices to publicly traded benchmarks such as NYMEX WTI (West Texas Intermediate) crude oil and ICE Brent crude oil. Brent (Brent Crude) - etalon mark of oil which is produced in North Sea. It is world etalon of oil because it features, quality and composition are optimal from refining and petroleum derivatives point of view. That is why Brent oil is a basis for pricing about 40% of world various sorts of crude oil.

Also, the interbank UAH/USD rate is used to capture the effect of exchange rate fluctuations because price of Brent oil is expresses in US dollars.

Figure A1 from the appendix shows that dynamics of all fuel marks in Ukraine were very similar during the investigated period. This suggests us that we can use one of the petrol marks as a main dependent variable in our research. The best choice here would be to take A-95 mark of benzene as the most consumed fuel.

Below you can see the graphs of used in this paper time series. Figure 1 shows that there is possible cointegration between three time series: fuel prices in Ukraine (UAH/l), world crude oil prices (USD/bar) and exchange rate UAH/USD for 2007-2008. We can say that fuel prices in Ukraine repeat the dynamics of the world crude oil price until the exchange rate starts to depreciate heavily.

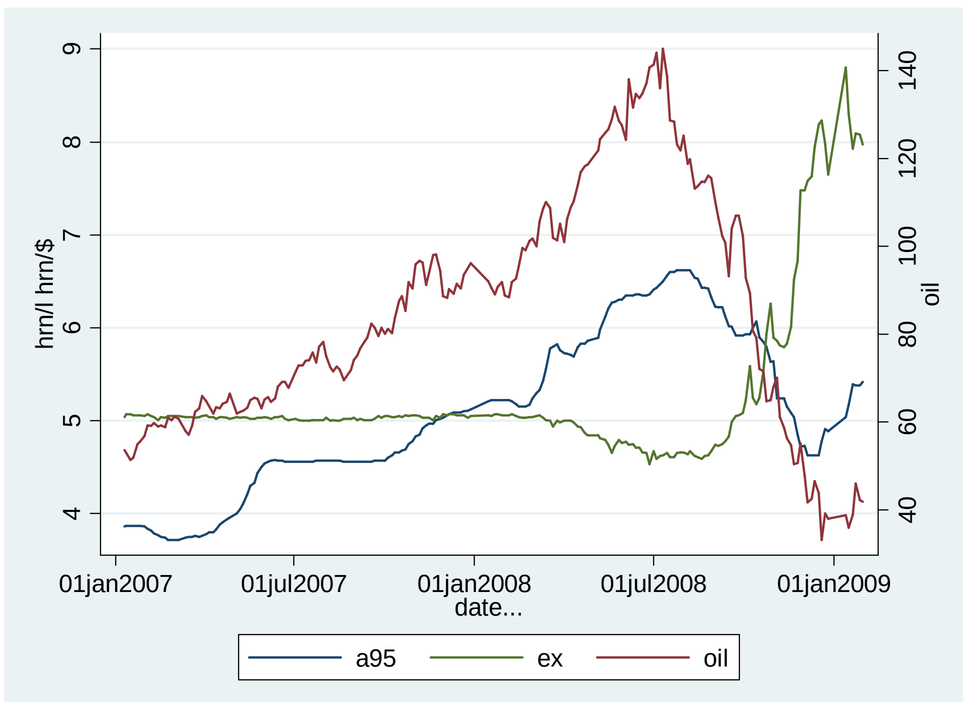

Figure 1. Dynamic of fuel prices in Ukraine (UAH/l), world crude oil prices (USD/bar) and exchange rate UAH/USD for 2007-2008 (all in logarithms)

Chapter 4

METHODOLOGY

It was discussed in the literature review that pre-cointegration techniques can not be used if there is cointegration between price series (von Cramon-Taubadel & Loy (1996) and von Cramon-Taubadel (1998)). It will be shown in chapter 5 that our price series for crude oil, petroleum and exchange rate are indeed cointegrated and we can omit the explanation of pre-cointegration techniques.

The variables are said to be cointegrated if there is a linear combination of integrated variables that is stationary. The order of integration should be the same for all variables. When cointegration between variables is discovered this implies long-run relationship between them, so that they can not wander arbitrarily far from each other. In order to determine the presence and number of unit roots in our series we can use the augmented Dickey-Fuller and the Philip-Perron tests.

Considering our case and assuming symmetric price adjustment we can write the simplest model as:

$$\ln(p)_t = \alpha + \beta_1 \cdot \ln(oil)_t + \beta_2 \cdot \ln(ex)_t + u_t , \tag{1}$$

where $\mathbf{p_t}$ stands for petrol price, $\mathbf{oil_t}$ - price of crude oil and $\mathbf{ex_t}$ – official exchange rate for period t.

