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Bachelor thesis:

Oil rents dependence, oil prices and exchange rates: evidence from daily data

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Prohlášení

Prohlašuji, že jsem bakalářskou práci na téma „Závislost na ropných výnosech, ceny ropy a měnové kurzy: analýza denních dat“ zpracoval samostatně. Veškerou použitou literaturu a další podkladové materiály uvádím v seznamu použité literatury.

Declaration

I declare that I prepared the bachelor thesis „Oil rents dependence, oil prices and exchange rates: evidence from daily data“ individually. All used literature and other sources are presented in the attached list of references.

V Praze dne 9. ledna 2017 ....

Roman Budkov

Poděkování:

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Abstrakt

Název práce: Závislost na ropných výnosech, ceny ropy a měnové kurzy: analýza denních dat
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Vedoucí práce: Ing. Jan Zouhar, Ph.D.

Tato práce zkoumá vztah mezi cenami ropy a měnovými kurzy zemí vyvážejících ropu z hlediska jejich závislosti na ropných výnosech. V práci byly použity denní hodnoty cen a kurzů za období 2005-2015. V první části jsou popsána data a základní charakteristiky jednotlivých zemí. Druhá část zahrnuje ekonometrickou teorii, na níž je založena praktická část. Aplikace modelu korekce chyby vede ke kontroverzním výsledkům. Analýza založená na přístupu GARCH prokazuje pozitivní vztah mezi hodnotou měn a cenou ropy, avšak souvislost s závislostí na ropných výnosech není zcela zřejmá. Práce rovněž podporuje závěry existujících výzkumů, jako například negativní vztah mezi hodnotou amerického dolaru a cenami ropy.

Klíčová slova: ropné výnosy, ceny ropy, měnové kurzy, VEC, GARCH

Abstract

Title: Oil rents dependence, oil prices and exchange rates: evidence from daily data
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This paper studies the relationship between the oil prices and exchange rates of oil exporting countries, in terms of their dependence on oil rents. The study is based on data at the daily frequency over the period 2005-2015. In the first chapter, the data set and basic characteristics of the countries are described. The second chapter represents the econometric framework for the practical section. Applying a vector error correction model mainly produced controversial results. Analysis based on a GARCH approach found a positive relationship between the value of the currencies and the oil prices, although the link with the oil rents dependence is not sufficiently evident. The paper also supports stylized facts, such as a negative relationship between the U.S. dollar value and the oil prices.

Keywords: oil rents, exchange rates, oil prices, VEC, GARCH

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Introduction

World oil prices are one of the most important economic indicators, and have a direct impact on the global economy. Since the last century, world oil consumption has been steadily increasing. Oil market forecasts take into account the development of national budgets and investment projects in a business sector. The oil prices substantially affect production costs and economic indicators of all countries.

Oil market tendencies have especially noticeable effects on the economies of oil exporting countries. In such countries, revenues from oil and other energy resources determine the dynamics of economic growth and the inflation rate, and also influence the formation of government budgets, and have a large scale impact on the value of the national currency. Periods of high oil prices provide favourable conditions for development of domestic economies, but a sharp decline in the oil market may lead to a crisis. The effect depends on the structure of the country's economy. If the country is a net exporter, the decline in oil prices adversely impacts the balance of payments, and consequently leads to a depreciation of the national currency. On the other hand, an increase in oil prices triggers the reverse process and ensures an appreciation of the national currency. If a country is a net importer, the situation is the converse: the decline in oil prices changes the balance of payments in favour of importers and leads to a strengthening of its currency, while the increase in oil prices leads to a depreciation. Countries that are neither net exporters nor net importers experience a much lesser impact from oil price shocks on their currencies. However, there is no country which would be totally independent of the oil price market.

Regarding the theory, there are many papers devoted to the influence of oil prices on economic indicators as well as on exchange rates. For example, Ferraro et al. (2015) report that commodity prices can be useful to forecast commodity currencies in the short run. Basher et al. (2012) conclude that changes in oil prices lead to a response in exchange rates in the short term. The study also supports the hypothesis that an increase in oil prices results in a long-run depreciation in currencies of oil importers and an appreciation in currencies of oil exporters. On the other hand, Akram (2004) found evidence of a negative relationship between the value of the Norwegian exchange rate and crude oil prices. In addition, he noted an effect of a monetary policy on the impacts of oil price shocks, which was also suggested by Manera and Cologni (2008). For our study, the most important findings are represented in the works of Amano and van Norden (1998) and Aloui et al. (2013). Amano and van Norden (1998) document the existence of a cointegrating relationship between the real U.S. dollar value against other currencies and the real oil price. Moreover, Granger causality tests show that oil prices can impact exchange rates, but not vice versa. Furthermore, an error correction model indicates a stable relationship between these variables. Aloui et al's report (2013), using a copula-GARCH approach, shows a significant dependence between the U.S. dollar exchange rates against five major currencies and oil prices. The study suggests that a rise in oil prices is mainly associated with a depreciation of the U.S. dollar. Finally, Narayan et al. (2008) find, from GARCH and EGARCH models, that an increase in oil prices leads to an appreciation of the Fijian Dollar against the U.S. Dollar.

In summary, most of the surveyed works principally established the relationship between oil prices and the value of the U.S. Dollar.

The key contribution of the present study is twofold. Firstly, unlike the extant studies, the purpose is to examine the relationship between the oil prices and currencies of oil exporting countries in terms of their varying dependence on oil rents. Secondly, our goal is to establish the relationship between exchange rates and oil prices, excluding the dollar effect. The national currencies, as well as the oil prices, are denominated in U.S. Dollars; therefore a dependence may occur due to the relationship between the oil prices and the dollar. In other words, the relationship between these variables can largely be explained by the response of the U.S. Dollar value to the oil price shocks. In some of the previous papers, this issue has been resolved by calculating a domestic currency in a different currency to the U.S. Dollar. In this paper, in order to eliminate this effect, we included the U.S. Dollar rate per SDR (Special Drowning Rights) – a supplementary reserve and payment instrument issued and maintained by the International Monetary Fund, the value of which is based on a basket of five major currencies (as for 2016). Adding this variable is important in order to distinguish the impact of the U.S. Dollar dynamics on the currencies of the countries studied and the changes effected by the oil price fluctuations.

The paper consists of theoretical and practical parts. Firstly, we describe our data and the main characteristics of each country. The second chapter introduces an econometric framework on which the study is based. In the third chapter our empirical results are represented. The last section briefly summarizes conclusions based on the results obtained in the practical part of the study.

1 Oil prices, exchange rates, and country characteristics

1.1 Main dataset

The subject of study includes the nominal exchange rates of five oil exporting countries (Brazil, Canada, Indonesia, Norway and Russia), and the exchange rate of SDR. The oil prices are represented by two major oil benchmarks (WTI and Brent). The data sources are "International Monetary Fund (2016)" and "U.S. Energy Information Administration (2016)". The sample contains 2869 observations over an almost eleven-year period, from 03/01/2005 to 31/12/2015. The list of variables, and the notation used throughout the text, is as follows:

Variable *brl* – USD per unit of Brazilian real

Variable *cad* – USD per unit of Canadian dollar

Variable *idr* – USD per unit of Indonesian rupiah

Variable *nok* – USD per unit of Norwegian krone

Variable *rub* – USD per unit of Russian rouble

Variable *brent* – USD per barrel

Variable *wti* – USD per barrel

Variable *sdr* – USD per unit of SDR

All of the variables are logarithmically transformed.

Table 1-1: Descriptive statistics of logarithmically transformed time series

	brl	*cad*	*idr*	*nok*	*rub*	*brent*	*wti*	*sdr*
Mean	−0.743	−0.087	−9.210	−1.820	−3.454	4.367	4.325	0.416
Median	−0.722	−0.065	−9.154	−1.803	−3.405	4.355	4.369	0.420
Maximum	−0.428	0.087	−8.988	−1.601	−3.141	4.969	4.979	0.501
Minimum	−1.434	−0.336	−9.598	−2.176	−4.289	3.518	3.410	0.313
Std. dev.	0.205	0.088	0.132	0.113	0.245	0.322	0.289	0.039
Skewness	−1.051	−0.585	−1.130	−1.023	−1.817	−0.297	−0.453	−0.458
Kurtosis	4.101	2.348	3.084	4.142	5.863	1.960	2.493	2.955
Jarque-Bera	576.75*	194.42*	554.13*	607.88*	2324.25*	165.93*	124.54*	98.07*
Observations	2459	2604	2601	2656	2607	2777	2769	2798
Missing values	410	265	268	213	262	92	100	71

Note: * indicates the rejection of the null hypothesis of no normality at 1% level of significance, according to Jarque-Bera statistic.

From Table 1-1 we see that all the series contain missing values. The reason is that most of the markets are closed during national holidays. The series are skewed and display high kurtosis. The Jarque-Bera statistic reports that none of them are normally distributed.

1.2 Brief overview of the countries

The main criterion for the selection of countries for this study was the exchange rate regime. For obvious reasons, for the purposes of the research, we had to choose currencies with floating exchange rates. In order to make the model more diverse and provide broader perspective on the studied issue, the chosen states have different economic characteristics.

Brazil is the biggest economy in South America and the oil reserves at its disposal are at the second highest level in the region, after Venezuela. The country has been a net exporter of oil since 2006 and its oil production has significantly increased over the last decade. However, the country still imports petroleum products to cover national consumption.

Canada has a highly developed economy. The country is one of the largest producers and exporters of oil. The proven oil reserves in Canada are the second largest in the world. The biggest importer of Canadian oil is the United States.

Indonesia is the largest country in Southeast Asia and one of the world's fast growing economies. The country was the only OPEC member in its region, but left the cartel in 2009 as from it changed from being an exporter of oil to a net importer due to the increase of domestic demand. Nevertheless, Indonesia still exports oil and remains the largest oil producer in Southeast Asia; however, at the same time, its oil production has been steadily declining in recent years.

Norway is one of the most developed countries in the world. However, oil exports play a significant role in Norwegian economy. The country is one of the leading oil exporters to the EU. The oil industry brings almost one-third of government revenue and has a big impact on other sectors of the economy. Therefore, in recent years the government has made several attempts to provide economic diversification.

Russia is a developing country and one of the world's biggest oil producers and exporters. It is in second place only to Saudi Arabia and the eighth by oil reserves. Russia's economy is highly dependent on oil. The energy sector accounts for about seventy percent of total exports and more than half of revenues to the federal budget. A decrease in oil prices leads to a reduction of dollar revenues of oil companies and, consequently, to the depreciation of the Russian currency.

One of the most important indicators when discussing a country's dependence on oil are oil rents. This term refers to the difference between the value of crude oil production at world prices and total costs of production.

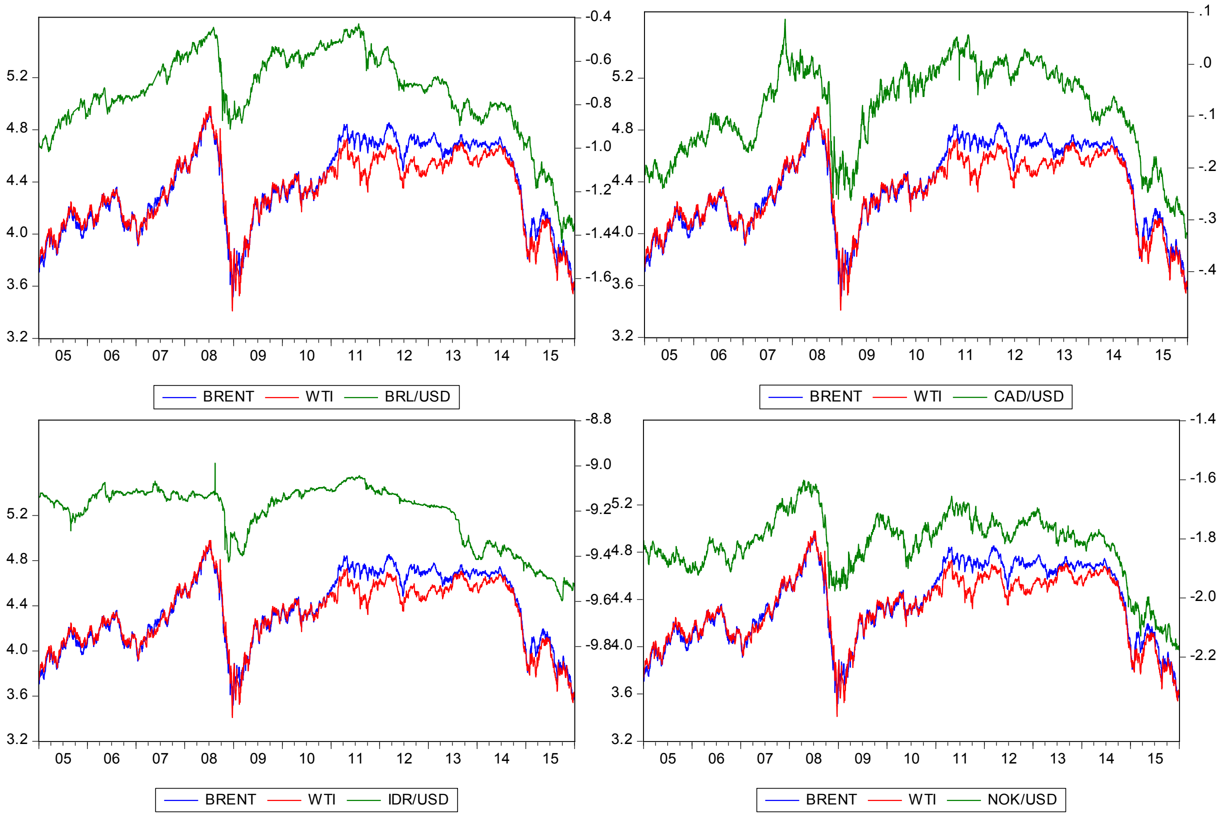
Table 1-2: Oil rents (% of GDP)

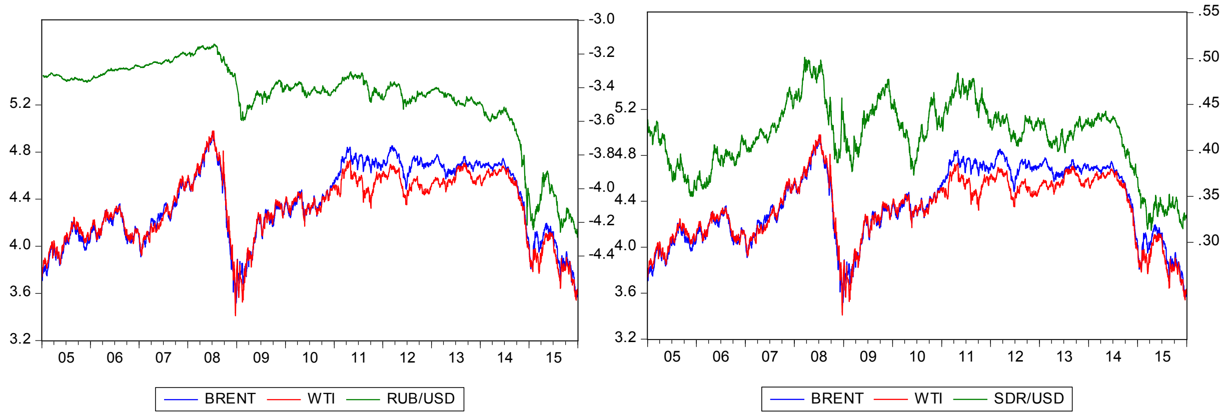
	Brazil	Canada	Indonesia	Norway	Russia
2005	3.0	3.0	5.8	14.5	20.2
2006	3.1	3.5	5.3	14.6	19.3
2007	2.7	3.5	4.6	12.6	16.5
2008	3.2	4.6	5.6	14.5	17.8
2009	2.0	2.6	2.7	9.2	13.4
2010	2.1	3.2	2.6	10.0	14.7
2011	2.4	4.2	2.9	10.8	16.1
2012	2.4	4.1	2.6	9.4	14.9
2013	2.3	4.0	2.3	8.3	13.7
2014	2.2	3.4	1.8	7.6	12.7

Source: "The World Bank (2016)"

The percentages of the oil rents in the GDP's of the researched countries (Table 1-2) shows that the most oil dependent states are Norway and the Russian Federation. Canada and Brazil exhibit a lower degree of dependence on oil rent. As of 2014, oil rents constitute an insignificant part of the Indonesian GDP. Over the last decade, we can observe a common tendency of decreasing of this indicator that can be explained by diversification policy or by a growth in national demand. Based on the oil rents factor, we can assume that the exchange rates of states whose oil rents account for a significant part of their GDP will show a stronger relationship with oil prices in an econometrical model.

