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Dynamic conditional correlation and causality relationship among foreign exchange, stock and commodity markets: Evidence from 2014 Russian financial crisis

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Abstract

The political events of the beginning of 2014 led to a series of economic sanctions against and by Russia. The combination of sanctions and declining oil prices devaluating the Russian national currency (the rouble) had a significant negative affect on the Russian economy. The crisis in Russia is partly transmitted to the countries dependent on remittances from and trade with Russia. This paper highlights the dynamic conditional correlation and causality relationship among the foreign exchange, stock and commodity markets before and during the ongoing Russian financial crisis. The derived results promote a better understanding of the relationship between these markets and have important implications for policy makers and investors in Russia and the countries affected by Russian crisis.

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1. Introduction

The political events of the beginning of 2014 led to a series of economic sanctions against and by Russia. The coincidence of sanctions with a fall in price of oil, devaluating the Russian national currency and affecting the Russian economy, caused a severe crisis that is referred to as the Russian financial crisis.

Oil and natural gas make up a major share of Russia's exports. In 2014, the oil and gas sector accounted for over 16% of the GDP, 49% of general government revenues and 70% of total exports. The fall of oil prices and international sanctions influenced the balance of trade and the portfolio balance, and caused the devaluation of the rouble and Russian Trading System Cash Index (RTS). The consequences of the mentioned shocks and a decline in confidence in the Russian economy caused real GDP growth rate to fall in 2014 and contract 3.7% in 2015. Average consumer prices increased by 7.8% in 2014 and 15.5% in 2015. The decrease in real income has had a significant impact on poverty rate. The poverty rate increased from 10.8% in 2013 to 11.2% in 2014 and 13.4% in 2015.

During the past few years there have been many studies about the impact of oil price on financial and non-financial markets. In particular, the effects of oil price shocks on the production, price level, and exchange rate of eight important industrialized countries (Yoshizaki and Hamori, 2013), the effects of oil shocks by their respective causes and volatility spillover including leverage effects (Baek and Seo, 2015), the influence of oil prices on Canadian stock market (Shahriar and Mahbobi, 2013), the relation of the US dollar with oil prices, gold prices, and the US stock market (Azar, 2015), and oil price fluctuations impacts on Indian economy (Gupta and Goyal, 2015) were addressed.

The studies, such as those by Hayo and Kutan (2005), Bhar and Nikolova (2010), and Peresetsky (2014) have examined the relationship between the oil price and the Russian financial markets. Hayo and Kutan (2005) analyzed the impact of news, oil prices, and international financial market developments on daily returns of Russian bond and stock markets, and detected a significant effect of the growth in oil prices on Russian stock returns. Bhar and Nikolova (2010) showed a significant impact of oil price returns on Russian equity returns and volatility, and highlighted Russia's importance as one of the major suppliers of oil. Peresetsky (2014) tested the dependence of the Russian stock market on the world stock market, world oil prices and Russian political and economic news during the period 2001–2010 and showed that the effect of oil prices are not significant after 2006. Nevertheless, there is little research on the dynamic linkage and causality relationship among foreign exchange, stock and commodity markets in the oil-exporting Russian economy and the factors affecting that relationship. The ongoing financial crisis in Russia, which started in mid-2014, may cause a deep recession in Russia and partly spread to other Eurasian countries. The new academic papers covering different aspects of the crisis have important implications for policy makers and investors in Russia and the countries affected by the Russian crisis.

This paper highlights the dynamic relationship among foreign exchange, stock and commodity markets before and during the Russian financial crisis. The derived results promote a better understanding of the impact of oil prices on Russian foreign exchange and stock markets.

2. Methodology

In the first step, we estimate the dynamic conditional correlation (DCC) between the logarithmic return series of the rouble's exchange rate, RTS index and crude oil price (Brent and WTI). We estimate the parameters of the DCC multivariate generalized autoregressive conditionally heteroskedastic (GARCH) model, in which the conditional variances are modelled as a univariate GARCH model (Bollerslev, 1986), and the conditional co-variances are modelled as nonlinear functions of the conditional variances (Engle, 2002).

The mean equation of the model is

$$y_t = \omega + Cx_t + \varepsilon_t, \tag{1}$$

where $\varepsilon_t = H_t^{1/2} v_t$; $H_t = D_t R_t D_t$; $R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2}$

and $Q_t = (1-\lambda_1-\lambda_2)R + \lambda_1 \tilde{\varepsilon}_{t-1}\tilde{\varepsilon}'_{t-1} + \lambda_2 Q_{t-1}$.