As noted by BCG, using logarithmic transformation allowed us to capture the effect that crude-retail margin increase with rise in the price of crude oil. For the long-run relationship to exist we need the error term u_t to be stationary. In order to check the null of non-cointegration between the price series, we apply OLS to estimate ϕ in the relationship below:

$$\Delta \hat{u}_t = \phi \hat{u}_{t-1} + \varepsilon_t \,, \tag{2}$$

where ε_t is white noise. If we cannot reject the null hypothesis $|\phi| = 0$, we can conclude that variables in (1) are not cointegrated. Instead, the acceptance of alternative hypothesis $\phi < 0$ implies that residual sequence is stationary and the price series are cointegrated. Such specification assumes symmetric adjustment since the change in $\hat{u}_t$ does not depend on whether $\hat{u}_{t-1}$ is positive or negative.

If the residuals from (2) do not appear to be white noise we can use an augmented form of the test. It involves the estimation of the following specification:

$$\Delta \hat{u}_t = \rho \hat{u}_{t-1} + \sum_j \gamma_j \Delta \hat{u}_{t-j} + \varepsilon_t \,, \tag{3}$$

where the number of lags is included so that ε_t is white noise. The appropriate lag length is chosen based on Breusch-Godfrey Serial Correlation LM Test. The null and alternative hypothesis is the same as in the previous case and can be tested in the same way. Again, if the null $|\phi| = 0$ can be rejected at the chosen level of significance, we can say that $\hat{u}_t$ is stationary and the price series in (1) are cointegrated.

If the cointegration is discovered then Error Correction Model (ECM) can be applied. The most common representation has the following form:

$$
\begin{aligned}
\Delta\ln(p)_t = \alpha_0 + \sum_{i=0}^{T_1}\beta_{1,i}\cdot\Delta\ln(oil)_{t-i} + \sum_{i=0}^{T_2}\beta_{2,i}\cdot\Delta\ln(ex)_{t-i} + \\
+ \sum_{i=1}^{T_3}\beta_{3,i}\cdot\Delta\ln(p)_{t-i} + \phi\cdot\hat{u}_{t-i} + \varepsilon_t
\end{aligned}
\tag{4}
$$

where ε_t – should be white noise, ϕ - estimate of the speed of adjustment of the petrol prices to shocks in the crude oil prices and exchange rate dynamic, T_i – number of periods over which the shock is felt. Such specification implies equal speed of adjustment of petrol prices to positive and negative changes in the crude oil price or exchange rate. The next step is to introduce asymmetry in such specification.

Asymmetric ECM:

Borenstein at al. (1997) and Reilly and Witt (1998) use the following model for determining short-run responses:

$$
\begin{aligned}
\Delta\ln(p)_t = \alpha_0 + \sum_{i=0}^{T_1}\beta^{+}_{1,i}\cdot\Delta^{+}\ln(oil)_{t-i} + \sum_{i=0}^{T_2}\beta_{1,i}\cdot\Delta\ln(oil)_{t-i} + \\
+ \sum_{i=0}^{T_3}\beta^{+}_{2,i}\cdot\Delta^{+}\ln(ex)_{t-i} + \sum_{i=0}^{T_4}\beta_{2,i}\cdot\Delta\ln(ex)_{t-i} + \\
+ \sum_{i=1}^{T_5}\beta_{3,i}\cdot\Delta\ln(p)_{t-i} + \alpha_1\cdot trend + \phi\cdot\hat{u}_{t-i} + \varepsilon_t
\end{aligned}
\tag{5}
$$

it is implicitly assumed that first differences of explanatory variables are separated on positive and negative phases. If the coefficients on Δ^{+} are statistically different from zero we can say about presence of the asymmetry. If $\beta^{+}_{1,i}$ is positive and statistically different from zero than immediate response of the petrol prices is greater for increases in the crude oil prices than for decreases. The trend variable is used for allowing for influence of different factors that were increasing over investigated period, such as real wages or inflation in the country, which obviously influence the fuel prices. Such specification is used to accomplish the short-run effects in the response of petrol prices to upstream prices.

In order to estimate the asymmetry in the speed of adjustment to the long-run equilibrium after shocks to upstream prices Granger and Lee (1989) propose the following technique:

$$\begin{aligned}\Delta \ln(p)_t = \alpha_0 &+ \sum_{i=0}^{T_1} \beta_{1,i} \cdot \Delta \ln(oil)_{t-i} + \sum_{i=0}^{T_2} \beta_{2,i} \cdot \Delta \ln(ex)_{t-i} + \\ &+ \sum_{i=1}^{T_3} \beta_{3,i} \cdot \Delta \ln(oil)_{t-i} + \alpha_1 \cdot trend + \\ &+ \phi^+ \cdot \hat{u}^{+}_{t-1} + \phi^- \cdot \hat{u}^{-}_{t-1} + \varepsilon_t\end{aligned} \tag{6}$$

where Wolfram-type separation of the error-correction term is introduced to model (4). The equation (6) can be estimated by using estimated value of residuals for error correction term and applying OLS. Lags are introduced such that errors appear to be white noise. Speed of adjustment should be estimated and significance tests should be performed. We can use standard F-test for symmetry hypothesis $|\phi^+| = |\phi^-|$. If this hypothesis is rejected we can make conclusion about asymmetric responses.