Figure 1-1: Logarithms of daily crude oil prices and the exchange rates





The relationship between oil prices and exchange rates becomes obvious if we look at the market dynamics over the last decade (Figure 1-1). We can observe significant likenesses between the curves. This is especially noticeable during the period of the mortgage crisis which began in 2008, and the dramatic drop in oil prices in 2014.

The Brent and WTI curves are mostly similar to each other, but we can see the difference in dynamics during the 2011–2014 period. Such a distinction can substantially affect results. Therefore, both of them are included in the research.

2 Econometric framework

This section briefly describes the theory and methods on which the practical part of the study is based. Initially, it was necessary to eliminate the data deficiencies in the form of the missing values. Further, were conducted the stationarity, Granger causality and cointegration tests. The next step was the construction and testing of VEC models, and also the study of impulse responses. At the end, GARCH models were applied and tested.

The presented material has become a part of standard time series methodology, and is briefly covered here for the sake of completeness. Most of it has been compiled from three sources, (Wooldridge, 2013; Enders, 2010; EViews 8: User's guide, 2014).

2.1 Interpolation

One of the ways to fill in missing values is a linear interpolation method. This method consists of creating new data points using a linear approximation, based on values that are non-missing according to the formula:

$$IV_{Lin} = (1-\lambda)P_{i-1} + \lambda P_{i+1},$$

where IV_{Lin} is the interpolated value, P_{i-1} is the previous missing value, P_{i+1} is the next non-missing value, and λ is the relative position of the missing value divided by the total number of missing values in a row (EViews 8: User's guide, 2014).

2.2 Stationarity

Generally, stationarity means that some properties of a stochastic process do not change over time.

A stochastic process $\{x_t : t = 1, 2, ...\}$ is (*strongly*) stationary if for every collection of time indices $1 \le t_1 < t_2 < ... < t_m$, the joint distribution of $(x_{t_1}, x_{t_2}, ..., x_{t_m})$ is the same as the joint distribution of $(x_{t_1+h}, x_{t_2+h}, ..., x_{t_m+h})$ for all integers $h \ge 1$.

However, this definition is too rigid; therefore, for the purposes of the study, the definition of covariance stationary process will be used.

A stochastic process $\{x_t : t = 1, 2, ...\}$ with a finite second moment $[E(x_t^2) < \infty]$ is covariance (*weakly*) stationary if

$E(x_t)$ is constant;

$Var(x_t)$ is constant;

and for any t, $h \ge 1$, $Cov(x_t, x_{t+h})$ depends only on h and not on t.

In other words, under the second definition, the $\{x_t\}$ sequence is stationary if its mean, variance and covariance are stable over time. The stationarity assumption is important in regression analysis for understanding the relationship between variables. Stationary time series can be used in a regression model without any transformation and are said to be integrated of order zero − $I(0)$. Sometimes, when the process is nonstationary, a covariance stationary time series can be obtained by taking the first differences. Such series are said to be integrated of order one − $I(1)$ (Wooldridge, 2013).

2.3 Unit root test

Weak stationarity is one of the assumptions needed for statistical inference of a regression model. If one of the variables is nonstationary, it can cause a spurious regression, when measures of fit indicate a good quality of model, but the results are economically and statistically meaningless, because t-statistics are not valid. Therefore, testing the variables in a regression for non-stationarity is highly important. In a case in which all of the variables are nonstationary and have the same order of integration, a frequent recommendation is to estimate the equation in the first differences.

The common method for determining whether a time series is stationary is the Dickey-Fuller (DF) test for a unit root.

Consider the first-order autoregressive model

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + e_t \, .$$

We can write the equivalent form, by subtracting y_{t-1} from each side of the equation where $\gamma = \alpha_1 - 1$:

$$\Delta y_t = \alpha_0 + \gamma y_{t-1} + e_t \, .$$

Under the null hypothesis of the test the $\{y_t\}$ sequence has a unit root, if $\gamma = 0$. After estimating the equation, the t-statistic corresponding to the obtained value of γ is compared with the appropriate value reported in the Dickey-Fuller tables. If the null hypothesis fails to be rejected, then a time series is nonstationary.

The augmented Dickey-Fuller (ADF) test is used for more complicated models. The augmented equation of order p can be represented as follows:

$$\Delta y_t = \alpha_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + e_t \, ,$$

where $\gamma = -(1 - \sum_{i=1}^{p} a_i)$ and $\beta_i = -\sum_{j=i}^{p} a_j$

In the same way, if $\gamma = 0$, the equation contains a unit root (Enders, 2010).

2.4 Granger causality

The basic idea of Granger causality (Granger, 1969) is that the past values of one time series can be useful to predict the future values of another one, in addition to its own past values.

Consider a vector autoregression with two series:

$$y_t = \delta_0 + \alpha_1 y_{t-1} + \gamma_1 z_{t-1} + \alpha_2 y_{t-2} + \gamma_2 z_{t-2} + \dots,$$
$$z_t = \eta_0 + \beta_1 y_{t-1} + \rho_1 z_{t-1} + \beta_2 y_{t-2} + \rho_2 z_{t-2} + \dots,$$

where each equation contains an error that has zero expected value given past information on y_t and z_t. We say that z Granger causes y if

$$E(y_t | I_{t-1}) \neq E(y_t | J_{t-1}),$$

where I_{t-1} contains past information on y and z, and J_{t-1} contains only information on past y. In other words, past z can help, in addition to past y, to forecast y_t.

Under the null hypothesis of the test z does not in Granger cause y, if all the coefficients of lags of z in the first equation are equal to zero.

Hence, $H_0 : \gamma_1 = \gamma_2 = \dots = 0$. Testing of the hypothesis is based on the F-test of joint significance (Wooldridge, 2013).

2.5 Cointegration

In section 2.3 a problem of the spurious regression was mentioned, which can occur if one of the variables is nonstationary. It was also suggested that in the presence of $I(1)$ variables a regression model should be estimated in the first differences. Nevertheless, in some cases the $I(1)$ variables can be used in levels.

Consider two stationary processes $\{y_t : t = 0,1,\dots\}$ and $\{x_t : t = 0,1,\dots\}$, integrated of order one. If x and y are unrelated, the process $y_t - \beta x_t$ is also $I(1)$ for any number β. However, there is a possibility that for some $\beta \neq 0$, $y_t - \beta x_t$ is an $I(0)$ process. If such a β exists, it is said that y and x are cointegrated, where β is the cointegration parameter (Wooldridge, 2013).

2.6 Johansen test

The Johansen test is used for determining whether variables are cointegrated. If the $I(1)$ variables are cointegrated, there is a linear combination of them, which is stationary and is called the cointegrating equation.

Consider a vector autoregression of order p:

$$y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + Bx_t + e_t,$$

where y_t is a k-vector of nonstationary variables integrated of order one, x_t is a d-vector of deterministic variables, and e_t is a vector of error terms. The equation can be written in the equivalent form:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p=1} \Gamma_i \Delta y_{t-i} + Bx_t + e_t,$$

where:

$$\Pi = \sum_{i=1}^{p} A_i - I \ , \ \Gamma_i = -\sum_{j=i+1}^{p} A_j$$

According to Granger's theorem (Granger, 1969), if the rank of the Π matrix is less than the number of endogenous variables $r < k$, the matrix can be represented as $\Pi = \mathrm{AB}'$, where A and B are the $k \times r$ matrices, and r-vector representing a collection of r stationary processes, where r is the number of cointegrating relations.

There are two tests statistics, but for this study, only the results based on a trace statistic will be considered. Under the null hypothesis of the test the number of cointegrating relations is equal to r. The alternative hypothesis is that there are k cointegrating relations, where k is the number of independent variables, for $r = 0,1,...,k-1$. The trace statistic is defined as:

$$LR_{tr} = (r|k) = -T \sum_{i=r+1}^{k} \log(1-\lambda_i) \ ,$$

where λ_i is the i-th largest eigenvalue of the Π matrix (EViews 8: User's guide, 2014).

2.7 Error correction model

In section 2.5, it was mentioned that a regression model, which includes $I(1)$ variables, should be estimated in the first differences, unless the variables are cointegrated. The error correction model allows for estimation of a regression with $I(1)$ variables that are cointegrated, in levels.

If y_t and x_t are the nonstationary variables integrated of order one and are cointegrated with parameter β, then the stationary variable $y_t - \beta x_t$ can be included in a regression equation. Hence, a simple error correction model including one lag can be represented as follows:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta y_{t-1} + \gamma_0 \Delta x_t + \gamma_1 \Delta x_{t-1} + \delta(y_{t-1} - \beta x_{t-1}) + u_t \ ,$$

where $\delta(y_{t-1} - \beta x_{t-1})$ is the error correction term, $E(u_t | I_{t-1}) = 0$, and I_{t-1} contains information on Δx_t and all past values of x and y (Wooldridge, 2013).

A vector error correction (VEC) model is a restricted vector autoregression. Consider a simple system with two variables y_t and x_t without lags, and one cointegrating equation:

$$y_t = \beta x_t$$

Then the VEC model can be represented as:

$$\Delta x_t = \alpha_1 (y_{t-1} - \beta x_{t-1}) + \varepsilon_{1,t}$$
$$\Delta y_t = \alpha_2 (y_{t-1} - \beta x_{t-1}) + \varepsilon_{2,t}$$

The error correction term equates to zero in long-run equilibrium, unless the endogenous variables deviate from it. The speed of adjustment of the dependent variables, in order to restore the equilibrium after the deviation, is measured by the coefficients α_1 and α_2 (EViews 8: User's guide, 2014).

2.8 Impulse response

A vector autoregression can be represented in a vector moving-average form. First, consider a vector autoregression with two variables written in matrix form:

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \alpha_{10} \\ \alpha_{20} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix}$$

Then the moving-average representation in matrix form can be written as follows:

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \bar{y} \\ \bar{z} \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} \varphi_{11}(i) & \varphi_{12}(i) \\ \varphi_{21}(i) & \varphi_{22}(i) \end{bmatrix} \begin{bmatrix} \varepsilon_{yt-i} \\ \varepsilon_{zt-i} \end{bmatrix}$$

or, in the equivalent form,

$$x_t = \mu + \sum_{i=0}^{\infty} \Phi_i \varepsilon_{t-i} ,$$

where $\mu = [\bar{y}\,\bar{z}]'$,

and $\bar{y} = [\alpha_{10}(1-\alpha_{22}) + \alpha_{12}\alpha_{20}] / \Delta$; $\bar{z} = [\alpha_{20}(1-\alpha_{11}) + \alpha_{21}\alpha_{10}] / \Delta$; $\Delta = (1-\alpha_{11})(1-\alpha_{22}) - \alpha_{12}\alpha_{21}$. Hence, $\bar{y}$ and $\bar{z}$ are the unconditional means of y_t and z_t. Φ_i is the matrix with elements $\varphi_{jk}(i)$, which are impact multipliers, and ε_{t-i} is the matrix of shocks.

Usage of the moving-average representation allows for provision of a deeper analysis of the interplay between the variables. The ε_{yt} and ε_{zt} terms are the shocks and the four groups of coefficients $\varphi_{11}(i)$, $\varphi_{12}(i)$, $\varphi_{21}(i)$, $\varphi_{22}(i)$ are the impulse response functions. The impact of the shocks on the $\{y_t\}$ and $\{z_t\}$ sequences throughout the entire subsequent time can be produced by the coefficients of φ_i. Graphical representation of the impulse response functions is often used to demonstrate the reaction of the time series on different shocks.

In order to identify the impulse responses there must be imposed an additional restriction on vector autoregression system. One of the possibilities of ordering variables is to use Cholesky decomposition of covariance matrix. (Enders, 2010).

2.9 Model adequacy (VEC)

A constructed model may not be accurate if the fundamental assumptions are violated. The estimated residuals should be serially uncorrelated, display no conditional heteroscedasticity, and be approximately normally distributed (Johansen, 1995).

The serial correlation in the residuals does not necessarily lead to a bias or inconsistency in the coefficient estimates. Nevertheless, the usual standard errors and statistics cannot be trusted, which affects the efficiency of estimators and invalidates statistical inference (Wooldridge, 2013).

The first assumption can be checked using an LM test for residual autocorrelation where, under the null hypothesis, the residuals are not serially correlated. The method is that the estimated residuals are regressed on the initial regressors and the residual lagged s. The test statistic is then calculated as:

$$LM(s) = (T - pk - m - p - 0.5)\log\frac{|\hat{\Omega}|}{|\tilde{\Omega}|},$$

where $\hat{\Omega}$ is the original variance estimate, $\tilde{\Omega}$ is the estimate from the auxiliary regression, T is the number of observations, p is the number of dimensions, k is the lag length and m is the number of seasonal dummies. The LM statistic is asymptotically distributed as χ^2 with $f = p^2$ degrees of freedom (Johansen, 1995).

In the same way, the heteroscedasticity negatively affects the usual standard errors, t-statistics, and F-statistics, while the coefficient estimates can be still unbiased and consistent. The presence of heteroscedasticity in the residuals can be tested by using the White test (Wooldridge, 2013).

The null hypothesis of the test is homoscedasticity. White's test statistic is computed as:

$$LM = TR^2_{\hat{e}^2},$$

where T is the number of observations and $R^2_{\hat{e}^2}$ is the coefficient of determination based on the auxiliary regression:

$$e_t^2 = \alpha_0 + \alpha_1 x_t + \alpha_2 z_t + \alpha_3 x_t^2 + \alpha_4 z_t^2 + \alpha_5 x_t z_t + v_t$$

The test statistic is asymptotically distributed as a χ^2 with f degrees of freedom, where f is the number coefficients in the auxiliary regression, excluding the intercept (EViews 8: User's guide, 2014).

The normality assumption is important for utilising the statistical inference, like testing for serial correlation, for joint significance, or for individual significance of independent variables, although it is mostly related to small samples (Wooldridge, 2013).

The normality test is based on the Jarque-Bera statistic, where the null hypothesis is that the residuals are multivariate normal. The statistic for the joint test is:

$$\lambda = \lambda_3 + \lambda_4 \rightarrow \chi^2(2k),$$

where

$$\lambda_3 = Tm_3'm_3 / 6 \rightarrow \chi^2(k)$$

$$\lambda_4 = T(m_4 - 3)'(m_4 - 3)/24 \rightarrow \chi^2(k)$$

The λ_3 and λ_4 are the statistics for the joint tests for the third and fourth moments respectively, where m_3 is the estimated skewness and m_4 is the estimated kurtosis for individual orthogonal residual component (EViews 8: User's guide, 2014).

2.10 Generalized autoregressive conditional heteroscedasticity

The behaviour of many economic time series illustrates that periods of high volatility alternate with periods of relative stability. In other words, the variance of some series is not constant over time. Hence, under such conditions, the homoscedasticity assumption is not suitable. One of the approaches for modelling the volatility is use of the GARCH model.

Consider a simple regression:

$$y_t = \alpha_0 + \beta x_t + \varepsilon_t$$

and let the error process be such that

$$\varepsilon_t = v_t \sqrt{h_t} ,$$

where v_t is white-noise process such that $\sigma_v^2 = 1$, and

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i h_{t-i}$$

The equation above represents a GARCH(*p,q*) model and the first equation is the model of the mean, where h_t is the conditional variance of ε_t.

It is important to note that all coefficients in the variance equation must have a positive value. Additionally, the sum of the slope coefficients must be less than unity for the variance to be finite (Enders, 2010).

2.11 Model adequacy (GARCH)

To ensure that an estimated GARCH model is well specified, the assumptions of both the model of the mean and the model of the variance, have to be satisfied. There should be no serial correlation and no remaining conditional volatility in the estimated residuals (Enders, 2010).

The first assumption can be tested using the Ljung-Box Q-statistics for the standardized residuals. The Q-statistic at lag k is calculated as:

$$Q_{LB} = T(T+2)\sum_{j=1}^{k} \frac{\tau_j^2}{T-J} ,$$

where T is the number of observations and τ_j is the j-th autocorrelation.

If there is no serial correlation in the mean equation, the values of all test statistics will be insignificant.