Here, y_t is an m×1 vector of the dependent variables, C is an m×k matrix of the parameters and x_t is a k×1 vector of independent variables that may contain lags of the dependent variables too. $H_t^{1/2}$ is the Cholesky factor of the time-varying conditional covariance matrix H_t, v_t is an m×1 vector of innovations and D_t is a diagonal matrix representing the conditional volatilities from variance equation. Additionally, $\tilde{\varepsilon}_t$ is an m×1 vector of standardized residuals, and λ_1 and λ_2 are parameters of the dynamics of conditional quasi-correlation. And λ_1 and λ_2 are non-negative and satisfy the condition $0 \le \lambda_1 + \lambda_2 < 1$.

The variance equation of the model is

$$\sigma_{i,t}^2 = \omega_i + \sum\nolimits_{j=1}^{p_i} a_j \varepsilon_{i,t-j}^2 + \sum\nolimits_{j=1}^{q_i} \beta_j \sigma_{i,t-j}^2 . \tag{2}$$

We modelle the conditional means of the returns as vector autoregressive (VAR) processes and the conditional co-variances as DCC-GARCH processes in which the variance of each disturbance term follows a GARCH(1,1) process. We use the Akaike information criterion (AIC), the Bayesian information criterion (BIC), log-likelihood ratio and the Ljung–Box Q test for the selection of the lag order for VAR and the definition of the parameters of GARCH. Variances and co-variances derived from Equations 1 and 2 are used in the estimation of the DCC coefficients.

In the next step, we apply the cross-correlation function (CCF) approach developed by Cheung and Ng (1996) to examine the causality-in-mean and variance between the logarithmic return series. We used an autoregressive (AR) model and an exponential GARCH (EGARCH) model (Nelson, 1991) to compute the conditional mean and conditional variance. The mean equation is

$$y_t = \omega + \sum_{i=1}^{k} a_i y_{t-i} + \varepsilon_t , \tag{3}$$

and the variance equation is

$$\ln(\sigma_t^2) = \omega + \sum_{i=1}^{p} (\gamma_i \varepsilon_{t-i} / \sigma_{t-i} + \alpha_i (| \varepsilon_{t-i} / \sigma_{t-i} | - (2/\pi)^{1/2})) + \sum_{i=1}^{q} \beta_i \ln(\sigma_{t-i}^2) . \tag{4}$$

In Equation 3 the current value of the dependent variable can be explained by its past values. The values of k, p and q in Equations 3 and 4 are chosen based on AIC, BIC, log-likelihood ratio and the Ljung–Box Q test.

We use the standardized residuals and their squared values from Equations 3 and 4 in CCF to test the causality-in-mean and causality-in-variance. A generalized version of Cheung and Ng's (1996) chi-square test statistic suggested by Hong (2001), with an asymptotic critical values of 1.645 at the 5% level and 2.326 at the 1% level, are used to test the hypothesis of no causality from lag 1 to a given lag of k in the cross-correlation coefficients.

The standardized version of Cheung and Ng's (1996) chi-square test statistic proposed by Hong (2001) is

$$Q = (S - k)/(2k)^{1/2} , \tag{5}$$

which follows a normal distribution with zero mean and unit variance. In view of the fact that Q is a one-sided test, upper-tailed N (0; 1) critical values are used. Also, k is the number of lags used in estimation, and S is Cheung and Ng's (1996) chi-square test statistic coefficient defined as

$$S = T \sum_{i=j}^{k} \hat{r}_{uv}(i)^2 . \tag{6}$$

T is the sample size, and $\hat{r}_{uv}(i)$ is the sample cross-correlation coefficient at lag i for the standardized residuals while estimating causality in the mean and for the squared standardized residuals while estimating causality in the variance.

3. Data

The daily logarithmic return series of exchange rate of the rouble, RTS and crude oil price (Brent and WTI) for the period from 9 January 2013 to 30 December 2015 are used in the estimations. RTS is one of the largest stock exchanges in Russia and East Europe. Its index is calculated based on the prices of the 50 most liquid Russian stocks of the largest Russian issuers. The index is denominated in US dollars. For the oil price, we use Brent Crude (Brent) and West Texas Intermediate (WTI) – two major trading classifications of sweet light crude oil that serve as benchmark prices for purchases of oil worldwide. The exchange rates of the rouble are from the Central Bank of Russia. The Moscow Exchange is source of data on RTS's index. Datastream is the source of data on crude oil price.