More recent research of Frey and Manera (2005) for European markets proposes the following technique:

$$\Delta \ln(p)_t = \alpha_0 + \sum_{i=0}^{p} \beta^{+}_{1,i} \cdot \Delta^{+} \ln(oil)_{t-i} + \sum_{i=0}^{p} \beta_{1,i} \cdot \Delta \ln(oil)_{t-i} +$$
$$+ \sum_{i=0}^{p} \beta^{+}_{2,i} \cdot \Delta^{+} \ln(ex)_{t-i} + \sum_{i=0}^{p} \beta_{2,i} \cdot \Delta \ln(ex)_{t-i} + \qquad (7)$$
$$+ \phi^{+} \cdot \hat{u}^{+}_{t-1} + \phi^{-} \cdot \hat{u}^{-}_{t-1} + \varepsilon$$

which is a combination of previous two models (5) and (6). This model accomplishes the asymmetry in the speed of adjustment to the long-run equilibrium after shocks to crude oil price or exchange rate and the short-run responses of petrol prices to upstream prices. Based on the sign and statistical significance of the estimated coefficients we can make judgment about asymmetric price responses. But Galeotti et al. (2003) argue that standard F-test is misspecified in such case. They propose "to boostrap the calculated F statistic and obtain the corresponding rejection frequencies via simulation."

Threshold Autoregressive Models (TAR):

As was noted in the literature review, Balke and Fomby (1997) and Enders and Granger (1998) show that "tests for unit root and cointegration have some serious drawbacks in the presence of asymmetric adjustment" when ECM is used. They suggest a threshold cointegration approach introduced by Tong (1983) for model in which there is asymmetric adjustment to the long run equilibrium. The following specification can be applied when considering introduction of asymmetry into the model:

$$\Delta \hat{u}_t = \phi_1 \hat{u}_{t-1} D^+(\hat{u}_{t-1} \geq 0) + \phi_2 \hat{u}_{t-1} D^-(\hat{u}_{t-1} < 0) + \varepsilon_t \qquad (8)$$

where dummies are introduced such that they equal 1 when condition in parentheses holds and 0 otherwise. Here we can think about equation $\hat{u}_{t-1} = 0$ as a threshold.

In order to have long-run equilibrium relationship between time series we need residuals from (1) u_t converge to 0. For the case when u_{t-1} is above the long-run equilibrium, the adjustment is $\phi_1 u_{t-1}$. On opposite, when u_{t-1} is below the long-run equilibrium, the adjustment is $\phi_2 u_{t-1}$. If we can reject the null that $\phi_1 = \phi_2 = 0$ than we can reject the hypothesis of nonstationarity and test for symmetric versus asymmetric adjustment. If we fail to reject the hypothesis that $\phi_1 = \phi_2$, equation (2) is a special case of equation (8) and adjustment is symmetric. If stationarity is proved it is possible to use standard F-test to make a conclusion about statistical difference between ϕ_1 and ϕ_2.

If error terms in (8) are not appear to be white noise we can use an augmented version with the following specification:

$$\begin{aligned}\Delta \hat{u}_t &= \phi_1 \hat{u}_{t-1} D^+(\hat{u}_{t-1} \geq 0) + \phi_2 \hat{u}_{t-1} D^-(\hat{u}_{t-1} < 0) \\ &+ \sum_j \gamma_j \Delta \hat{u}_{t-j} + \varepsilon_t\end{aligned}, \qquad (9)$$

where the lag length is chosen so that residuals are white noise. The null and alternative hypothesis is the same as in the previous case and can be tested in the same way. Again, if the null $\phi_1 = \phi_2 = 0$ can be rejected at the chosen level of significance, we can say that $\hat{u}_t$ is stationary and the series revert to long-run equilibrium value.

In the model (9) it is assumed that the value of the threshold is zero. But there is no reason for this to be true. The threshold is unknown and should be estimated along with other parameters of the TAR model. Chan (1993) propose the following technique to consistently estimate the value of threshold. Firstly, to sort estimated residuals from model (1) in ascending order, than 15% of the smallest and the largest values. Use remaining 70% of estimated residuals as an indicator in model (9), instead of zero, run the corresponding regression and choose those with the smallest sum of squared residuals. There also can be several thresholds in the model.