The assumption for the variance equation can be checked using the ARCH LM test where, under the null hypothesis, there is no remaining ARCH effect in the standardized residuals up to order q. The test is based on an auxiliary regression:

$$e_t^2 = \beta_0 + (\sum_{s=1}^{q} \beta_s e_{t-s}^2) + v_t ,$$

where e is the residual, and the test statistic $LM = TR_{e^2}^2$ is asymptotically distributed as a $\chi^2(q)$ (EViews 8: User's guide, 2014).

3 Empirical results

In this chapter, the previously described theoretical methods are applied to statistical data. The data has been analysed using the statistical software *Eviews 8*. To create the appropriate model the following steps were applied:

1) Interpolation

2) Testing stationarity

3) Granger causality

4) Cointegration tests and estimation of VEC

5) Estimation of GARCH

3.1 Interpolation

The first problem that occurred in processing the high frequency data was the presence of missing values (Table 1-1). Some of the series contain a high amount of empty data, which can cause difficulties in fitting them into a model. Reducing the size of the sample may result in a loss of important information. Therefore, to make the data suitable for further analysis, it is necessary to fill in the missing parts of the series.

Using the method of linear interpolation (See 2.1), we constructed new data points. Thus, the total amount of observations in the sample increased by 1681 values, which is about 7% of all the data to be used in the next parts of analysis. However, it should also be mentioned, that this method is not very precise and may influence the results.

3.2 Testing stationarity

In this section, the variables are tested for the presence of a unit root using the ADF tests (See 2.3). Under the null hypothesis of the test, a variable is considered to have a unit root. Firstly, the variables are tested in log-levels (Table 3-1).

The table shows *p*-values of the tests for a unit root presence in the individual series for the three cases, where constant, constant and trend or none are exogenous. We failed to reject the null hypothesis at a 5% level of significance for all of the variables. Hence, the test indicates that the data are nonstationary.

Subsequently, the series were converted to logarithmic returns. After applying the test on the differenced data, the *p*-values indicate rejection of the null hypothesis at a 1% level of significance in all of the cases (Table 3-2). Thus, all of the variables are integrated of order one, or $I(1)$.

Table 3-1: ADF test in log-levels

	Intercept	Trend and intercept	None
wti	0.3357	0.8055	0.6038
brent	0.5418	0.9655	0.6138
brl	0.9893	0.9871	0.9087
cad	0.6431	0.9225	0.4144
idr	0.9625	0.9381	0.9516
nok	0.8773	0.9468	0.8922
rub	1.0000	0.9983	0.9947
sdr	0.5713	0.8073	0.3662

Note: values in the table denote the *p*-values

Table 3-2: ADF test in first log-differences

	Intercept	Trend and intercept	None
wti	0.0001	0.0000	0.0001
brent	0.0001	0.0000	0.0001
brl	0.0001	0.0000	0.0001
cad	0.0001	0.0000	0.0001
idr	0.0001	0.0000	0.0001
nok	0.0001	0.0000	0.0001
rub	0.0000	0.0000	0.0000
sdr	0.0001	0.0000	0.0001

Note: values in the table denote the *p*-values

3.3 Granger causality

Before constructing a model, it may be helpful to establish the existence of causal relationships between the variables. Thus, it is necessary to determine whether the oil prices can influence the exchange rates. For that purpose, the variables are tested for Granger causality (Table 3-3). The Granger causality test (See 2.4) shows whether a variable and its lagged values can be useful for predicting another one.

The null hypothesis of the test is that variables $brent$, wti and sdr do not Granger cause variables brl, cad, idr, nok and rub. There are two lags of each variable included. The table shows F-statistics and the *p*-values of the tests between single pairs of the variables. In most of the cases the null hypothesis was rejected for the oil prices. Hence, the oil prices do Granger cause the exchange rates. The only exception is in Brent and the Canadian Dollar pair. The difference in the results may lie in the fact mentioned in part 1.2 – the dynamics of Brent and WTI varied over a period of time. Also, the test indicates casual relationships between sdr and brl, idr, and rub, while for the rest of the variables we are not presented with such evidence.

Table 3-3: Granger causality tests

	brent		*wti*		*sdr*	
	F-statistic	p-value	F-statistic	p-value	F-statistic	p-value
brl	109.25	0.0000*	95.4253	0.0000*	57.19	0.0000*
cad	0.61	0.5459	14.3689	0.0000*	0.90	0.4051
idr	29.27	0.0000*	37.4647	0.0000*	16.80	0.0000*
nok	29.45	0.0000*	57.3708	0.0000*	0.02	0.9758
rub	66.19	0.0000*	127.862	0.0000*	11.23	0.0000*

Note: * indicates rejection of the null hypothesis at 1% level of significance.

3.4 Cointegration and VEC

3.4.1 Johansen test

The next step is to test whether the variables are cointegrated. To establish the presence of cointegrating relationships, we applied the Johansen Cointegration test (See 2.6) to ten groups of the series (Table 3-4). As in the previous section, the data were tested in log-levels.

The table shows the number of cointegrating equations indicated by the Johansen test. In most of the cases, the null hypothesis of no cointegrating relationships was rejected at a 5% level of significance. However, in models containing the Indonesian Rupiah, the test indicates zero cointegrating equations, while in the remaining cases, only one cointegrating equation was detected. Thus, we can conclude the presence of at least one cointegrating relationship between the variables in eight models.

Table 3-4: Johansen Cointegration Test

Data trend	Linear	Linear
Deterministic component	Intercept No trend	Intercept Trend
brl , brent , sdr	1	0
brl , wti , sdr	1	0
cad , brent , sdr	1	0
cad , wti , sdr	1	0
idr , brent , sdr	0	0
idr , wti , sdr	0	0
nok , brent , sdr	0	1
nok , wti , sdr	1	1
rub , brent , sdr	0	1
rub , wti , sdr	0	1

Note: values in the table denote the number of cointegrating relations

The series are assumed to be linear trending; therefore, the results for other cases are not taken into consideration. The deterministic components are selected according to the existence of cointegration between the tested variables. Thus, the trend was included in models with the Russian Rouble and in one case with the Norwegian Krone.

3.4.2 Vector error correction model

Based on the previous conclusions, we estimated eight VEC models (See 2.7) for each group of the variables. Each of the equations include a variable that represents one of the exchange rates, one of the crude oil benchmarks and the variable sdr. Lag length for each model was selected individually according to Akaike information criterion (See Enders, 2010, p. 317). However, the results should be taken with caution as some of the model assumptions were violated (See 3.4.4). Therefore, we will briefly interpret only the coefficients in the cointegrating equations that are listed below.

$$brl_t = -1,2291 brent_t + 15,6482 sdr_t - 1,8728$$

$$brl_t = -1,8864 wti_t + 19,4111 sdr_t - 0,6474$$

$$cad_t = 0,2528 brent_t + 0,0838 sdr_t - 1,2275$$

$$cad_t = 0,4139 wti_t - 0,8352 sdr_t - 1,5311$$

$$nok_t = 0,2299 brent_t + 1,0827 sdr_t - 0,0001t - 3,1996$$

$$nok_t = 0,3064 wti_t + 0,7327 sdr_t - 3,4499$$

$$rub_t = 0,4992 brent_t + 0,9180 sdr_t - 0,0003t - 5,5835$$

$$rub_t = 0,7620 wti_t - 0,6400 sdr_t - 0,0003t - 6,0658$$

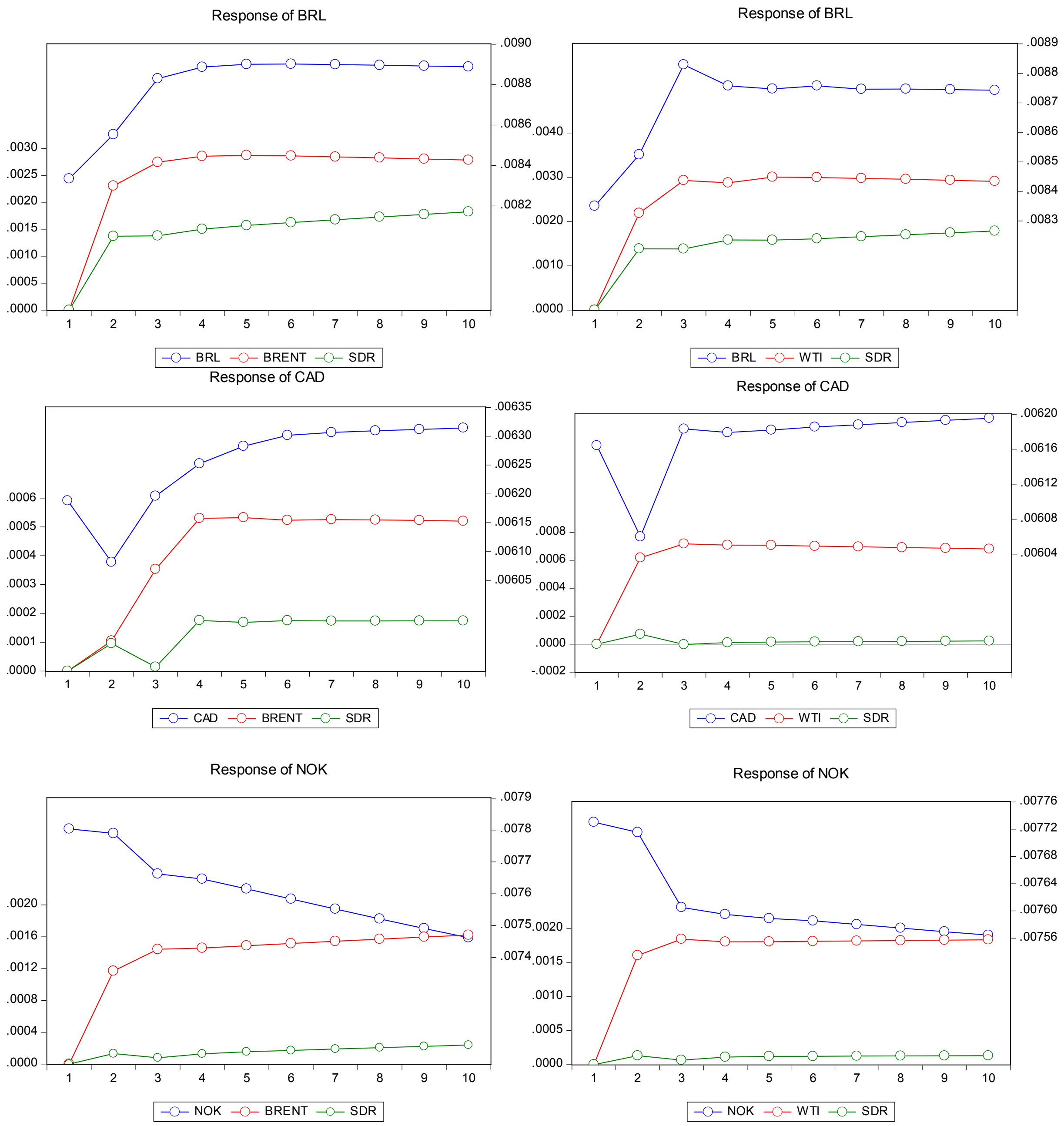
The coefficients of the variable sdr_t in all of the cointegrating equations show the existence of a long term dependence between the exchange rates and SDR/USD rate. However, the observed relationships are negative in the fourth and eighth equations. On the other hand, the equations indicate negative relationships between the oil prices and the Brazilian currency. Hence, we can suggest that the observed similarity in the Brazilian Real exchange rate and the crude oil prices dynamics may be presumed to be explained largely by the impact of the U.S. Dollar value changes, rather than oil price fluctuations. Variables $brent_t$ and wti_t in the remaining of equations have coefficients with positive values, meaning that in the long run, growth in oil prices leads to additional appreciations of the national currencies. According to the results, in the long run, the value of the Russian Rouble is strongly associated with the oil prices. However, the coefficients of variable wti_t are much higher in all of the cases of positive relationships with the exchange rates.

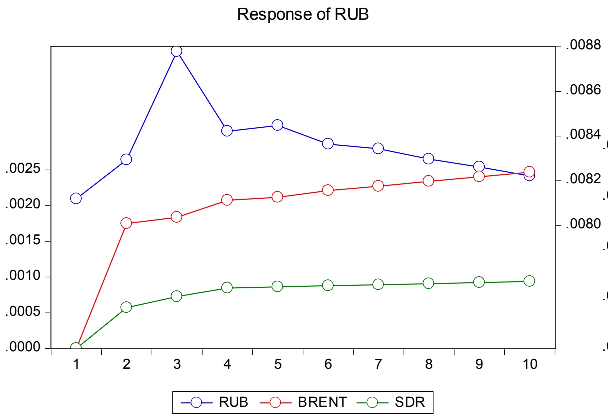
3.4.3 Impulse response

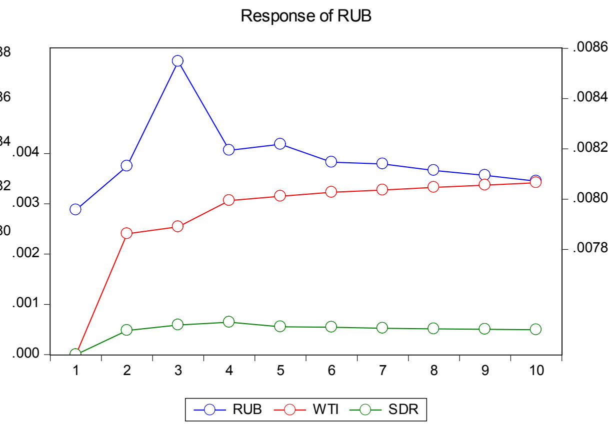
Figure 3-1 displays the impulse responses (See 2.8) of the exchange rates. The right axis shows the responsiveness of a currency to its own shock and the left one to a shock of an oil price and SDR exchange rate.

In all of the cases, it is shown that giving one standard deviation shock to an oil price leads to significant growth of an exchange rate after the next few days, before the reaction becomes stable. However, the responses of the Russian Rouble (and Norwegian Krone in the case with Brent), continue to be gradually increasing.

Figure 3-1: Impulse responses







The reactions on SDR shocks are different. Thus, the impulse responses of the Brazilian currency show a perceptible increase within two days, and afterwards tend to be growing with time. In models with the Canadian Dollar, the reaction becomes steady after several fluctuations. In the remaining cases, the exchange rates' responses to the shocks also exhibit stability.

It is also noteworthy to describe the currencies' reactions to their own standard deviation shocks. The Brazilian Real's exchange rate is increasing and becomes stable after a three day period. Initially, the Canadian Dollar's impulse responses are showing a decline in its value, but it starts to grow after two days. The reaction lines of the Norwegian Krone are gradually decreasing over the whole ten day period following the shocks. The value of the Russian Rouble is increasing within three days and decreasing afterwards.

3.4.4 Model adequacy

In order to check the models for adequacy, we implemented residual diagnosis. The assumptions are that the estimated residuals are normally distributed, serially uncorrelated and have the same finite variance (See 2.9).

The Jarque-Bera test rejects that the residuals are multivariate normal in all of the estimated models.

Based on the LM test, the residuals were checked for autocorrelation. In all eight cases, the test indicated no presence of serial correlation. Therefore, the residuals in the models are not serially correlated.

To check the third assumption, we applied the White Heteroscedasticity test. According to the p -values, the hypothesis of homoskedasticity was rejected at a 1% level of significance for all of the models.

The obtained results demonstrate that the two assumptions are violated. For this reason, the conclusions and forecasts based on the constructed models may be inefficient, biased or deceptive. Hence, to obtain satisfactory results, we should consider a different model.