Table 1. Descriptive statistics for the logarithmic return series

Variables	Obs.	Mean	Std. Dev.	Skewness	Kurtosis	Jarque–Bera	ADF	ARCH effect
Rouble	712	0.0012	0.0149	0.4296	20.7586	9378.0***	-4.757***	137.620***
RTS	712	-0.0010	0.0202	-0.3202	11.0917	1955.0***	-6.528***	189.163***
Brent	712	-0.0016	0.0185	-0.8929	15.2342	4535.0***	-5.362***	12.979**
WTI	712	-0.0013	0.0215	-0.7223	9.8952	1472.000***	-4.864***	25.919***

Notes:

*** in the Jarque–Bera test indicate that the null hypothesis of "normal distribution" is rejected at the 1% significant level.

The maximum number of lags for the ADF test selected by Schwarz information criterion (SIC) was 19. For the ADF test, *** mean smaller than the critical value at the 1% significant level. DF-GLS and Phillips-Perron test for unit root prove the robustness of the ADF unit root test.

The ARCH effect reports the LM test for ARCH(5) disturbance. For the ARCH effect, *** and ** mean the rejection of null hypothesis of "no ARCH effect" at 1% and 5% significant levels.

The data for the entire mentioned period are used in estimations of the coefficients of DCCs. Descriptive statistics are presented in Table 1. The observations for weekends and holidays are omitted. All variables have mean and standard deviations very close to zero. Positive mean values for the rouble exhibit its depreciation. Negative means for RTS, Brent and WTI show a decrease in the indices. Skewness values show the distribution skewed on the right for the rouble, demonstrating longer tails on higher returns; for the other variables, the distribution is skewed on the left, demonstrating longer tails on lower returns. The kurtosis values are higher than the normal distribution. The Jarque–Bera test rejects the null hypothesis of "normal distribution" at the 1% significance level for all variables. The standard Augmented Dickey–Fuller (ADF) test statistics (Dickey and Fuller, 1979, 1981) reject the null hypothesis of a unit root at the 1% significance level. The Lagrange multiplier (LM) test for autoregressive conditional heteroskedasticity (ARCH) disturbance rejects the null hypothesis of "no ARCH effect" at the 5% significance level for all variables[1]. Data description substantiates the use of GARCH-type models.

Two subsets of data are formed from the original data to look at the causal relationships in the mean and variance between the logarithmic return series (Tables 2

[1] The LM test for ARCH disturbance with 10 lags rejects the null hypothesis of "no ARCH effect" at the 1% significance level for all variables, excluding Brent. The null hypothesis of "no ARCH effect" is not rejected for Brent at 10 to 13 lags. That is why WTI is used in all estimations together with Brent.

and 3). The first subset covers the period before the financial crisis – from 9 January 2013 to 30 June 2014. The second subset comprises the financial crisis period – 1 July 2014 to 30 December 2015.

Table 2. Descriptive statistics for logarithmic return series, before the financial crisis

Variables	Obs.	Mean	Std. Dev.	Skewness	Kurtosis	Jarque–Bera	ADF
Rouble	350	0.0003	0.0053	-0.2677	4.6041	41.710***	-4.399***
RTS	350	-0.0004	0.0155	-1.2472	16.0980	2593.0***	-4.968***
Brent	350	-0.0001	0.0104	0.0072	3.3514	1.8040	-5.408***
WTI	350	0.0004	0.0118	-0.8804	8.2454	446.50***	-5.086***

Notes:

*** in the Jarque–Bera test indicate that the null hypothesis of "normal distribution" is rejected at the 1% significant level.

The maximum number of lags for the ADF test selected by Schwarz information criterion (SIC) was 16. For the ADF test, *** mean smaller than the critical value at the 1% significant level. DF-GLS and Phillips-Perron test for unit root prove the robustness of the ADF unit root test.

The mean values for the second subset show higher depreciation for all variables[2] as compared with the first subset of data. The higher standard deviations in the second subset of data demonstrate higher volatility of the return series during the financial crisis period as compared with the pre-crisis period. The Jarque–Bera test rejects the null hypothesis of "normal distribution" at the 1% significance level for all variables (excluding Brent before the crisis). The ADF test statistics reject the null hypothesis of a unit root at the 1% significance level.