Enders (2004) suggests as the alternative to the basic TAR model use the momentum threshold autoregressive (M-TAR) model. Since the exact nature of the nonlinearity may be unknown, it is possible to allow the adjustment to depend on the change in u_{t-1} (or Δu_{t-1}) instead of the level of u_{t-1}. In this case model becomes:

$$\begin{aligned}\Delta \hat{u}_t &= \phi_1 \hat{u}_{t-1} D^+(\Delta \hat{u}_{t-1} \geq 0) + \phi_2 \hat{u}_{t-1} D^-(\Delta \hat{u}_{t-1} < 0) \\ &+ \sum_j \gamma_j \Delta \hat{u}_{t-j} + \varepsilon_t\end{aligned}, \tag{10}$$

Such specification allows a variable to display differing amounts of autoregressive decay depending on whether it is increasing or decreasing. This model is especially relevant when the adjustment is such that the series exhibits more momentum in one direction than the other. As there is no presumption whether to use the TAR or M-TAR model, the recommendation is to select adjustment mechanism by a model selection criterion such as the AIC or SBC.

Chapter 5

ESTIMATION

The plots for examined time series suggest that the data series for all prices are non-stationary. We can also prove this by applying unit root tests. The results of conventional augmented Dickey-Fuller (ADF) unit root test are presented in the Table 1 If the value of ADF statistic is less that the critical value than we can reject the hypothesis that series is non-stationary. The null hypothesis of the Durbin's alternative test for autocorrelation is that serial correlation is not present. In order to get rid from serial correlation we can include lagged difference terms. We can see from the Table 1 that used data series are non-stationary in levels, but their first differences are stationary.

Table 1 Augmented Dickey-Fuller unit root test

	Dickey-Fuller test for unit root					
Variable	Test Statistic	5% Critical Value	MacKinnon approximate p-value	number of lagged differ-rence terms	Durbin's alternative test for autocorre-lation	Conclusion
ln(p)	-1.623	-2.883	0.4712			unit root
ln(oil)	-0.490	-2.883	0.8940			unit root
ln(ex)	1.392	-2.883	0.9971			unit root
Δln(p)	-4.227	-2.883	0.0000	2	0.9215	white noise
Δln(oil)	-14.694	-2.883	0.0000	0	0.277	white noise
Δln(ex)	-13.956	-2.883	0.0000	0	0.802	white noise

However, the ADF test has been shown to have relatively low power to reject its null hypothesis: that the series is non-stationary rather than stationary. In particular, any sort of structural break in the series can cause a failure to reject, even if the series is stationary before and after structural break (Baum, 2006). So, I use two additional unit root tests: Phillips-Perron and DF-GLS. Their results are presented in the appendix. Both tests confirm the results of the ADF test and suggest that we should use the differenced time series, which are stationary.

So, all time series for prices are I(1). Now we can apply cointegration technique.

Long-run Relationship:

Surely, we can think about crude oil prices and exchange rate dynamics as exogenous variables in the regression on fuel prices in Ukraine.

Using data series in levels the long run relationship (1) was estimated:

$$\ln(p)_t = -3.00 + 0.67 \cdot \ln(c)_t + 1.01 \cdot \ln(ex)_t + u$$
$$(-16.05) \quad (28.14) \quad (17.39)$$

The diagnostic tests for this regression are provided in the Table A2 and we can say that model passes the array of post-estimation tests.

It is possible to assume that coefficient on crude oil prices and exchange rate in the level equation is the same and we can use instead the sum of this two variables (as they are in logarithmic form it would be the same as multiplying original values of crude oil prices given in US dollars and exchange rate

UAH/USD). But the Wald test for equality of these coefficients gives value of the test statistic 62.4 and p-value of zero implying that we should reject the null of equality of coefficients on crude oil prices and exchange rate. Thus, we cannot use the sum of those two variables instead.

Now we can check the residuals from (1) for the presence of a unit root. The test for the null hypothesis that ϕ is equal to zero in (2) is shown in Table 2.

Table 2 Checking residuals for the presence of a unit root.

Variable	Test-statistics	t-stat	Decision
Residuals from (1)	-3.79	-1.942	rejected

*decision is based on 5% level of significance.

So, we can reject the hypothesis that ϕ is equal to zero in (2) which implies that linear combination of examined series is stationary and these three price series are cointegrated. So, now we can proceed with error-correction model.

Asymmetric ECM:

It was discussed in methodology that we can introduce asymmetry in error-correction model in two ways: either by separating explanatory variables into positive and negative phases or by using Wolfram-type separation of the error correction term. The first way can give us insight into short-run asymmetry and the second into the long-run.

The model (5) from methodology section is employed for determining short-run responses. The results are presented in the Table 3.