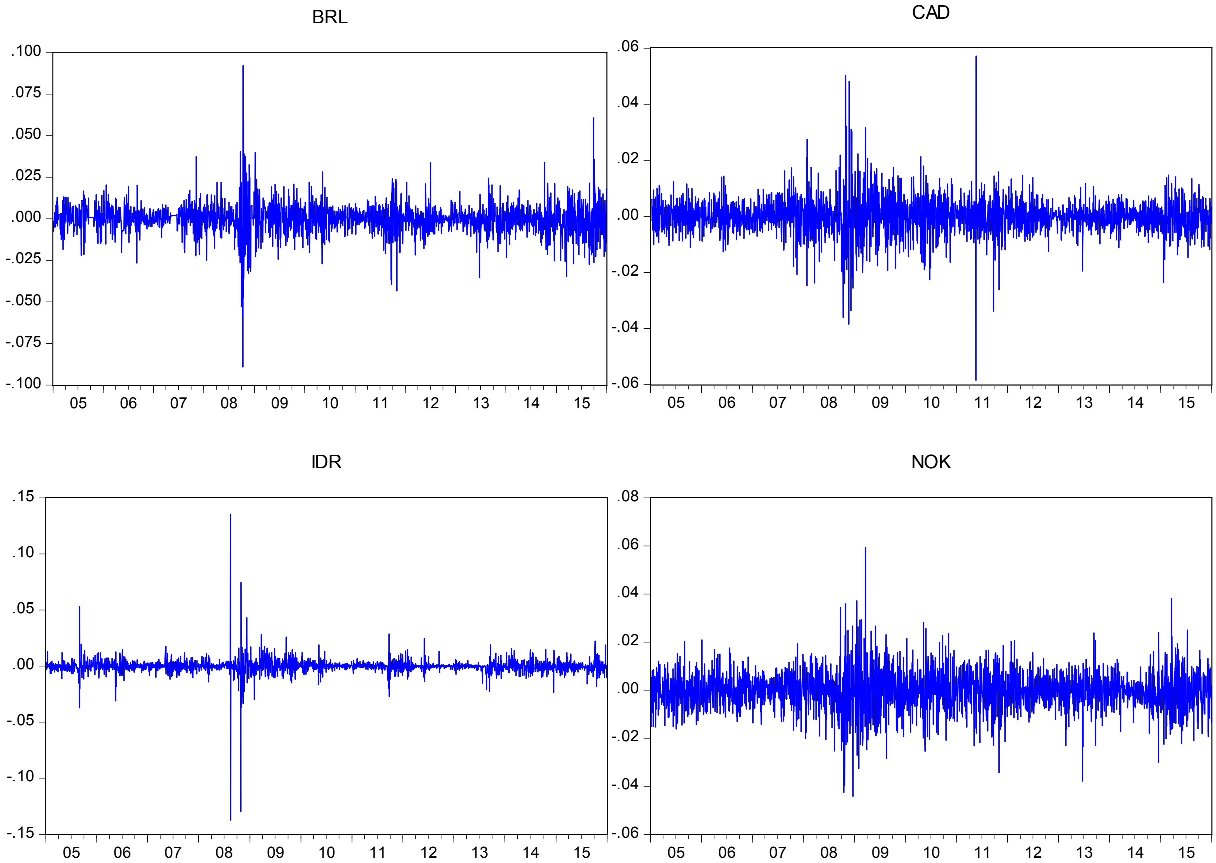
3.5 Generalized conditional autoregressive heteroscedasticity

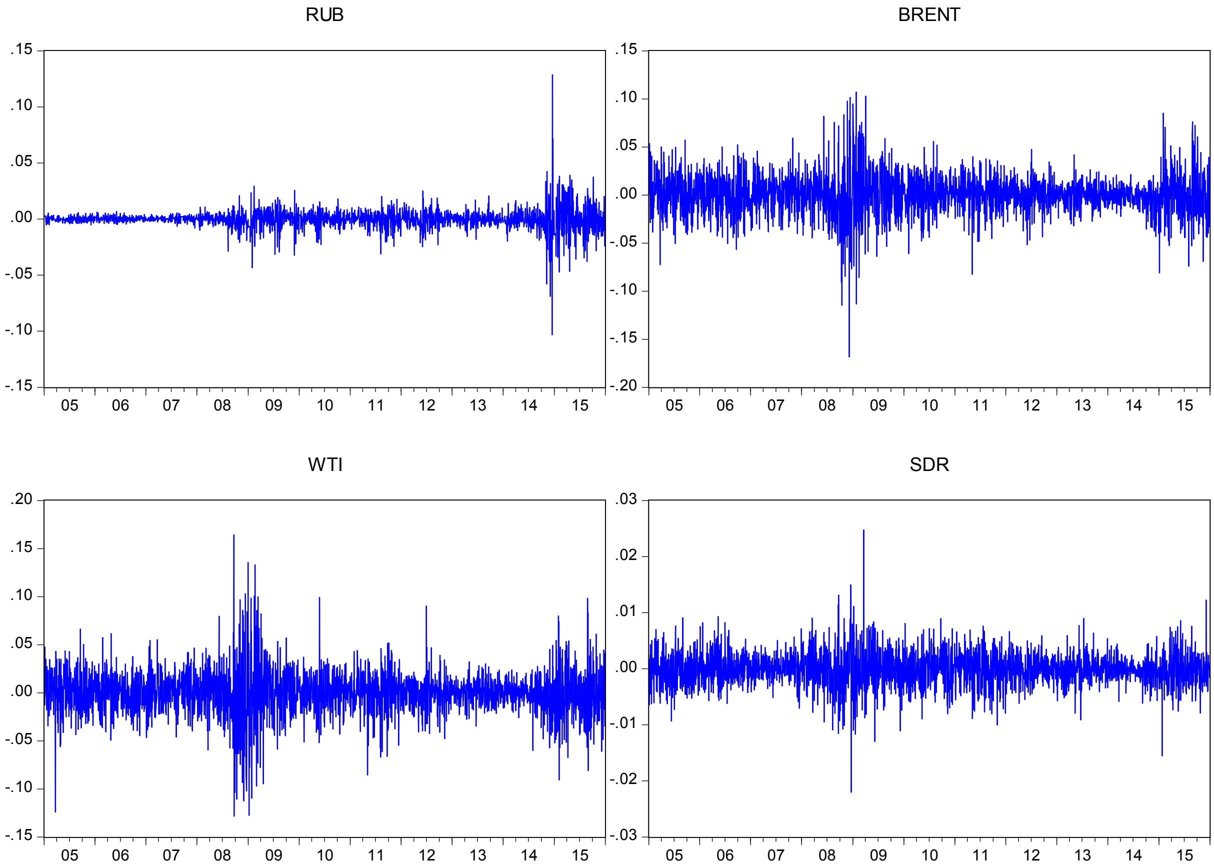
In the previous section, after the estimation of VEC models, we faced a problem of the residuals' non-normality and heteroscedasticity. However, the error terms' normal distribution may not be very important; especially when considering a large sample, neglecting the effects of the absence of homoscedasticity may lead to inefficient results. The difference in variance of the residuals makes their standard deviations inconsistent and consequently affects statistical inference in the whole model.

The unit root tests implemented in part 3.2 indicated that all of the series are nonstationary and are integrated of order one. Since estimating models with nonstationary series gave controversial results, the further analysis will be realized using the log returns.

It is seen that the volatility of returns shows high instability over several periods of time (Figure 3-2). For the most part, the substantial deviations can be observed during the crisis period of 2008 and the oil price fall in 2014. For this reason, the heteroscedasticity problem that occurred in the previous models is likely to be caused by clustering volatility in the estimated residuals. Therefore, it may be reasonable to apply a GARCH model (See 2.10) to the data.

Figure 3-2: Returns on daily crude oil prices and USD exchange rates





3.5.1 Estimation of GARCH

Hence, the GARCH models were estimated for ten pairs of the variables. Each model consists of a mean equation and a variance equation. As our aim is also to compare the effect of oil price change on the domestic currencies' exchange rates, all of the mean equations include the variables with the same lag length. After some experimentation, based on goodness-of-fit criteria (See Enders, 2010, p. 150), choosing the lag of order two was found to be optimal.

The estimated models can be generally represented in the following way:

$$y_t = \alpha + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \beta_3 x_t + \beta_4 x_{t-1} + \beta_5 x_{t-2} + \beta_6 sdr_t + \beta_7 sdr_{t-1} + \beta_8 sdr_{t-2} + \varepsilon_t ,$$

for $y = brl, cad, idr, nok, rub$ and $x = brent, wti$

$$h_t = \gamma + \sum_{i=1}^{q} \lambda_i \varepsilon_{t-i}^2 + \varphi h_{t-1} ,$$

where $q = 1$ for $y = brl, idr$, and $q = 2$ for $y = cad, nok, rub$

Here, the y term means one of the five exchange rates represented by variables brl, cad, idr, nok and rub. The x term serves as one of the two crude oil benchmarks corresponding to variables $brent$ and wti. The rest of the mean equation in all ten models contains variable sdr and the error term.

The variance equation is calculated from residuals obtained after estimation of the mean equation. Hence, h_t denotes present volatility of an exchange rate, ε_{t-i}^2 are ARCH terms of order q, which provide information about volatility in past periods, and h_{t-1} is a GARCH term expressing an exchange rate's volatility in a previous day. The order of the ARCH terms was selected in each model differently, according to heteroscedasticity tests (See 3.5.4). In addition, we used Student's t error distribution as it was shown to give good results in GARCH models for the oil and exchange rate markets in Aloui et al. (2013).

3.5.2 Interpretation

Thereby, we estimated four GARCH(1,1) and six GARCH(1,2) models. The coefficients in the mean equations indicate the average change in the endogenous variable for a 1% change in the exogenous variable, *ceteris paribus*. Their estimates and *p*-values are reported in Table 3-5.

Brazilian Real

In the first two models, we see that the current value of the Brazilian currency is positively associated with its previous day's value. A one percentage increase in the exchange rate is expected to lead to a further appreciation of the Brazilian Real against the U.S. Dollar by approximately 0.12% on the next day. Afterwards, the effect subsides as variable brl_{t-2} is not significant in both of the cases.

In a group of variables representing the oil prices, only $brent_{t-1}$ and wti_{t-1} appeared to be significant, indicating that we would expect an increase in the exchange rate by nearly 0.05% on the next day after a 1% growth in the oil prices. Hence, the reaction is not immediate in both cases, but is always delayed by one day.

The coefficients $\hat{\beta}_6$ and $\hat{\beta}_7$ demonstrate that an SDR/USD rate gain of 1% affects an increase of the Brazilian exchange rate by roughly 0.16% and 0.37% respectively. Thus, the Dollar's depreciation against SDR is expected to have a higher effect on its depreciation against the Brazilian Real on a previous day than on a current day. The variables sdr_{t-2} in both cases are less significant and show negative relationships with the dependent variable, indicating that after two days the response is expected to decline slightly by about 0.07%. Most likely, this is due to natural fluctuations of the market when rapid growth is followed by a minor decline and finally leads to stabilization.

In addition, considering that the difference between the significant coefficients in both models is not substantial, we can conclude that there is no major distinction in the impact on the Brazilian exchange rate between Brent and WTI oil prices.

Canadian Dollar

The results in the models with the Canadian Dollar are significantly different. The first mean equation implies that the exchange rate on previous days has no significant effect on its current value. However, in the mean equation with WTI, the coefficient of the first variable is significant, suggesting an inverse relationship between the current value of the Canadian currency and its value on a previous day. In consequence of a 1% growth, the expected decline on the next day is 0.05%.

In the case of the variables expressing the oil price, the observed difference is more fundamental. In the second mean equation, all of the coefficients are statistically significant, while in the first one, the value of the variable lagged one day is not substantial. Thus, an increase in price of Brent by 1% would lead to the strengthening of the national currency against the U.S. Dollar by 0.089% in a current period, and would not affect the exchange rate on the next day, but would cause an additional increase by 0.016% two days later. In the case with WTI, the expected growth is 0.077% on the same day, which would gradually be decreasing thereafter. An additional effect is increases of 0.029% and 0.013% on the second and third days respectively.

Thus, the total effect exerted on the exchange rate by the changes in the oil price is higher in the case with WTI. According to this, we can assume that the price of Brent has a smaller impact on the Canadian currency.

The variable sdr_t has approximately the same value in both of the cases. A one percent increase in the SDR/USD rate is expected to lead to an appreciation of the Canadian currency against the U.S. dollar by 0.37%. However, this would not affect the exchange rate in the following days.

Indonesian Rupiah

In models with the Indonesian Rupiah, the coefficients $\hat{\beta}_1$ and $\hat{\beta}_2$ are insignificant, which indicates the absence of a serious impact of previous exchange rate values on its current value.

With regard to oil prices, the variables lagged one day are particularly important. The variable wti_t is also statistically significant at the 5% level. After a 1% increase in WTI price, it is expected that the exchange rate will respond with an increase of 0.004% and will continue to grow for the next day by 0.011%. In the case with Brent, the expected reaction is weaker and occurs only on the next day appreciating the Rupiah by 0.009%.

The expected response to a 1% increase in the value of the variable sdr_t, is hovering at around 0.14% growth in the current period and 0.09% on the next day in both cases. Afterwards, this would not influence the exchange rate, as variables sdr_{t-2} show no significance.

Norwegian Krone

In both models with the Norwegian Krone, all of the variables are significant. It is seen that the current exchange rate is negatively dependent on its previous values. Thus, we would expect that a 1% appreciation of the Norwegian currency against the U.S. Dollar would be followed by a decrease in the exchange rate on the next two days by a total of 0.15% in both cases.

With a growth of Brent price by 1%, it is expected that the national currency will increase by 0.054%, and will continue to grow over the next two days by 0.03% and 0.013%, respectively. The response to the change in price of WTI is slightly lower on a current day, but relatively higher than in the subsequent. Thus, the expected growth of the exchange rate is 0.042% at the beginning, and 0.039% and 0.017% in the future days. The total effect in both cases is approximately the same.

The values of the last three coefficients in both mean equations have no essential distinctions. Thus, we would expect that a 1% increase in the SDR/USD rate would significantly affect the appreciation of the Norwegian currency. On a current day, the expected growth will be about 1.74%, and over the next two days 0.15% and 0.09% respectively.

Russian Rouble

According to the results of the last two models, the Russian rouble also shows an inverse relationship regarding its previous values. The expected reduction the day after a 1% growth will be 0.05%.

The reaction of the exchange rate to changes in oil price is expected to emerge only the next day, as only the variables lagged one day are significant in both mean equations. A 1% increase in the oil price will be reflected in an appreciation of the Rouble against the U.S. Dollar of 0.012% and 0.016% for Brent and WTI respectively.

We can see that the increase in value of the variable sdr_t by 1%, will lead to a strengthening of the domestic currency by approximately 0.58%, and will also have an additional effect on the second and third days in the region of around 0.24% and 0.037% respectively.

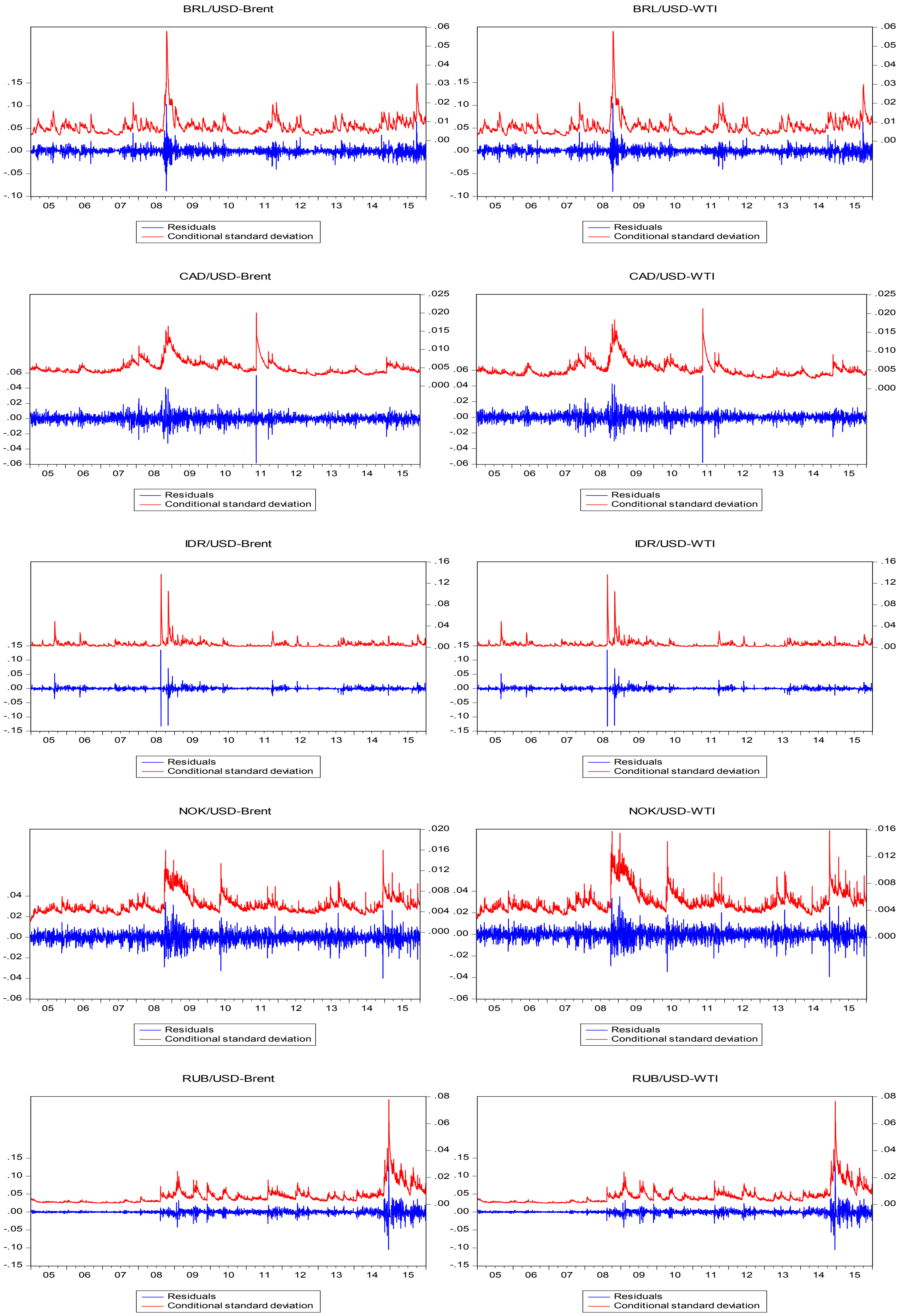
The variance equations contain one ARCH term in models with Brazilian Real and Indonesian Rupiah, and two ARCH terms in the rest of the models. All of the coefficients there are significant. Hence, the volatility of the exchange rates can be explained by the impact of their own shocks. This is seen in Figure 3-3, which shows the conditional standard deviation compared to the residuals in all of the estimated models. However, the sum of the slope coefficients in models with the Brazilian Real roughly equates to unity, which indicates that volatility is persistent. In models with the Indonesian Rupiah, the sum of the coefficients is much greater than unity, implying that the volatility explodes over time.