Table 3. Descriptive statistics for the logarithmic return series, the financial crisis period

Variables	Obs.	Mean	Std. Dev.	Skewness	Kurtosis	Jarque–Bera	ADF
Rouble	362	0.0021	0.0203	0.2202	11.9991	1224.0***	-3.875**
RTS	362	-0.0016	0.0237	-0.0039	8.4684	451.00***	-4.785***
Brent	362	-0.0031	0.0238	-0.6755	10.7077	923.60***	-3.988***
WTI	362	-0.0029	0.0277	-0.4520	6.6556	213.90***	-3.742***

Notes:

*** in the Jarque–Bera test indicate that the null hypothesis of "normal distribution" is rejected at the 1% significant level.

The maximum number of lags for the ADF test selected by Schwarz information criterion (SIC) was 16. For the ADF test, *** mean smaller than the critical value at the 1% significant level. DF-GLS and Phillips-Perron test for unit root prove the robustness of the ADF unit root test.

2 Exchange rate of the rouble is given as the number of roubles per one U.S. dollar. That's why an increase in the exchange rate of the rouble means its depreciation.

4. Empirical findings

Tables 4 and 5 provide the results obtained from the estimation of the mean and variance equations of the multivariate GARCH models.

Table 4. Results of the multivariate DCC–GARCH model: The rouble, RTS and Brent

	Rouble	RTS	Brent
Mean			
Rouble $_{t-1}$	-0.1268*** (0.0383)	0.0541 (0.0638)	0.0954* (0.0529)
RTS $_{t-1}$	-0.1652*** (0.0172)	-0.0119 (0.0456)	-0.0017 (0.0328)
Brent $_{t-1}$	-0.0720*** (0.0178)	0.0182 (0.0428)	0.0958** (0.0403)
Constant	0.0004** (0.0002)	-0.0002 (0.0006)	-0.0006 (0.0005)
Variance			
α_1	0.3189*** (0.0554)	0.1219*** (0.0390)	0.0684*** (0.0147)
β_1	0.6929*** (0.0430)	0.8109*** (0.0674)	0.9324*** (0.0136)
ω	2.76e-06*** (8.29e-07)	2.59E-05** (1.31E-05)	1.54e-06* (9.35e-07)
DCC			
λ_1	0.0163*** (0.0046)		
λ_2	0.9731*** (0.0057)		
Diagnostic			
Q (10)	13.8874 (0.1782)	11.3832 (0.3285)	21.5553 (0.0175)
Q^2 (10)	9.2793 (0.5058)	2.1217 (0.9953)	4.1429 (0.9407)

Notes:

The numbers in parentheses are standard errors.

Q (10) is the Ljung–Box Q statistics for the null hypothesis that states that there is no autocorrelation up to orders 10 for standardized residuals.

The *, ** and *** mean significance at the 10%, 5% and 1% levels.

The derived results from the mean equation show that the rouble's exchange rate logarithmic returns are explained by the previous logarithmic returns of its exchange rate, RTS, Brent and WTI. The lagged returns of WTI explain the RTS's returns. The estimates for the variance equation demonstrate that the conditional variances of the variables are significantly affected by their own previous information and variances. The lambda magnitudes point out that conditional correlations are not constant and depend more on their past values than on lagged residuals' innovations. Also, λ_1 and λ_2 are non-negative and satisfy the condition of $0 \le \lambda_1 + \lambda_2 < 1$.

The dynamic conditional correlation coefficients based on the variances and co-variances derived from the multivariate DCC–GARCH model are depicted in Figures 1 and 2. In Figures 1 and 2, the letter "S" is used to refer to the start of the period including economic sanctions and "FC" is used to refer to the start of the financial crisis.

The coefficients of dynamic conditional correlation between rouble's exchange rate and oil price are negative and their average absolute values are higher as compared with the pre-crisis period. It means during the crisis low oil price returns coincided with comparatively higher depreciation of rouble. The volatility of the coefficients also is higher during the crisis period.

For the most of observation beginning from March 2014 when the sanctions started, the coefficients have decreasing trend, which means increasing negative correlation between the return series. The absolute values of rouble's dynamic conditional correlation coefficients with Brent are larger than the dynamic conditional correlation coefficients with WTI.