Table 3 Estimates for determining short-run responses

Dependent variable: $\Delta\log(p)_t$	(5)	(5), corrected for heteroscedasticity	(5')	(5'), corrected for heteroscedasticity
	estimate/se	estimate/se	estimate/se	estimate/se
$\Delta^+\log(oil)_{t-2}$	0.075* (0.044)	0.075 (0.057)	0.077* (0.043)	0.077 (0.058)
$\Delta^+\log(oil)_{t-3}$	0.070** (0.033)	0.070* (0.042)	0.073** (0.032)	0.073 (0.047)
$\Delta\log(oil)_{t-2}$	0.042*** (0.016)	0.042** (0.017)	0.043*** (0.016)	0.043* (0.018)
$\Delta\log(oil)_{t-3}$	0.002 (0.022)	0.002 (0.039)	-0.000 (0.022)	-0.000 (0.040)
$\Delta^+\log(ex)_{t-1}$	0.028 (0.042)	0.028 (0.087)		
$\Delta\log(ex)_{t-1}$	0.045 (0.036)	0.045 (0.088)	0.046 (0.036)	0.046 (0.086)
$\Delta\log(p)_{t-1}$	0.154** (0.073)	0.154 (0.112)	0.158** (0.073)	0.158 (0.113)
$\Delta\log(p)_{t-2}$	0.262*** (0.070)	0.262* (0.157)	0.257*** (0.070)	0.257 (0.157)
$\Delta\log(p)_{t-3}$	0.191*** (0.072)	0.191** (0.079)	0.180*** (0.070)	0.180* (0.080)
ECT_{t-1}	-0.031*** (0.010)	-0.031*** (0.010)	-0.030*** (0.010)	-0.030** (0.010)
Constant	-0.002* (0.001)	-0.002* (0.001)	-0.002* (0.001)	-0.002* (0.001)
R-squared	0.413	0.413	0.412	0.412
AIC	-1210.52	-1210.52	-1212.05	-1212.05
BIC	-1174.98	-1174.98	-1179.73	-1179.73
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	0.00		0.00	
Ramsey RESET test	0.43		0.65	
Durbin's alternative test for autocorrelation	0.70		0.31	

* p<0.10, ** p<0.05, *** p<0.01

Such specification passes the array of diagnostic tests accept Breusch-Pagan/Cook-Weisberg test for heteroskedasticity. The estimates taking in account hetereskedasticity are reported in the third column. In both cases the estimates for the third lag of positive difference of the crude oil prices appear with positive and statistically significant coefficients compared to critical values at 5% significance level. The results presented in the Table 3 suggest that 1% increase in the price of crude oil in period t-3 (about two weeks earlier to petrol price response) cause the fuel prices to increase by 0.07% at period t, while 1% decrease in the price of crude oil in period t-3 causes the petrol prices to decrease by 0.002% (this estimate is not statistically different from zero). Also, the estimate for the second lag of positive difference of the crude oil prices appears with positive and statistically different from zero coefficient compared to critical values at 10% significance level. We can conclude that 1% increase in the price of crude oil in period t-2 (about ten days earlier to petrol price response) causes the fuel prices to increase by 0.117% (0.117=0.075+0.042) at period t with the same response for crude oil price decrease. The estimates for exchange rate changes appear as expected with positive signs but they are insignificant, suggesting that petrol prices respond symmetrically to exchange rate changes in the short-run.

In the forth column the results of the same model but without positive difference of the exchange rate (appearing insignificant in the second and third columns) are reported. Again, new specification passes the array of diagnostic tests accept Breusch-Pagan/Cook-Weisberg test for heteroskedasticity. The estimates taking in account hetereskedasticity are reported in the fifth column. We can see that point estimates are almost the same as previously and the same conclusions about asymmetry in the short-run responses of petrol prices to changes in the crude oil prices could be derived.

To test for the long-run responses the model (6) from methodology was estimated. The results are presented in the Table 4.

Table 4 Estimates for long-run responses

Dependent variable: $\Delta\log(p)_t$	(6)	(6), corrected for heteroscedasticity
	estimate/se	estimate/se
$\Delta\log(oil)_{t-1}$	-0.062*** (0.015)	-0.062*** (0.020)
$\Delta\log(ex)_{t-1}$	0.025 (0.034)	0.025 (0.080)
$\Delta\log(p)_{t-1}$	0.152** (0.066)	0.152 (0.107)
$\Delta\log(p)_{t-2}$	0.288*** (0.067)	0.288* (0.153)
$\Delta\log(p)_{t-3}$	0.231*** (0.065)	0.231*** (0.084)
ECT^{+}_{t-1}	-0.058*** (0.016)	-0.058*** (0.019)
ECT^{-}_{t-1}	-0.058*** (0.020)	-0.058** (0.018)
Constant	0.000 (0.001)	0.000 (0.001)
R-squared	0.393	0.393
AIC	-1268.9	-1268.9
BIC	-1242.77	-1242.77
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	0.00	
Ramsey RESET test	0.182	
Durbin's alternative test for autocorrelation	0.202	
Test $ECT^{+}_{t-1} = ECT^{-}_{t-1}$	0.9879	0.9877