Table 3-5: Coefficient estimates

	BRL/USD		CAD/USD		IDR/USD		NOK/USD		RUB/USD	
	Brent	WTI	Brent	WTI	Brent	WTI	Brent	WTI	Brent	WTI
Mean equation										
c	0.0003 (0.0016)***	0.0003 (0.0006)***	2.84E-05 (0.7110)	3.28E-05 (0.6647)	-0.0001 (0.0011)***	-0.0001 (0.0008)***	8.48E-05 (0.3053)	9.05E-05 (0.2728)	9.37E-05 (0.0232)**	9.56E-05 (0.0213)**
y_{t-1}	0.1212 (0.0000)***	0.1190 (0.0000)***	-0.0260 (0.1791)	-0.0530 (0.0065)***	-0.0252 (0.1935)	-0.0258 (0.1821)	-0.0977 (0.0000)***	-0.1036 (0.0000)***	-0.0482 (0.0192)**	-0.0472 (0.0218)**
y_{t-2}	0.0142 (0.4302)	0.0161 (0.3697)	-0.0199 (0.2721)	-0.0089 (0.6250)	0.0112 (0.5538)	0.0124 (0.5110)	-0.0478 (0.0071)***	-0.0469 (0.0076)***	-0.0069 (0.6941)	-0.0089 (0.6090)
x_t	0.0032 (0.5602)	-0.0039 (0.4221)	0.0892 (0.0000)***	0.0770 (0.0000)***	0.0034 (0.1231)	0.0040 (0.0459)**	0.0538 (0.0000)***	0.0424 (0.0000)***	0.0031 (0.1761)	0.0031 (0.1373)
x_{t-1}	0.0513 (0.0000)***	0.0462 (0.0000)***	0.0003 (0.9512)	0.0294 (0.0000)***	0.0089 (0.0001)***	0.0106 (0.0000)***	0.0304 (0.0000)***	0.0397 (0.0000)***	0.0119 (0.0000)***	0.0156 (0.0000)***
x_{t-2}	-0.0008 (0.8895)	0.0123 (0.0201)**	0.0161 (0.0009)***	0.0132 (0.0016)***	0.0028 (0.1998)	0.0009 (0.6739)	0.0129 (0.0064)***	0.0173 (0.0001)***	-0.0006 (0.7952)	-0.0031 (0.1716)
sdr_t	0.1652 (0.0000)***	0.1614 (0.0000)***	0.3711 (0.0000)***	0.3730 (0.0000)***	0.1474 (0.0000)***	0.1403 (0.0000)***	1.7477 (0.0000)***	1.7380 (0.0000)***	0.5889 (0.0000)***	0.5844 (0.0000)***
sdr_{t-1}	0.3744 (0.0000)***	0.3677 (0.0000)***	0.0149 (0.6266)	0.0044 (0.8865)	0.0955 (0.0000)***	0.0943 (0.0000)***	0.1526 (0.0010)***	0.1569 (0.0007)***	0.2388 (0.0000)***	0.2473 (0.0000)***
sdr_{t-2}	-0.0703 (0.0512)*	-0.0783 (0.0289)**	0.0310 (0.3110)	0.0332 (0.2756)	-0.0214 (0.1463)	-0.0184 (0.2005)	0.0938 (0.0311)**	0.0975 (0.0242)**	0.0366 (0.0710)*	0.0379 (0.0654)*
Variance equation										
c	1.02E-06 (0.0001)***	9.37E-07 (0.0001)***	1.59E-07 (0.0039)***	1.70E-07 (0.0036)***	6.69E-07 (0.0000)***	6.10E-07 (0.0000)***	3.00E-07 (0.0018)***	2.56E-07 (0.0039)***	3.21E-08 (0.0155)**	3.57E-08 (0.0102)**
ε_{t-1}^2	0.1605 (0.0000)***	0.1583 (0.0000)***	0.0906 (0.0001)***	0.1127 (0.0001)***	0.6341 (0.0000)***	0.6247 (0.0000)***	0.1402 (0.0000)***	0.1424 (0.0000)***	0.2861 (0.0000)***	0.2724 (0.0000)***
ε_{t-2}^2	-	-	-0.0601 (0.0137)**	-0.0733 (0.0096)***	-	-	-0.1062 (0.0003)***	-0.1097 (0.0002)***	-0.1928 (0.0000)***	-0.1762 (0.0000)***
h_{t-1}	0.8414 (0.0000)***	0.8458 (0.0000)***	0.9628 (0.0000)***	0.9542 (0.0000)***	0.6558 (0.0000)***	0.6637 (0.0000)***	0.9552 (0.0000)***	0.9583 (0.0000)***	0.9164 (0.0000)***	0.9136 (0.0000)***

Note: The values in parenthesis represent the p-values of the coefficients. *, ** and *** indicate rejection of null hypothesis of no significance at the 10%, 5% and 1% levels respectively.

Figure 3-3: Residuals and Conditional standard deviation



3.5.3 Comparing the results

After interpreting the relationships between the variables in each of the estimated models, we can compare the results.

Since all of the exchange rates are denominated in U.S. Dollars, the coefficients of variables corresponding to the SDR/USD rate have the highest values in all of the equations for obvious reasons. Over the studied period, the rate of a unit of SDR was calculated based on the weighted average rate of four major currencies. Therefore, in the research, this variable was introduced as a kind of measuring instrument to determine the U.S. dollar value and its fluctuations. As has already been noted, the observed correlation between the oil price and the dollar value of national currencies can largely be explained by relationships between the oil price and the U.S. Dollar itself. Thus, the inclusion of the variable was necessary in the first place in order to determine the extent to which the exchange rates fluctuations are associated with changes in value of the U.S. Dollar, and where they are exceptionally caused by changes in the oil price. In other words, we tried to measure the additional effect of the oil price impact on the exchange rates. Of course, the value of each national currency also depends on many other factors, such as trade balance, inflation, GDP, interest rates, etc. However, for the purposes of this study, primarily based on the daily data, inclusion of these parameters was not possible.

Going back to the obtained results, it is also worth mentioning that the total effect of the independent variables corresponding to the oil price and the SDR/USD rate differs insignificantly for each of the five exchange rates. For example, in the case of the Canadian Dollar the total effect within three days, after a 1% increase in the oil price, will be an increase in the exchange rate of 0.11% in case of Brent and 0.12% in case of WTI. Similarly, the total effect of the SDR/USD rate will be 0.42% and 0.41% in the first and in the second case, respectively.

Thus, the estimated coefficients of variable sdr_t confirm the assumption that the depreciation of the U.S. dollar against the national currencies of oil exporting countries (or on the contrary, the appreciation of it) is mainly explained by decreases or increases in its own value. To the largest extent, this applies to the Norwegian Krone. More than twice as small a value is observed in the case of the Russian Rouble. The results in the models with the Canadian Dollar and the Brazilian Real are quite similar. The lowest interrelation is seen in the Indonesian Rupiah.

Another hypothesis of this study was that the national currencies of countries that are dependent on revenues from oil exports to a greater extent will show closer relationships with the oil price fluctuations.

Indeed, in all of the cases variables corresponding to the oil price, or at least their lags, appeared to be significant. Thus, we can conclude the presence of the additional impact, caused by changes in the oil price, on the exchange rates of these countries. If we consider the total effect of the variables, the highest values are observed in models with two of the leading countries in oil exports, Canada and Norway. However, despite the fact that the share of the oil rents in the Norwegian GDP is much higher, this was not reflected in the results. The next one, according to the total effect is Brazil, which is less dependent on oil exports, and is also importing part of the petroleum products from other countries to cover the domestic demand. Quite logically, one of the lowest values is observed in the case of Indonesia, as the country eventually became a net-importer of oil. Unexpectedly, models with the Russian Rouble show a small dependence of the exchange rate on the oil prices. The country is one of the world's major oil exporters and the oil rents share in the Russian GDP is the highest among the surveyed countries. Here, the factor of the exchange rate policy implemented by the Central Bank should be considered. The analysed period saw the managed floating exchange rate regime in Russia, meaning that the Bank of Russia smoothed the sharp fluctuations of the Rouble exchange rate through foreign exchange interventions. However, in November 2014 the Bank of Russia abolished the managed exchange rate policy mechanism, thereby switching to a fully floating exchange rate (Bank of Russia, 2016). Hence, we assume that this largely influenced the result. The Indonesian authorities also conducted foreign exchange interventions in order to avoid strong fluctuations of the Rupiah, but, unlike in Russia, continue to manage the exchange rate at present (Edwards and Sahminan, 2008; Bank Indonesia, 2016). This is clearly evident in Figure 1-1. The reaction of the Rouble and the Rupiah to changes in the oil prices is softer than in the cases of other currencies. However, after 2014, the correlation between the Rouble and the oil prices becomes much more apparent, while the Indonesian currency continues to react in the same way.

Overall, we can conclude that we managed to demonstrate the impact of the oil prices on the exchange rates of the researched countries. However, due to the reasons listed above, the relationships between the oil rents and the dependence of the currencies on the oil prices have not been fully demonstrated.

3.5.4 Model adequacy

In addition, the estimated models should meet the necessary criteria for the conclusions and forecasts based on them not to be biased or misleading. The residuals should not display serial correlation and should be homoscedastic (See 2.11).

To check the first assumption we tested the standardized residuals for autocorrelation. Based on the *Q*-statistics we indicated the absence of serial correlation in the residuals in most of the cases, where according to the *p*-values the null hypothesis was rejected at the 10% level of significance. However, in models with the Indonesian Rupiah and Russian Rouble, the residuals appeared to be serially correlated.

Based on the ARCH LM test, we checked the second assumption. First, we implemented the test using the GARCH(1,1) model for all ten pairs of the variables. In models with the Brazilian Real and Indonesian Rupiah, the test indicated the absence of conditional volatility. However, in the rest of the models the residuals displayed the remaining GARCH effects.

Therefore, the second ARCH terms were included in the rest of the models. After that, the test results signified that the assumption had not been violated.

The presence of autocorrelation in the mean equation in models with the Indonesian Rupiah and the Russian Rouble may be explained by the fact already mentioned in section 3.5.3. The monetary policy conducted in these countries over the study period makes it difficult to capture all of the dynamics of the currencies at the daily frequency. Thus, we would need to consider most of the foreign exchange interventions to avoid the misspecification of these models. Apparently for the same reason, the variance equation in models with the Indonesian Rupiah, shows that the variance is not finite. A possible solution could be the inclusion of dummy variables, as we can observe in Figure 1-1 a sharp deviation from the corresponding curve in 2008. In addition, using other models of conditional variance, like IGARCH, would be more plausible, for models with Indonesian Rupiah as well as for models with Brazilian Real. Nevertheless, we assume that this did not affect the coefficient estimates in the mean equations significantly. However, considering all the facts mentioned above, some of the interpreted results should be taken with caution.

Conclusion

This paper studied the relationship between the exchange rates of oil exporting countries and oil prices. One of the assumptions was that countries, whose share of oil rents in the GDP is higher will show a stronger dependence between oil prices and their national currencies.

First, the data were applied on a VEC model. However, the obtained empirical results were controversial and the residual diagnosis indicated that the model is not appropriate, as some of the fundamental assumptions appeared to be violated.

Subsequently, we estimated ten GARCH models for each pair of variables. Our empirical results suggest that there is a positive link between oil prices and the exchange rates of the oil exporting countries, excluding the dollar effect. However, the dependence of the domestic currencies on the oil rents have not been fully illustrated, due to the monetary policy factor. In addition, our results provide the evidence of a negative relationship between the U.S. Dollar value and the oil prices.

Finally, the results of this paper may be used for a further analysis of exchange rates and oil prices using IGARCH or EGARCH approaches. Another interesting point could be to analyse the relationship in short time periods, or to use data at the monthly or quarterly frequencies, which would allow for inclusion of more explanatory variables.

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Appendices

Appendix 1: ADF tests for variable *brent* in level

Null Hypothesis: BRENT has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.484019	0.5418

Null Hypothesis: BRENT has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.786157	0.9655

Null Hypothesis: BRENT has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.201591	0.6138

Appendix 2: ADF tests for variable *brl* in level

Null Hypothesis: BRL has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	0.582068	0.9893

Null Hypothesis: BRL has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.413806	0.9871

Null Hypothesis: BRL has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	0.944378	0.9087

Appendix 3: ADF tests for variable *cad* in level

Null Hypothesis: CAD has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.275383	0.6431

Null Hypothesis: CAD has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.130202	0.9225

Null Hypothesis: CAD has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.698645	0.4144

Appendix 4: ADF tests for variable *idr* in level

Null Hypothesis: IDR has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	0.057887	0.9625

Null Hypothesis: IDR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.030846	0.9381

Null Hypothesis: IDR has a unit root
Exogenous: None
Lag Length: 1 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	1.300701	0.9516

Appendix 5: ADF tests for variable *nok* in level

Null Hypothesis: NOK has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.557437	0.8773

Null Hypothesis: NOK has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.965965	0.9468

Null Hypothesis: NOK has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	0.840348	0.8922

Appendix 6: ADF tests for variable *rub* in level

Null Hypothesis: RUB has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	2.229025	1.0000

Null Hypothesis: RUB has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	0.231396	0.9983

Null Hypothesis: RUB has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	2.259501	0.9947

Appendix 7: ADF tests for variable *sdr* in level

Null Hypothesis: SDR has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.425232	0.5713

Null Hypothesis: SDR has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.563098	0.8073

Null Hypothesis: SDR has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.807883	0.3662

Appendix 8: ADF tests for variable *wti* in level

Null Hypothesis: WTI has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.893410	0.3357

Null Hypothesis: WTI has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.567848	0.8055

Null Hypothesis: WTI has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-0.229444	0.6038

Appendix 9: ADF tests for variable *brent* in 1st difference

Null Hypothesis: D(BRENT) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-52.07501	0.0001

Null Hypothesis: D(BRENT) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-52.15738	0.0000

Null Hypothesis: D(BRENT) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-52.08394	0.0001

Appendix 10: ADF tests for variable *brl* in 1st difference

Null Hypothesis: D(BRL) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-51.31706	0.0001

Null Hypothesis: D(BRL) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-51.48111	0.0000

Null Hypothesis: D(BRL) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-51.31468	0.0001

Appendix 11: ADF tests for variable *cad* in 1st difference

Null Hypothesis: D(CAD) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-54.35769	0.0001

Null Hypothesis: D(CAD) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-54.42185	0.0000

Null Hypothesis: D(CAD) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-54.36542	0.0001

Appendix 12: ADF tests for variable *idr* in 1st difference

Null Hypothesis: D(IDR) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-64.32176	0.0001

Null Hypothesis: D(IDR) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-64.34768	0.0000

Null Hypothesis: D(IDR) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-64.30089	0.0001

Appendix 13: ADF tests for variable *nok* in 1st difference

Null Hypothesis: D(NOK) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-53.27718	0.0001