Table 5. Results of the multivariate DCC–GARCH model: The rouble, RTS and WTI

	Rouble	**RTS**	**WTI**
Mean			
Rouble $_{t-1}$	-0.0864** (0. 0367)	-0.0025 (0.0644)	-0.0580 (0.0816)
RTS $_{t-1}$	-0.1526*** (0.0169)	-0.0341 (0.0439)	0.0253 (0.0399)
WTI $_{t-1}$	-0.1070*** (0.0151)	0.1075*** (0.0373)	-0.0646 (0.0417)
Constant	0.0004* (0.0002)	-2.2E-05 (0.0006)	-0.0005 (0.0006)
Variance			
α_1	0.3055*** (0.0539)	0.1092*** (0.0281)	0.0489*** (0.0107)
β_1	0.7151*** (0.0402)	0.8519*** (0.0400)	0.9472*** (0.0111)
ω	2.15e-06*** (6.72e-07)	1.72e-05** (7.47e-06)	3.51e-06** (1.44e-06)
DCC			
λ_1	0.0048 (0.0043)		
λ_2	0.9886*** (0.0040)		
Diagnostic			
$Q(10)$	10.5942 (0.3900)	8.4730 (0.5827)	10.1753 (0.4252)
$Q^2(10)$	7.9005 (0.6386)	2.7434 (0.9868)	2.4563 (0.9915)

Notes:

The numbers in parentheses are standard errors.

Q (10) is the Ljung–Box Q statistics for the null hypothesis that states that there is no autocorrelation up to orders 10 for standardized residuals.

The *, ** and *** mean significance at the 10%, 5% and 1% levels.

The coefficients of dynamic conditional correlation between RTS and oil price are positive and their values are higher as compared with the pre-crisis period. It means during the crisis low oil price returns coincided with comparatively higher fall in RTS's returns. The volatility of the coefficients also is higher during the crisis period.

For most of observation period, beginning in March 2014 when the sanctions started, the coefficients have an increasing trend, which means an increasing positive correlation between the return series. The absolute values of RTS's dynamic conditional correlation coefficients with Brent are larger than the dynamic conditional correlation coefficients with WTI (Figures 1 and 2).