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Again, the specification passes the array of diagnostic tests accept Breusch-Pagan/Cook-Weisberg test for heteroskedasticity. The estimates taking in account hetereskedasticity are reported in the third column. The F-test on equality of estimates for positive and negative phases of the lagged error correction terms can not reject the hypothesis that these coefficients are different from each other (F[1, 186] = 0.00; Prob>F = 0.9877). So, we can not reject the hypothesis about symmetry in the long-run responses of petrol prices to changes in the crude oil prices and exchange rate changes. But coefficient on the lag of the first difference of the crude oil price appears with negative and significant coefficient. I can explain this only by the fact that crude oil price is more volatile than fuel prices and when oil price change its dynamic from positive to negative phase the petrol price continues still to rise responding to previous trend in oil prices. The estimates for exchange rate changes appear as expected with positive sign but they are not statistically different from zero.

Proceeding further, we estimate the model that accomplishes the asymmetry in the speed of adjustment to the long-run equilibrium after shocks to crude oil price or exchange rate and the short-run responses of petrol prices to upstream prices. The results are presented in the Table 5 below.

According to the results the short-run asymmetric responses are again present for the third lag of positive difference of the crude oil prices which appears with positive and statistically significant coefficients compared to critical values at 5% significance level. Also, the estimate for the second lag of positive difference of the crude oil prices is positive and statistically different from zero at 10% significance level. The F-test on equality of estimates for positive and negative phases of the lagged error correction terms can not reject the hypothesis that these coefficients are different from each other (F[1, 175] = 0.08; Prob>F = 0.783). So, we can not reject the hypothesis about symmetry in the long-run responses of petrol prices to changes in the crude oil prices and exchange rate changes in this specification.

So, as previous two models, this model also shows that asymmetry is present in the short-run for the positive difference of the crude oil prices and that we can not reject symmetry for the long-run adjustment of fuel prices to changes in the crude oil prices and exchange rate changes.

Table 5 Estimates for short-run and long-run responses

Dependent variable: $\Delta \log(p)_t$	(7)	(7), corrected for heteroscedasticity
	estimate/se	estimate/se
$\Delta^+ \log(oil)_{t-2}$	0.074* (0.044)	0.074 (0.058)
$\Delta^+ \log(oil)_{t-3}$	0.070** (0.033)	0.070* (0.035)
$\Delta \log(oil)_{t-2}$	0.042*** (0.016)	0.042** (0.018)
$\Delta \log(oil)_{t-3}$	0.003 (0.023)	0.003 (0.040)
$\Delta^+ \log(ex)_{t-1}$	0.028 (0.043)	0.028 (0.087)
$\Delta \log(ex)_{t-1}$	0.045 (0.037)	0.045 (0.088)
$\Delta.\log(p)_{t-1}$	0.152** (0.074)	0.152 (0.112)
$\Delta.\log(p)_{t-2}$	0.265*** (0.071)	0.265* (0.159)
$\Delta.\log(p)_{t-3}$	0.192*** (0.073)	0.192** (0.078)
ECT^+_{t-1}	-0.028* (0.016)	-0.028 (0.018)
ECT^-_{t-1}	-0.036* (0.021)	-0.036* (0.019)
Constant	-0.002 (0.001)	-0.002 (0.001)
R-squared	0.376	0.376
AIC	-1208.59	-1208.59
BIC	-1169.82	-1169.82
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	0.00	
Ramsey RESET test	0.437	
Durbin's alternative test for autocorrelation	0.778	
Test $ECT^+_{t-1} = ECT^-_{t-1}$	0.791	0.783

* p<0.10, ** p<0.05, *** p<0.01

Threshold Autoregression Model:

In order to estimate threshold autoregression model we use the residuals obtained from long-run relationship (1). The differenced residuals are regressed on the lagged error-correction terms split on positive and negative parts (assuming zero threshold). For the momentum threshold autoregression model the differenced residuals are regressed on the lagged differences of error-correction terms also split on positive and negative parts (again, assuming zero threshold). The results are presented in the Table 6.

Table 6 Estimation of TAR and M-TAR models

Dependent variable: ΔECT_t	TAR Estimate /se	M-TAR Estimate /se
ECT^+_{t-1}	-0.094 (0.065)	
ECT^-_{t-1}	-0.181** (0.086)	
ΔECT_{t-1}	-0.076 (0.073)	
ΔECT^+_{t-1}		-0.170*** (0.051)
ΔECT^-_{t-1}		-0.109* (0.056)
Constant	-0.003 (0.005)	0.001 (0.003)
R-squared	0.061	0.062
AIC	-697.8	-711.76
BIC	-684.7	-701.91
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	0.538	0.767
Ramsey RESET test	0.235	0.414
Durbin's alternative test for autocorrelation	0.318	0.11
Test $ECT^+_{t-1}= ECT^-_{t-1}=0$ ($\Delta ECT^+_{t-1}=\Delta ECT^-_{t-1}=0$)	0.004	0.0007
Test $ECT^+_{t-1}= ECT^-_{t-1}$ ($\Delta ECT^+_{t-1}=\Delta ECT^-_{t-1}$)	0.497	0.421