Null Hypothesis: D(NOK) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-53.30692	0.0000

Null Hypothesis: D(NOK) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-53.27338	0.0001

Appendix 14: ADF tests for variable *rub* in 1st difference

Null Hypothesis: D(RUB) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-34.88796	0.0000

Null Hypothesis: D(RUB) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-35.01484	0.0000

Null Hypothesis: D(RUB) has a unit root
Exogenous: None
Lag Length: 1 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-34.81829	0.0000

Appendix 15: ADF tests for variable *sdr* in 1st difference

Null Hypothesis: D(SDR) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-53.08189	0.0001

Null Hypothesis: D(SDR) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-53.08510	0.0000

Null Hypothesis: D(ISDR) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-53.08332	0.0001

Appendix 16: ADF tests for variable *wti* in 1st difference

Null Hypothesis: D(WTI) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-54.87414	0.0001

Null Hypothesis: D(IWTI) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-54.92589	0.0000

Null Hypothesis: D(WTI) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=27)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-54.88335	0.0001

Appendix 17: Granger causality tests

Pairwise Granger Causality Tests
Sample: 1/03/2005 12/31/2015
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
BRL does not Granger Cause BRENT	2867	5.55687	0.0039
BRENT does not Granger Cause BRL		109.247	2.E-46
CAD does not Granger Cause BRENT	2867	8.25813	0.0003
BRENT does not Granger Cause CAD		0.60541	0.5459
IDR does not Granger Cause BRENT	2867	6.72488	0.0012
BRENT does not Granger Cause IDR		29.2697	3.E-13
NOK does not Granger Cause BRENT	2867	8.81440	0.0002
BRENT does not Granger Cause NOK		29.4498	2.E-13
RUB does not Granger Cause BRENT	2867	4.72798	0.0089
BRENT does not Granger Cause RUB		66.1865	8.E-29
BRL does not Granger Cause WTI	2867	5.55658	0.0039
WTI does not Granger Cause BRL		95.4253	8.E-41
CAD does not Granger Cause WTI	2867	5.65984	0.0035
WTI does not Granger Cause CAD		14.3689	6.E-07
IDR does not Granger Cause WTI	2867	4.18706	0.0153
WTI does not Granger Cause IDR		37.4647	9.E-17
NOK does not Granger Cause WTI	2867	9.35878	9.E-05
WTI does not Granger Cause NOK		57.3708	4.E-25
RUB does not Granger Cause WTI	2867	4.45355	0.0117
WTI does not Granger Cause RUB		127.862	6.E-54
BRL does not Granger Cause SDR	2867	6.14296	0.0022
SDR does not Granger Cause BRL		57.1866	4.E-25
CAD does not Granger Cause SDR	2867	30.8384	6.E-14
SDR does not Granger Cause CAD		0.90387	0.4051
IDR does not Granger Cause SDR	2867	3.13281	0.0437
SDR does not Granger Cause IDR		16.8015	6.E-08
NOK does not Granger Cause SDR	2867	3.86087	0.0212
SDR does not Granger Cause NOK		0.02453	0.9758
RUB does not Granger Cause SDR	2867	3.00469	0.0497
SDR does not Granger Cause RUB		11.2264	1.E-05

Appendix 18: Johansen test for variables *brl, brent, sdr*

Included observations: 2864
Series: BRL BRENT SDR
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	1	0	0
Max-Eig	1	0	0	0	0

Appendix 19: Johansen test for variables *brl, wti, sdr*

Included observations: 2864
Series: BRL WTI SDR
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	1	0	0
Max-Eig	1	0	1	0	0

Appendix 20: Johansen test for variables *cad, brent, sdr*

Included observations: 2864
Series: CAD BRENT SDR
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	1	0	0
Max-Eig	0	0	0	0	0

Appendix 21: Johansen test for variables *cad, wti, sdr*

Included observations: 2864
Series: CAD WTI SDR
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	1	0	0
Max-Eig	0	0	1	0	0

Appendix 22: Johansen test for variables *idr, brent, sdr*

Included observations: 2864
Series: IDR BRENT SDR
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	0	0	0
Max-Eig	0	0	0	0	0

Appendix 23: Johansen test for variables *idr, wti, sdr*

Included observations: 2864
Series: IDR WTI SDR
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	0	0	0
Max-Eig	1	0	0	0	0

Appendix 24: Johansen test for variables *nok, brent, sdr*

Included observations: 2864
Series: NOK BRENT SDR
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	0	1	1
Max-Eig	0	0	0	1	1

Appendix 25: Johansen test for variables *nok, wti, sdr*

Included observations: 2864
Series: NOK WTI SDR
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	1	1	1	1
Max-Eig	1	1	1	1	1

Appendix 26: Johansen test for variables *rub, brent, sdr*

Included observations: 2864
Series: RUB BRENT SDR
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	0	0	0	1	1
Max-Eig	0	0	0	0	0

Appendix 27: Johansen test for variables *rub, wti, sdr*

Included observations: 2864
Series: RUB WTI SDR
Lags interval: 1 to 4
Selected (0.05 level*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	1	0	0	1	1
Max-Eig	1	0	0	0	0

Appendix 28: VEC models (Cointegrating equations)

Included observations: 2866 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
BRL(-1)	1.000000
BRENT(-1)	1.229117 (0.33578) [3.66052]
SDR(-1)	-15.64822 (2.82044) [-5.54815]
C	1.872775

Included observations: 2865 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
BRL(-1)	1.000000
WTI(-1)	1.886388 (0.50219) [3.75630]
SDR(-1)	-19.41106 (3.77893) [-5.13665]
C	0.647422

Included observations: 2865 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
CAD(-1)	1.000000
BRENT(-1)	-0.252812 (0.03976) [-6.35880]
SDR(-1)	-0.083809 (0.33378) [-0.25109]
C	1.227483

Included observations: 2866 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
CAD(-1)	1.000000
WTI(-1)	-0.413882 (0.06789) [-6.09628]
SDR(-1)	0.835160 (0.51045) [1.63612]
C	1.531093

Included observations: 2866 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
NOK(-1)	1.000000
BRENT(-1)	-0.229900 (0.01833) [-12.5398]
SDR(-1)	-1.082694 (0.14711) [-7.35993]
@TREND(1/03/05)	5.23E-05 (5.4E-06) [9.72300]
C	3.199636

Included observations: 2866 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
NOK(-1)	1.000000
WTI(-1)	-0.261221 (0.02571) [-10.1608]
SDR(-1)	-1.006743 (0.19170) [-5.25161]
@TREND(1/03/05)	4.01E-05 (6.4E-06) [6.28159]
C	3.310844

Included observations: 2865 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
RUB(-1)	1.000000
BRENT(-1)	-0.499219 (0.08095) [-6.16674]
SDR(-1)	-0.918033 (0.64803) [-1.41665]
@TREND(1/03/05)	0.000302 (2.4E-05) [12.6917]
C	5.583467

Included observations: 2865 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
RUB(-1)	1.000000
WTI(-1)	-0.762028 (0.12006) [-6.34683]
SDR(-1)	0.639980 (0.89314) [0.71655]
@TREND(1/03/05)	0.000291 (3.0E-05) [9.76299]
C	6.065821

Appendix 29: Normality tests (Jarque-Bera statistics) for VEC models with variables:

brl, brent

Component	Jarque-Bera	df	Prob.
1	21268.12	2	0.0000
2	2554.275	2	0.0000
3	2076.359	2	0.0000
Joint	25898.75	6	0.0000

brl, wti

Component	Jarque-Bera	df	Prob.
1	24866.21	2	0.0000
2	2910.196	2	0.0000
3	2106.030	2	0.0000
Joint	29882.44	6	0.0000

cad, brent

Component	Jarque-Bera	df	Prob.
1	13820.18	2	0.0000
2	1356.446	2	0.0000
3	1494.209	2	0.0000
Joint	16670.84	6	0.0000

cad, wti

Component	Jarque-Bera	df	Prob.
1	14078.36	2	0.0000
2	3410.708	2	0.0000
3	1440.669	2	0.0000
Joint	18929.74	6	0.0000

nok, brent

Component	Jarque-Bera	df	Prob.
1	1434.931	2	0.0000
2	2305.911	2	0.0000
3	1447.183	2	0.0000
Joint	5188.025	6	0.0000

nok, wti

Component	Jarque-Bera	df	Prob.
1	1603.287	2	0.0000
2	2319.291	2	0.0000
3	1531.813	2	0.0000
Joint	5454.391	6	0.0000

rub, brent

Component	Jarque-Bera	df	Prob.
1	174948.4	2	0.0000
2	2600.250	2	0.0000
3	2599.756	2	0.0000
Joint	180148.4	6	0.0000

rub, wti

Component	Jarque-Bera	df	Prob.
1	194022.0	2	0.0000
2	2742.985	2	0.0000
3	2502.878	2	0.0000
Joint	199267.9	6	0.0000

Appendix 30: Autocorrelation LM tests for VEC models with variables:

brl, brent

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 1/03/2005 12/31/2015
Included observations: 2866

Lags	LM-Stat	Prob
1	10.11564	0.3412
2	5.438152	0.7946
3	7.332366	0.6026

Probs from chi-square with 9 df.

brl, wti

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 1/03/2005 12/31/2015
Included observations: 2865

Lags	LM-Stat	Prob
1	13.35428	0.1472
2	7.996927	0.5345
3	8.108379	0.5233
4	11.13563	0.2665

Probs from chi-square with 9 df.

cad, brent

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 1/03/2005 12/31/2015
Included observations: 2865

Lags	LM-Stat	Prob
1	5.364190	0.8015
2	3.631704	0.9339
3	6.890204	0.6485
4	4.161435	0.9005

Probs from chi-square with 9 df.

cad, wti

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 1/03/2005 12/31/2015
Included observations: 2866

Lags	LM-Stat	Prob
1	17.70262	0.0388
2	18.40560	0.0307
3	16.93816	0.0497

Probs from chi-square with 9 df.

nok, brent

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 1/03/2005 12/31/2015
Included observations: 2866

Lags	LM-Stat	Prob
1	12.44474	0.1894
2	7.513147	0.5839
3	10.34625	0.3232

Probs from chi-square with 9 df.

nok, wti

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 1/03/2005 12/31/2015
Included observations: 2866

Lags	LM-Stat	Prob
1	11.74687	0.2280
2	14.33777	0.1108
3	15.17922	0.0861

Probs from chi-square with 9 df.

rub, brent

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 1/03/2005 12/31/2015
Included observations: 2865

Lags	LM-Stat	Prob
1	7.667742	0.5679
2	15.15203	0.0868
3	7.255520	0.6105
4	12.75529	0.1740

Probs from chi-square with 9 df.

rub, wti

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Date: 01/07/17 Time: 02:01
Sample: 1/03/2005 12/31/2015
Included observations: 2865

Lags	LM-Stat	Prob
1	12.29353	0.1973
2	13.52564	0.1402
3	5.384482	0.7996
4	15.42904	0.0798

Probs from chi-square with 9 df.

Appendix 31: Heteroskedasticity tests for VEC models with variables:

brl, brent

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Sample: 1/03/2005 12/31/2015
Included observations: 2866

Joint test:

Chi-sq	df	Prob.
1759.828	84	0.0000

brl, wti

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Sample: 1/03/2005 12/31/2015
Included observations: 2865

Joint test:

Chi-sq	df	Prob.
1956.485	120	0.0000

cad, brent

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Sample: 1/03/2005 12/31/2015
Included observations: 2865

Joint test:

Chi-sq	df	Prob.
1090.527	120	0.0000

cad, wti

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Sample: 1/03/2005 12/31/2015
Included observations: 2866

Joint test:

Chi-sq	df	Prob.
969.1685	84	0.0000

nok, brent

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Sample: 1/03/2005 12/31/2015
Included observations: 2866

Joint test:

Chi-sq	df	Prob.
814.7821	84	0.0000

nok, wti

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Sample: 1/03/2005 12/31/2015
Included observations: 2866

Joint test:

Chi-sq	df	Prob.
833.7661	84	0.0000

rub, brent

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Sample: 1/03/2005 12/31/2015
Included observations: 2865

Joint test:

Chi-sq	df	Prob.
1876.200	120	0.0000

rub, wti

VEC Residual Heteroskedasticity Tests: No Cross Terms (only levels and squares)
Sample: 1/03/2005 12/31/2015
Included observations: 2865

Joint test:

Chi-sq	df	Prob.
1765.135	120	0.0000

Appendix 32: GARCH models

Dependent Variable: BRL
Method: ML - ARCH (Marquardt) - Student's t distribution
Sample (adjusted): 1/06/2005 12/31/2015
Included observations: 2866 after adjustments
Convergence achieved after 15 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
BRL(-1)	0.121169	0.019111	6.340217	0.0000
BRL(-2)	0.014189	0.017987	0.788819	0.4302
BRENT	0.003180	0.005459	0.582576	0.5602
BRENT(-1)	0.051265	0.005511	9.303130	0.0000
BRENT(-2)	-0.000804	0.005785	-0.138909	0.8895
SDR	0.165207	0.036292	4.552142	0.0000
SDR(-1)	0.374413	0.035159	10.64912	0.0000
SDR(-2)	-0.070261	0.036029	-1.950109	0.0512
C	0.000304	9.65E-05	3.150825	0.0016
		Variance Equation		
C	1.02E-06	2.55E-07	4.016407	0.0001
RESID(-1)^2	0.160507	0.018511	8.670860	0.0000
GARCH(-1)	0.841400	0.014977	56.18095	0.0000
T-DIST. DOF	5.223761	0.545731	9.572037	0.0000

R-squared	0.076606	Mean dependent var	-0.000130
Adjusted R-squared	0.074020	S.D. dependent var	0.008777
S.E. of regression	0.008446	Akaike info criterion	-7.219007
Sum squared resid	0.203791	Schwarz criterion	-7.191970
Log likelihood	10357.84	Hannan-Quinn criter.	-7.209260
Durbin-Watson stat	2.219141		

Dependent Variable: BRL
Method: ML - ARCH (Marquardt) - Student's t distribution
Sample (adjusted): 1/06/2005 12/31/2015
Included observations: 2866 after adjustments
Convergence achieved after 15 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
BRL(-1)	0.118974	0.019072	6.238083	0.0000
BRL(-2)	0.016078	0.017922	0.897068	0.3697
WTI	-0.003940	0.004908	-0.802711	0.4221
WTI(-1)	0.046247	0.004988	9.271315	0.0000
WTI(-2)	0.012302	0.005291	2.324965	0.0201
SDR	0.161367	0.036346	4.439743	0.0000
SDR(-1)	0.367658	0.035239	10.43326	0.0000
SDR(-2)	-0.078318	0.035852	-2.184453	0.0289
C	0.000331	9.60E-05	3.445887	0.0006
		Variance Equation		
C	9.37E-07	2.41E-07	3.889860	0.0001
RESID(-1)^2	0.158326	0.018276	8.663240	0.0000
GARCH(-1)	0.845841	0.014527	58.22744	0.0000
T-DIST. DOF	5.071471	0.521387	9.726882	0.0000

R-squared	0.075351	Mean dependent var	-0.000130
Adjusted R-squared	0.072762	S.D. dependent var	0.008777
S.E. of regression	0.008451	Akaike info criterion	-7.220189
Sum squared resid	0.204068	Schwarz criterion	-7.193152
Log likelihood	10359.53	Hannan-Quinn criter.	-7.210441
Durbin-Watson stat	2.213128		

Dependent Variable: CAD
Method: ML - ARCH (Marquardt) - Student's t distribution
Sample (adjusted): 1/06/2005 12/31/2015
Included observations: 2866 after adjustments
Convergence achieved after 19 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*RESID(-2)^2 + C(13)
*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
CAD(-1)	-0.026023	0.019371	-1.343437	0.1791
CAD(-2)	-0.019942	0.018158	-1.098253	0.2721
BRENT	0.089243	0.004308	20.71728	0.0000
BRENT(-1)	0.000292	0.004772	0.061157	0.9512
BRENT(-2)	0.016075	0.004842	3.319879	0.0009
SDR	0.371123	0.028961	12.81475	0.0000
SDR(-1)	0.014945	0.030722	0.486456	0.6266
SDR(-2)	0.030989	0.030585	1.013193	0.3110
C	2.84E-05	7.65E-05	0.370487	0.7110
		Variance Equation		
C	1.59E-07	5.52E-08	2.885824	0.0039
RESID(-1)^2	0.090591	0.023875	3.794328	0.0001
RESID(-2)^2	-0.060057	0.024370	-2.464392	0.0137
GARCH(-1)	0.962844	0.006616	145.5435	0.0000
T-DIST. DOF	6.061032	0.534670	11.33603	0.0000

R-squared	0.220499	Mean dependent var	-3.70E-05
Adjusted R-squared	0.218316	S.D. dependent var	0.006192
S.E. of regression	0.005474	Akaike info criterion	-7.881910
Sum squared resid	0.085613	Schwarz criterion	-7.852793
Log likelihood	11308.78	Hannan-Quinn criter.	-7.871412
Durbin-Watson stat	2.071750		

Dependent Variable: CAD
Method: ML - ARCH (Marquardt) - Student's t distribution
Sample (adjusted): 1/06/2005 12/31/2015
Included observations: 2866 after adjustments
Convergence achieved after 17 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*RESID(-2)^2 + C(13)
*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
CAD(-1)	-0.053043	0.019486	-2.722130	0.0065
CAD(-2)	-0.008917	0.018242	-0.488829	0.6250
WTI	0.077032	0.003766	20.45417	0.0000
WTI(-1)	0.029374	0.004151	7.076954	0.0000
WTI(-2)	0.013248	0.004209	3.147589	0.0016
SDR	0.373043	0.028734	12.98244	0.0000
SDR(-1)	0.004396	0.030807	0.142710	0.8865
SDR(-2)	0.033246	0.030493	1.090273	0.2756
C	3.28E-05	7.56E-05	0.433474	0.6647
		Variance Equation		
C	1.70E-07	5.85E-08	2.911622	0.0036
RESID(-1)^2	0.112743	0.027846	4.048823	0.0001
RESID(-2)^2	-0.073259	0.028276	-2.590880	0.0096
GARCH(-1)	0.954216	0.007689	124.0942	0.0000
T-DIST. DOF	6.174122	0.573969	10.75689	0.0000

R-squared	0.196406	Mean dependent var	-3.70E-05
Adjusted R-squared	0.194156	S.D. dependent var	0.006192
S.E. of regression	0.005558	Akaike info criterion	-7.878300
Sum squared resid	0.088259	Schwarz criterion	-7.849183
Log likelihood	11303.60	Hannan-Quinn criter.	-7.867803
Durbin-Watson stat	2.066956		

Dependent Variable: IDR
Method: ML - ARCH (Marquardt) - Student's t distribution
Sample (adjusted): 1/06/2005 12/31/2015
Included observations: 2866 after adjustments
Convergence achieved after 26 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
IDR(-1)	-0.025161	0.019348	-1.300434	0.1935
IDR(-2)	0.011207	0.018927	0.592099	0.5538
BRENT	0.003417	0.002216	1.541966	0.1231
BRENT(-1)	0.008883	0.002276	3.903516	0.0001
BRENT(-2)	0.002794	0.002179	1.281996	0.1998
SDR	0.147373	0.013992	10.53259	0.0000
SDR(-1)	0.095526	0.014208	6.723426	0.0000
SDR(-2)	-0.021356	0.014702	-1.452656	0.1463
C	-0.000129	3.95E-05	-3.253649	0.0011
	Variance Equation			
C	6.69E-07	1.39E-07	4.829235	0.0000
RESID(-1)^2	0.634085	0.097738	6.487609	0.0000
GARCH(-1)	0.655821	0.019212	34.13526	0.0000
T-DIST. DOF	2.779664	0.163340	17.01769	0.0000

R-squared	0.034763	Mean dependent var	-0.000137
Adjusted R-squared	0.032060	S.D. dependent var	0.006843
S.E. of regression	0.006732	Akaike info criterion	-8.487763
Sum squared resid	0.129486	Schwarz criterion	-8.460725
Log likelihood	12175.96	Hannan-Quinn criter.	-8.478015
Durbin-Watson stat	2.337905		

Dependent Variable: IDR
Method: ML - ARCH (Marquardt) - Student's t distribution
Sample (adjusted): 1/06/2005 12/31/2015
Included observations: 2866 after adjustments
Convergence achieved after 25 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
IDR(-1)	-0.025771	0.019314	-1.334313	0.1821
IDR(-2)	0.012435	0.018917	0.657354	0.5110
WTI	0.004045	0.002026	1.996560	0.0459
WTI(-1)	0.010611	0.002053	5.167519	0.0000
WTI(-2)	0.000870	0.002069	0.420825	0.6739
SDR	0.140251	0.013840	10.13377	0.0000
SDR(-1)	0.094265	0.014165	6.654888	0.0000
SDR(-2)	-0.018378	0.014356	-1.280202	0.2005
C	-0.000131	3.91E-05	-3.348800	0.0008
		Variance Equation		
C	6.10E-07	1.30E-07	4.698617	0.0000
RESID(-1)^2	0.624678	0.096171	6.495479	0.0000
GARCH(-1)	0.663720	0.018945	35.03448	0.0000
T-DIST. DOF	2.776483	0.162914	17.04268	0.0000

R-squared	0.036826	Mean dependent var	-0.000137
Adjusted R-squared	0.034129	S.D. dependent var	0.006843
S.E. of regression	0.006725	Akaike info criterion	-8.490439
Sum squared resid	0.129209	Schwarz criterion	-8.463402
Log likelihood	12179.80	Hannan-Quinn criter.	-8.480691
Durbin-Watson stat	2.335718		

Dependent Variable: NOK
Method: ML - ARCH (Marquardt) - Student's t distribution
Sample (adjusted): 1/06/2005 12/31/2015
Included observations: 2866 after adjustments
Convergence achieved after 15 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*RESID(-2)^2 + C(13)
*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
NOK(-1)	-0.097667	0.020153	-4.846196	0.0000
NOK(-2)	-0.047828	0.017764	-2.692394	0.0071
BRENT	0.053763	0.004477	12.00948	0.0000
BRENT(-1)	0.030375	0.004849	6.264439	0.0000
BRENT(-2)	0.012858	0.004717	2.725778	0.0064
SDR	1.747656	0.029152	59.94905	0.0000
SDR(-1)	0.152643	0.046266	3.299272	0.0010
SDR(-2)	0.093795	0.043497	2.156375	0.0311
C	8.48E-05	8.27E-05	1.025156	0.3053
		Variance Equation		
C	3.00E-07	9.61E-08	3.122781	0.0018
RESID(-1)^2	0.140189	0.028847	4.859814	0.0000
RESID(-2)^2	-0.106157	0.029181	-3.637898	0.0003
GARCH(-1)	0.955209	0.008820	108.3013	0.0000
T-DIST. DOF	7.192868	0.825231	8.716186	0.0000

R-squared	0.520236	Mean dependent var	-0.000119
Adjusted R-squared	0.518893	S.D. dependent var	0.007891
S.E. of regression	0.005474	Akaike info criterion	-7.786737
Sum squared resid	0.085596	Schwarz criterion	-7.757620
Log likelihood	11172.39	Hannan-Quinn criter.	-7.776239
Durbin-Watson stat	1.962135		

Dependent Variable: NOK
Method: ML - ARCH (Marquardt) - Student's t distribution
Sample (adjusted): 1/06/2005 12/31/2015
Included observations: 2866 after adjustments
Convergence achieved after 15 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*RESID(-2)^2 + C(13)
*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
NOK(-1)	-0.103572	0.020014	-5.174934	0.0000
NOK(-2)	-0.046903	0.017558	-2.671371	0.0076
WTI	0.042375	0.004029	10.51683	0.0000
WTI(-1)	0.039733	0.004172	9.524686	0.0000
WTI(-2)	0.017280	0.004298	4.021028	0.0001
SDR	1.738007	0.029318	59.28099	0.0000
SDR(-1)	0.156938	0.046218	3.395607	0.0007
SDR(-2)	0.097482	0.043235	2.254705	0.0242
C	9.05E-05	8.25E-05	1.096739	0.2728
	Variance Equation			
C	2.56E-07	8.87E-08	2.883756	0.0039
RESID(-1)^2	0.142403	0.029533	4.821769	0.0000
RESID(-2)^2	-0.109733	0.029826	-3.679121	0.0002
GARCH(-1)	0.958316	0.008365	114.5685	0.0000
T-DIST. DOF	6.816181	0.743928	9.162423	0.0000

R-squared	0.516652	Mean dependent var	-0.000119
Adjusted R-squared	0.515298	S.D. dependent var	0.007891
S.E. of regression	0.005494	Akaike info criterion	-7.786124
Sum squared resid	0.086236	Schwarz criterion	-7.757007
Log likelihood	11171.52	Hannan-Quinn criter.	-7.775626
Durbin-Watson stat	1.960229		

Dependent Variable: RUB
Method: ML - ARCH (Marquardt) - Student's t distribution
Sample (adjusted): 1/06/2005 12/31/2015
Included observations: 2866 after adjustments
Convergence achieved after 18 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*RESID(-2)^2 + C(13)
*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
RUB(-1)	-0.048199	0.020578	-2.342223	0.0192
RUB(-2)	-0.006852	0.017420	-0.393350	0.6941
BRENT	0.003051	0.002255	1.353005	0.1761
BRENT(-1)	0.011901	0.002303	5.166475	0.0000
BRENT(-2)	-0.000598	0.002305	-0.259580	0.7952
SDR	0.588905	0.016335	36.05284	0.0000
SDR(-1)	0.238824	0.019928	11.98428	0.0000
SDR(-2)	0.036575	0.020260	1.805277	0.0710
C	9.37E-05	4.13E-05	2.270284	0.0232
	Variance Equation			
C	3.21E-08	1.32E-08	2.421161	0.0155
RESID(-1)^2	0.286091	0.041932	6.822801	0.0000
RESID(-2)^2	-0.192786	0.041848	-4.606782	0.0000
GARCH(-1)	0.916387	0.009365	97.84947	0.0000
T-DIST. DOF	5.623668	0.552011	10.18760	0.0000

R-squared	0.073090	Mean dependent var	-0.000331
Adjusted R-squared	0.070495	S.D. dependent var	0.008358
S.E. of regression	0.008058	Akaike info criterion	-8.144284
Sum squared resid	0.185498	Schwarz criterion	-8.115167
Log likelihood	11684.76	Hannan-Quinn criter.	-8.133786
Durbin-Watson stat	1.898239		

Dependent Variable: RUB
Method: ML - ARCH (Marquardt) - Student's t distribution
Sample (adjusted): 1/06/2005 12/31/2015
Included observations: 2866 after adjustments
Convergence achieved after 19 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(10) + C(11)*RESID(-1)^2 + C(12)*RESID(-2)^2 + C(13)
*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
RUB(-1)	-0.047158	0.020556	-2.294190	0.0218
RUB(-2)	-0.008913	0.017426	-0.511508	0.6090
WTI	0.003145	0.002117	1.485804	0.1373
WTI(-1)	0.015577	0.002152	7.237091	0.0000
WTI(-2)	-0.003096	0.002265	-1.367025	0.1716
SDR	0.584406	0.016302	35.84957	0.0000
SDR(-1)	0.247260	0.019787	12.49606	0.0000
SDR(-2)	0.037859	0.020550	1.842255	0.0654
C	9.56E-05	4.15E-05	2.302029	0.0213
		Variance Equation		
C	3.57E-08	1.39E-08	2.569644	0.0102
RESID(-1)^2	0.272359	0.040830	6.670583	0.0000
RESID(-2)^2	-0.176233	0.041036	-4.294636	0.0000
GARCH(-1)	0.913610	0.009584	95.32716	0.0000
T-DIST. DOF	5.579608	0.548347	10.17532	0.0000

R-squared	0.081074	Mean dependent var	-0.000331
Adjusted R-squared	0.078501	S.D. dependent var	0.008358
S.E. of regression	0.008023	Akaike info criterion	-8.151765
Sum squared resid	0.183900	Schwarz criterion	-8.122647
Log likelihood	11695.48	Hannan-Quinn criter.	-8.141267
Durbin-Watson stat	1.893399		

Appendix 33: Correlograms for GARCH models with variables:

brl, brent

	AC	PAC	Q-Stat	Prob*
1	-0.002	-0.002	0.0107	0.918
2	0.003	0.003	0.0372	0.982
3	0.014	0.014	0.5950	0.898
4	-0.001	-0.001	0.6005	0.963
5	0.027	0.027	2.6408	0.755
6	0.013	0.013	3.1344	0.792
7	0.009	0.009	3.3888	0.847
8	0.006	0.006	3.5077	0.899
9	-0.005	-0.005	3.5667	0.938
10	0.001	-0.000	3.5686	0.965
11	0.004	0.003	3.6108	0.980
12	0.018	0.017	4.5094	0.972
13	0.008	0.008	4.7010	0.981
14	0.036	0.036	8.4334	0.866
15	-0.030	-0.030	11.037	0.750
16	0.010	0.009	11.318	0.789
17	0.026	0.025	13.320	0.715
18	-0.028	-0.028	15.507	0.627
19	-0.003	-0.006	15.542	0.688
20	-0.014	-0.014	16.108	0.710
21	0.022	0.023	17.509	0.680
22	0.007	0.006	17.653	0.726
23	-0.007	-0.006	17.801	0.768
24	-0.005	-0.006	17.882	0.809
25	-0.002	-0.002	17.895	0.847
26	0.003	0.002	17.925	0.878
27	-0.018	-0.019	18.876	0.874
28	-0.002	-0.003	18.888	0.902
29	-0.004	-0.003	18.931	0.923
30	0.014	0.014	19.497	0.929
31	-0.038	-0.039	23.707	0.822
32	0.006	0.011	23.824	0.851
33	-0.002	-0.004	23.837	0.879
34	-0.005	-0.003	23.898	0.901
35	0.029	0.028	26.324	0.855
36	-0.020	-0.018	27.477	0.845

brl, wti

	AC	PAC	Q-Stat	Prob*
1	-0.002	-0.002	0.0156	0.901
2	0.004	0.004	0.0594	0.971
3	0.015	0.015	0.7194	0.869
4	-0.001	-0.001	0.7218	0.949
5	0.029	0.029	3.1569	0.676
6	0.011	0.011	3.5143	0.742
7	0.012	0.012	3.9204	0.789
8	0.004	0.003	3.9661	0.860
9	-0.009	-0.010	4.2157	0.897
10	-0.005	-0.006	4.2874	0.933
11	0.004	0.003	4.3322	0.959
12	0.018	0.018	5.2671	0.948
13	0.006	0.006	5.3706	0.966
14	0.040	0.040	9.9396	0.767
15	-0.028	-0.028	12.190	0.665
16	0.009	0.009	12.425	0.714
17	0.021	0.019	13.729	0.686
18	-0.027	-0.027	15.883	0.601
19	0.005	0.001	15.945	0.661
20	-0.014	-0.014	16.530	0.683
21	0.022	0.023	17.984	0.650
22	0.006	0.006	18.103	0.700
23	-0.005	-0.003	18.183	0.747
24	-0.003	-0.004	18.203	0.793
25	-0.005	-0.005	18.282	0.830
26	0.006	0.005	18.385	0.861
27	-0.019	-0.019	19.413	0.854
28	-0.006	-0.008	19.518	0.881
29	-0.011	-0.009	19.846	0.898
30	0.016	0.017	20.600	0.900
31	-0.035	-0.035	24.114	0.806
32	0.006	0.011	24.220	0.836
33	-0.007	-0.009	24.343	0.863
34	-0.005	-0.002	24.411	0.887
35	0.024	0.022	26.034	0.864
36	-0.020	-0.018	27.217	0.854

cad, brent

	AC	PAC	Q-Stat	Prob*
1	-0.018	-0.018	0.9104	0.340
2	0.007	0.006	1.0402	0.594
3	-0.012	-0.012	1.4387	0.696
4	-0.002	-0.002	1.4460	0.836
5	0.001	0.001	1.4500	0.919
6	0.003	0.003	1.4805	0.961
7	0.017	0.017	2.2743	0.943
8	0.001	0.001	2.2758	0.971
9	-0.033	-0.033	5.4741	0.791
10	-0.017	-0.018	6.2876	0.791
11	0.002	0.002	6.2989	0.853
12	-0.004	-0.005	6.3558	0.897
13	0.002	0.001	6.3642	0.932
14	-0.045	-0.046	12.327	0.580
15	-0.041	-0.042	17.119	0.312
16	0.004	0.005	17.170	0.375
17	0.018	0.018	18.058	0.385
18	-0.009	-0.011	18.291	0.437
19	-0.022	-0.024	19.646	0.416
20	0.005	0.005	19.724	0.475
21	-0.002	-0.000	19.738	0.538
22	-0.009	-0.008	19.963	0.585
23	0.005	0.001	20.024	0.640
24	-0.009	-0.014	20.281	0.681
25	0.004	0.003	20.337	0.729
26	-0.015	-0.013	20.974	0.743
27	-0.000	-0.002	20.974	0.787
28	0.004	0.000	21.020	0.825
29	0.032	0.028	23.972	0.730
30	-0.018	-0.018	24.908	0.729
31	-0.015	-0.014	25.525	0.744
32	-0.007	-0.006	25.662	0.778
33	-0.024	-0.028	27.379	0.743
34	-0.007	-0.010	27.521	0.776
35	0.009	0.009	27.767	0.803
36	0.003	0.001	27.798	0.834