*p<0.10, ** p<0.05, *** p<0.01

Using tabulated by Endors and Siklos (1999) critical values for F-test we can reject the null that $\phi^+ = \phi^- = 0$, and conclude that cointegration between price series exists. Tong (1990) show that if the long-run relationship is present than OLS estimates of ϕ^{+} and ϕ^{-} are asymptotically normally distributed and standard F-test can be used for the null hypothesis that $\phi^{+} = \phi^{-}$, meaning symmetric adjustment. The results of these tests are shown in the two bottom lines of the Table 6. All coefficients have the expected signs. According to the F-test we can not reject the null of symmetry in both models. We can try to apply the Chan's (1993) approach to find the true value of the threshold. For this we need to find such value of threshold that minimizes the sum of squared residuals in the model (9). The technique proposes to estimate the TAR model for each residual from (1) discarding the smallest and the largest 15% and estimate the model with the threshold that gives the smallest sum of the squared residuals. But graphical inspection does not show us that such threshold should be significantly different from zero:

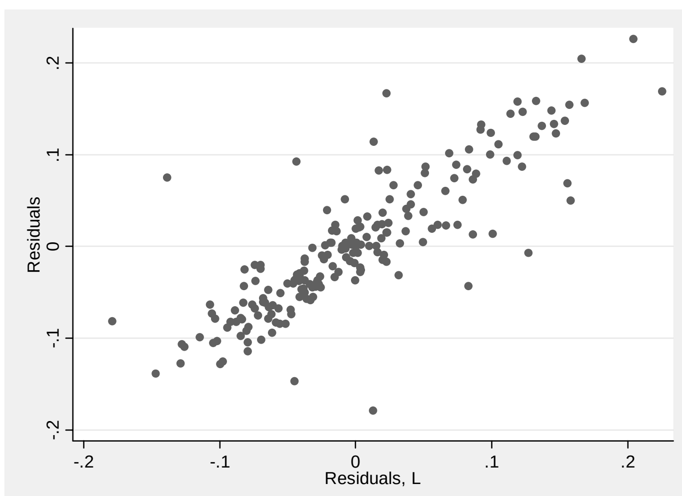

Figure 2 Graphical inspection for the threshold in TAR model

So, we can conclude that both TAR and M-TAR models do not provide the evidence for the asymmetric petrol prices adjustment to the long-run equilibrium neither with respect to size nor change in the market margin.

In order to answer the specific question that this research addresses I use Johansen methodology to construct impulse response functions which are shown on the Figure 2A. From IRF graph where world crude oil price is an impulse variable and Ukrainian price for A-95 mark of fuel as a response variable we see that it does not decay. Crude oil innovations appear to have strong lasting impact on petrol prices. So, we can say that drivers can benefit from observing world crude oil prices: if oil prices tend to increase drivers can buy more fuel for future use, and when tendency to decrease is observed drivers can use fuel bought earlier because it is like that fuel prices in Ukraine will also decrease. On average such strategy can help to spend less money on fuel than when simply buying fuel without observing the tendencies on the world crude oil market.

Chapter 6

CONCLUSION

The issue of asymmetric price transmission on the Ukrainian petroleum market is investigated. The employed error-correction model extended to include error correction terms which are split into negative and positive, the threshold autoregression and the momentum threshold autoregression models support the hypothesis that three investigated time series, namely fuel prices in Ukraine, world crude oil prices and dollar-hrivna exchange rate, are cointegrated. But also all used models fail to find an asymmetry in the long-run on the basis of two times per week data for 2007-2008 years. However, error-correction model shows that there is temporal (around two weeks) delay in the reaction of fuel prices to crude oil price changes which is greater for oil price increases than decreases, confirming the opinion held by many experts in this field about asymmetric behavior of the petrol market in Ukraine.

As we find no evidence for asymmetry in the long-run adjustment, we can say that there is a reasonable level of competition between Ukrainian petrol distributors (or refiners). Also, our results suggest that there is some short-run inefficiency in the Ukrainian fuel market. So, some improvements should be made by the government to reduce short-run asymmetry, but deeper research should be conducted in order to determine on what stage (production or distribution) short-run asymmetry arises and to find possible explanations of the terminal delay reaction of fuel prices to world crude oil price changes.

Also, it is relevant for further research to take a longer period for estimation and search for other than zero level of threshold.