cad, wti

	AC	PAC	Q-Stat	Prob*
1	-0.014	-0.014	0.5756	0.448
2	0.003	0.002	0.5955	0.743
3	-0.004	-0.004	0.6439	0.886
4	-0.017	-0.018	1.5225	0.823
5	0.004	0.004	1.5780	0.904
6	0.020	0.020	2.7037	0.845
7	0.006	0.006	2.7971	0.903
8	0.007	0.007	2.9411	0.938
9	-0.047	-0.046	9.2111	0.418
10	-0.030	-0.031	11.878	0.293
11	0.001	0.000	11.880	0.373
12	-0.006	-0.006	11.969	0.448
13	-0.002	-0.004	11.979	0.529
14	-0.043	-0.044	17.322	0.239
15	-0.035	-0.035	20.943	0.139
16	-0.006	-0.005	21.045	0.177
17	0.026	0.027	23.060	0.147
18	-0.010	-0.012	23.338	0.178
19	-0.009	-0.014	23.597	0.212
20	0.010	0.011	23.902	0.247
21	-0.001	0.002	23.907	0.298
22	0.003	0.003	23.931	0.351
23	-0.002	-0.007	23.941	0.407
24	-0.008	-0.014	24.123	0.455
25	0.015	0.012	24.798	0.474
26	-0.005	-0.003	24.868	0.526
27	-0.009	-0.010	25.128	0.567
28	0.005	-0.000	25.196	0.617
29	0.021	0.019	26.477	0.600
30	-0.014	-0.014	27.018	0.622
31	-0.025	-0.024	28.810	0.579
32	-0.017	-0.016	29.614	0.588
33	-0.018	-0.021	30.604	0.587
34	0.001	-0.001	30.605	0.635
35	0.014	0.015	31.188	0.653
36	0.014	0.013	31.740	0.671

idr, brent

	AC	PAC	Q-Stat	Prob*
1	0.058	0.058	9.6608	0.002
2	0.034	0.031	13.020	0.001
3	0.013	0.010	13.527	0.004
4	0.037	0.034	17.361	0.002
5	0.003	-0.001	17.393	0.004
6	0.026	0.024	19.410	0.004
7	0.029	0.025	21.801	0.003
8	0.005	-0.000	21.886	0.005
9	0.033	0.031	25.081	0.003
10	0.028	0.022	27.348	0.002
11	0.020	0.013	28.482	0.003
12	0.009	0.004	28.704	0.004
13	0.020	0.014	29.827	0.005
14	0.001	-0.003	29.833	0.008
15	0.015	0.012	30.490	0.010
16	0.013	0.009	31.008	0.013
17	0.017	0.012	31.860	0.016
18	0.023	0.019	33.349	0.015
19	0.011	0.004	33.694	0.020
20	0.002	-0.003	33.706	0.028
21	0.001	-0.002	33.710	0.039
22	0.018	0.014	34.613	0.043
23	-0.020	-0.024	35.770	0.044
24	0.027	0.026	37.856	0.036
25	0.004	-0.000	37.908	0.047
26	0.000	-0.005	37.908	0.062
27	-0.007	-0.008	38.047	0.077
28	0.007	0.003	38.187	0.095
29	0.021	0.020	39.479	0.093
30	0.008	0.005	39.679	0.111
31	-0.007	-0.011	39.811	0.133
32	0.001	0.001	39.812	0.161
33	-0.021	-0.023	41.098	0.157
34	0.000	0.001	41.098	0.188
35	-0.013	-0.014	41.615	0.205
36	-0.024	-0.024	43.315	0.187

idr, wti

	AC	PAC	Q-Stat	Prob*
1	0.058	0.058	9.5663	0.002
2	0.033	0.030	12.689	0.002
3	0.015	0.011	13.321	0.004
4	0.036	0.034	17.040	0.002
5	0.003	-0.002	17.060	0.004
6	0.027	0.025	19.186	0.004
7	0.030	0.027	21.812	0.003
8	0.006	-0.000	21.901	0.005
9	0.034	0.032	25.255	0.003
10	0.026	0.020	27.158	0.002
11	0.017	0.011	28.018	0.003
12	0.009	0.005	28.264	0.005
13	0.019	0.014	29.309	0.006
14	0.002	-0.003	29.316	0.009
15	0.015	0.012	29.975	0.012
16	0.014	0.009	30.512	0.016
17	0.014	0.009	31.046	0.020
18	0.021	0.018	32.371	0.020
19	0.013	0.006	32.840	0.025
20	0.003	-0.002	32.864	0.035
21	-0.000	-0.004	32.864	0.048
22	0.019	0.016	33.957	0.050
23	-0.018	-0.022	34.848	0.054
24	0.028	0.027	37.062	0.043
25	0.006	0.001	37.164	0.056
26	0.003	-0.002	37.184	0.072
27	-0.009	-0.010	37.432	0.087
28	0.005	0.002	37.515	0.108
29	0.022	0.021	38.971	0.102
30	0.008	0.005	39.150	0.122
31	-0.008	-0.013	39.327	0.145
32	0.002	0.002	39.340	0.174
33	-0.019	-0.021	40.342	0.177
34	-0.003	-0.003	40.372	0.209
35	-0.013	-0.014	40.846	0.229
36	-0.023	-0.023	42.430	0.213

nok, brent

	AC	PAC	Q-Stat	Prob*
1	0.005	0.005	0.0658	0.798
2	0.015	0.015	0.7072	0.702
3	-0.022	-0.023	2.1468	0.542
4	-0.007	-0.007	2.3012	0.681
5	0.003	0.003	2.3194	0.803
6	-0.022	-0.022	3.6669	0.722
7	0.005	0.005	3.7479	0.808
8	-0.016	-0.016	4.5279	0.807
9	-0.010	-0.011	4.8388	0.848
10	-0.012	-0.012	5.2845	0.871
11	-0.008	-0.008	5.4548	0.907
12	0.017	0.017	6.3290	0.899
13	-0.015	-0.015	6.9566	0.904
14	-0.026	-0.028	8.9764	0.833
15	-0.042	-0.041	14.126	0.516
16	-0.021	-0.021	15.358	0.499
17	0.017	0.016	16.191	0.510
18	-0.002	-0.004	16.206	0.578
19	-0.028	-0.032	18.542	0.487
20	0.001	0.001	18.543	0.552
21	-0.027	-0.028	20.637	0.481
22	0.013	0.010	21.125	0.513
23	0.027	0.026	23.249	0.446
24	0.010	0.006	23.556	0.487
25	-0.015	-0.018	24.219	0.507
26	-0.010	-0.009	24.522	0.546
27	-0.002	-0.003	24.539	0.600
28	-0.001	-0.003	24.544	0.653
29	-0.006	-0.011	24.659	0.696
30	-0.002	-0.005	24.675	0.741
31	-0.034	-0.034	27.996	0.621
32	0.007	0.007	28.124	0.663
33	0.005	0.006	28.197	0.705
34	0.004	-0.002	28.250	0.745
35	-0.001	-0.006	28.254	0.783
36	-0.003	-0.003	28.274	0.817

nok, wti

	AC	PAC	Q-Stat	Prob*
1	0.006	0.006	0.1171	0.732
2	0.015	0.015	0.7844	0.676
3	-0.026	-0.026	2.7220	0.436
4	-0.011	-0.011	3.0728	0.546
5	0.002	0.003	3.0802	0.688
6	-0.020	-0.020	4.1875	0.651
7	0.008	0.007	4.3654	0.737
8	-0.008	-0.007	4.5435	0.805
9	0.000	-0.001	4.5438	0.872
10	-0.004	-0.004	4.5878	0.917
11	-0.007	-0.008	4.7459	0.943
12	0.012	0.011	5.1508	0.953
13	-0.024	-0.024	6.7840	0.913
14	-0.026	-0.027	8.7771	0.845
15	-0.034	-0.033	12.192	0.664
16	-0.012	-0.012	12.625	0.700
17	0.021	0.020	13.932	0.672
18	-0.006	-0.008	14.036	0.727
19	-0.023	-0.026	15.510	0.690
20	0.002	0.003	15.524	0.746
21	-0.027	-0.027	17.568	0.676
22	0.019	0.018	18.630	0.668
23	0.024	0.025	20.351	0.621
24	0.011	0.007	20.688	0.657
25	-0.018	-0.019	21.621	0.658
26	-0.012	-0.011	22.057	0.686
27	-0.007	-0.008	22.211	0.727
28	-0.005	-0.006	22.285	0.768
29	-0.014	-0.018	22.866	0.783
30	-0.012	-0.013	23.271	0.804
31	-0.041	-0.041	28.091	0.616
32	0.005	0.004	28.155	0.662
33	0.001	0.001	28.157	0.707
34	0.005	-0.001	28.220	0.746
35	0.006	0.004	28.335	0.780
36	-0.000	-0.000	28.336	0.815

rub, brent

	AC	PAC	Q-Stat	Prob*
1	0.034	0.034	3.2974	0.069
2	0.018	0.017	4.2116	0.122
3	-0.006	-0.007	4.3165	0.229
4	0.005	0.005	4.3893	0.356
5	0.028	0.028	6.6031	0.252
6	-0.001	-0.003	6.6051	0.359
7	0.011	0.010	6.9324	0.436
8	0.011	0.011	7.3094	0.504
9	-0.004	-0.005	7.3484	0.601
10	0.054	0.053	15.683	0.109
11	0.055	0.052	24.434	0.011
12	0.020	0.014	25.546	0.012
13	0.037	0.035	29.488	0.006
14	0.024	0.022	31.167	0.005
15	0.028	0.022	33.426	0.004
16	0.006	0.002	33.531	0.006
17	0.009	0.007	33.790	0.009
18	0.049	0.045	40.737	0.002
19	0.004	-0.001	40.776	0.003
20	-0.024	-0.029	42.381	0.002
21	0.037	0.033	46.277	0.001
22	0.015	0.009	46.957	0.001
23	0.020	0.010	48.084	0.002
24	0.012	0.006	48.518	0.002
25	0.004	-0.002	48.565	0.003
26	0.024	0.016	50.198	0.003
27	0.017	0.014	51.060	0.003
28	0.007	-0.004	51.187	0.005
29	0.029	0.021	53.627	0.004
30	-0.028	-0.030	55.932	0.003
31	-0.021	-0.026	57.246	0.003
32	0.020	0.016	58.349	0.003
33	0.001	-0.005	58.350	0.004
34	0.028	0.022	60.686	0.003
35	-0.001	-0.003	60.688	0.005
36	0.018	0.010	61.631	0.005

rub, wti

	AC	PAC	Q-Stat	Prob*
1	0.036	0.036	3.7103	0.054
2	0.022	0.021	5.1570	0.076
3	-0.008	-0.010	5.3512	0.148
4	0.003	0.003	5.3799	0.250
5	0.027	0.027	7.4676	0.188
6	0.001	-0.002	7.4686	0.280
7	0.013	0.012	7.9520	0.337
8	0.007	0.007	8.1037	0.423
9	0.000	-0.001	8.1040	0.524
10	0.051	0.050	15.475	0.116
11	0.057	0.054	24.959	0.009
12	0.019	0.012	26.004	0.011
13	0.038	0.036	30.178	0.004
14	0.023	0.021	31.719	0.004
15	0.026	0.021	33.688	0.004
16	0.006	0.002	33.785	0.006
17	0.012	0.010	34.221	0.008
18	0.048	0.044	40.895	0.002
19	0.004	-0.001	40.950	0.002
20	-0.021	-0.027	42.200	0.003
21	0.038	0.034	46.297	0.001
22	0.019	0.012	47.331	0.001
23	0.018	0.007	48.218	0.002
24	0.014	0.007	48.775	0.002
25	0.006	0.000	48.891	0.003
26	0.026	0.019	50.831	0.002
27	0.015	0.011	51.520	0.003
28	0.008	-0.002	51.715	0.004
29	0.027	0.019	53.776	0.003
30	-0.030	-0.032	56.312	0.003
31	-0.018	-0.024	57.299	0.003
32	0.019	0.015	58.368	0.003
33	-0.002	-0.008	58.384	0.004
34	0.030	0.024	61.045	0.003
35	-0.007	-0.010	61.171	0.004
36	0.018	0.010	62.091	0.004

Appendix 34: ARCH LM tests for GARCH models with variables:

brl, brent

Heteroskedasticity Test: ARCH

F-statistic	0.347227	Prob. F(1,2863)	0.5557
Obs*R-squared	0.347427	Prob. Chi-Square(1)	0.5556

brl, wti

Heteroskedasticity Test: ARCH

F-statistic	0.419518	Prob. F(1,2863)	0.5172
Obs*R-squared	0.419750	Prob. Chi-Square(1)	0.5171

cad, brent including one ARCH term

Heteroskedasticity Test: ARCH

F-statistic	20.71498	Prob. F(1,2863)	0.0000
Obs*R-squared	20.58055	Prob. Chi-Square(1)	0.0000

cad, brent including two ARCH terms

Heteroskedasticity Test: ARCH

F-statistic	2.522947	Prob. F(1,2863)	0.1123
Obs*R-squared	2.522487	Prob. Chi-Square(1)	0.1122

cad, wti including one ARCH term

Heteroskedasticity Test: ARCH

F-statistic	12.94427	Prob. F(1,2863)	0.0003
Obs*R-squared	12.89501	Prob. Chi-Square(1)	0.0003

cad, wti including two ARCH terms

Heteroskedasticity Test: ARCH

F-statistic	0.825416	Prob. F(1,2863)	0.3637
Obs*R-squared	0.825755	Prob. Chi-Square(1)	0.3635

idr, brent

Heteroskedasticity Test: ARCH

F-statistic	0.001203	Prob. F(1,2863)	0.9723
Obs*R-squared	0.001204	Prob. Chi-Square(1)	0.9723

idr, wti

Heteroskedasticity Test: ARCH

F-statistic	0.001710	Prob. F(1,2863)	0.9670
Obs*R-squared	0.001711	Prob. Chi-Square(1)	0.9670

nok, brent including one ARCH term

Heteroskedasticity Test: ARCH

F-statistic	20.74873	Prob. F(1,2863)	0.0000
Obs*R-squared	20.61384	Prob. Chi-Square(1)	0.0000

nok, brent including two ARCH terms

Heteroskedasticity Test: ARCH

F-statistic	1.110142	Prob. F(1,2863)	0.2921
Obs*R-squared	1.110487	Prob. Chi-Square(1)	0.2920

nok, wti including one ARCH term

Heteroskedasticity Test: ARCH

F-statistic	24.83116	Prob. F(1,2863)	0.0000
Obs*R-squared	24.63485	Prob. Chi-Square(1)	0.0000

nok, wti including two ARCH terms

Heteroskedasticity Test: ARCH

F-statistic	1.297304	Prob. F(1,2863)	0.2548
Obs*R-squared	1.297622	Prob. Chi-Square(1)	0.2546

rub, brent including one ARCH term

Heteroskedasticity Test: ARCH

F-statistic	10.18231	Prob. F(1,2863)	0.0014
Obs*R-squared	10.15331	Prob. Chi-Square(1)	0.0014

rub, brent including two ARCH terms

Heteroskedasticity Test: ARCH

F-statistic	0.451240	Prob. F(1,2863)	0.5018
Obs*R-squared	0.451484	Prob. Chi-Square(1)	0.5016

rub, wti including one ARCH term

Heteroskedasticity Test: ARCH

F-statistic	10.94312	Prob. F(1,2863)	0.0010
Obs*R-squared	10.90907	Prob. Chi-Square(1)	0.0010

rub, wti including two ARCH terms

Heteroskedasticity Test: ARCH

F-statistic	0.715791	Prob. F(1,2863)	0.3976
Obs*R-squared	0.716112	Prob. Chi-Square(1)	0.3974