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APPENDIX

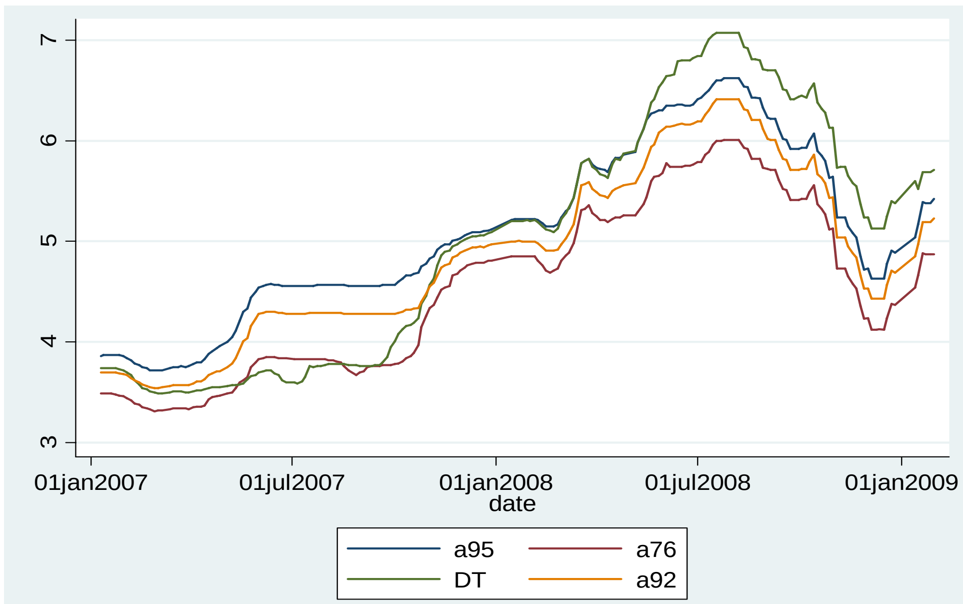

Figure A1. Dynamic of fuel prices in Ukraine for 2007-2008

Table A1. Phillips-Perron test for unit root

Variable	Test Statistic	5% Critical Value	MacKinnon approximate p-value	Conclusion
log(A-95)	-2.212	-13.902	0.5473	unit root
log(oil)	-0.885	-13.902	0.9030	unit root
log(ex)	3.226	-13.902	0.9976	unit root
Δlog(A-95)	-138.110	-13.900	0.0000	white noise
Δlog(oil)	-206.511	-13.900	0.0000	white noise
Δlog(ex)	-201.202	-13.900	0.0000	white noise

Table A2. Descriptive statistics for estimated Long-run relationship (1)

	Value	p-value
R-squared	0.805	
Durbin-Watson	0.29	
AIC	-477.124	
SBC	-467.244	
Durbin's alternative test for autocorrelation	512.5	0.000
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	0.16	0.69
Ramsey RESET test	0.83	0.48

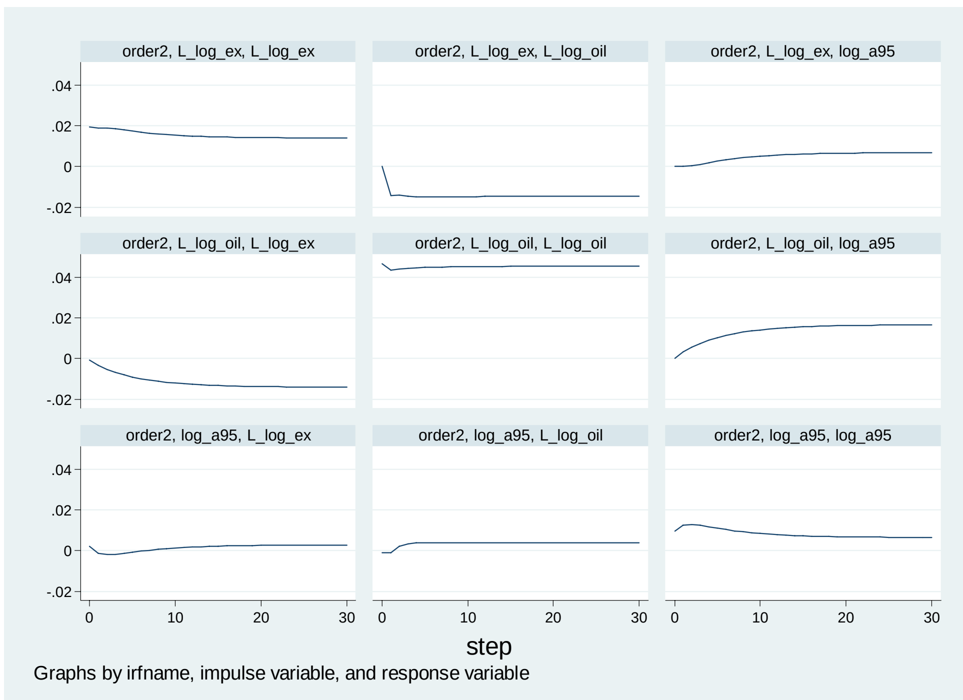

Figure A2 Impulse response functions