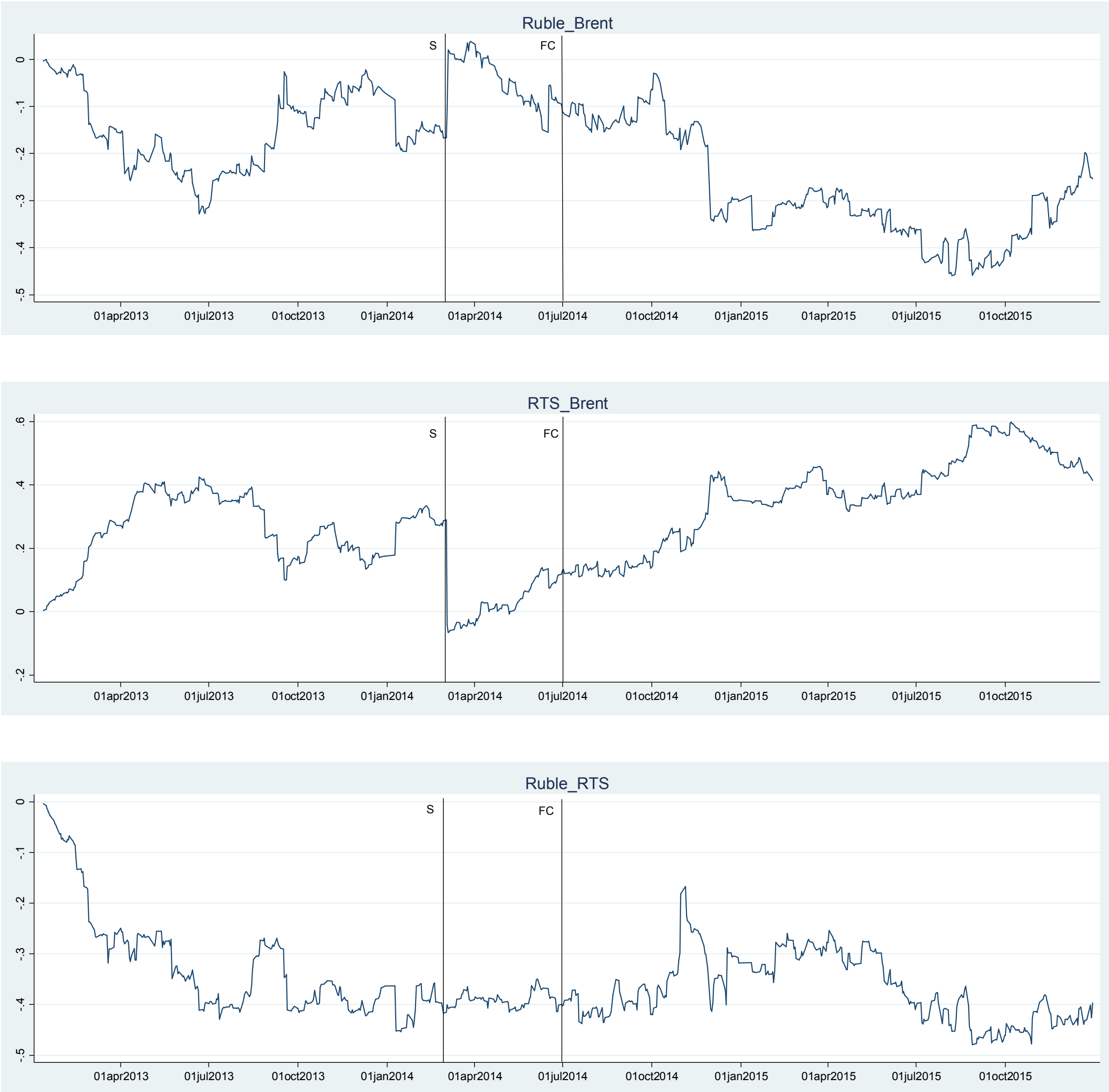

Figure 1. Dynamic conditional correlation between foreign exchange, stock and commodity markets: The rouble, RTS and Brent

The dynamic conditional correlation coefficients between RTS and the rouble are negative. This dynamic correlation during the crisis is very similar to the pre-crisis period. The only point which should be noticed is the fact that for the period of October 2014 to July 2015, its absolute value was slightly decreased and increased thereafter.

So far, we have explained the coefficients between the logarithmic return series. However, it is difficult to say what explain the cause or the consequence in this process. Using two subsets of the data for the pre-crisis and the crisis period in the CCF test, we estimated the causality-in-mean and casualty-in-variance between the return series.

Table 6 shows the results of AR-EGARCH for each variable. The data used in estimations are tested for structural breaks. The tests do not reject the null hypothesis of no structural break. The standardized residuals and their squared values based on residuals and variances derived from the models in Table 6 are used for the estimation of cross-correlation coefficients. The cross-correlation coefficients are used for the estimation of the causality in the mean and variance between the logarithmic return series.

Figure 2. Dynamic conditional correlation between foreign exchange, stock and commodity markets: The rouble, RTS and WTI

Table 7 shows the results obtained from the test statistics for causality in the mean and variance from the oil price to the rouble and RTS before and during the crisis period.

For 5 lags, which mean a week in our data set, there is evidence of causality in the mean from the oil price to the rouble and RTS before and during the crisis, and causality in the variance to the rouble before the crisis. It means that the trends of the return series of the exchange rate of the rouble and RTS index were significantly affected by the oil price. The impact on the rouble was especially significant during the crisis period. Furthermore, the volatility in the oil price (Brent) may have contributed to changes in the volatility of the rouble's exchange rate returns before the crisis. The volatility changes in the return series of the exchange rate of the rouble and RTS index during the crisis were not influenced by the volatilities in oil prices.

Table 6. Results of the AR-EGARCH models

Period	Before crisis				During crisis			
Market	Rouble	RTS	Brent	WTI	Rouble	RTS	Brent	WTI
Model	G(2, 1, 1)	G(1, 1, 1)	G(2, 1, 1)	G(1, 1, 1)	G(1, 1, 1)	G(1, 1, 1)	G(1, 1, 1)	G(1, 1, 1)
Mean								
a_1	0.0399 (0.0468)	0.1133** (0.0468)	0.0299 (0.0529)	-0.0549 (0.0463)	0.0296 (0.0574)	0.0869 (0.0532)	0.0620 (0.0410)	-0.1344*** (0.0493)
a_2	-0.0182 (0.0446)		-0.0255 (0.0529)					
Constant	0.0005** (0.0002)	-0.0006 (0.0005)	-0.0001 (0.0005)	0.0006 (0.0006)	0.0023*** (0.0006)	-0.0026** (0.0011)	-0.0019** (0.0007)	-0.0048*** (0.0012)
Variance								
α_1	-0.0070 (0.0161)	0.0423 (0.1014)	-0.1654*** (0.0624)	-0.0581 (0.0537)	0.1027* (0.0554)	-0.0970*** (0.0189)	-0.0620* (0.0358)	-0.0856*** (0.0215)
γ_1	0.1078** (0.0492)	0.2828** (0.1342)	0.0541 (0.0727)	-0.0684 (0.0834)	0.5278*** (0.0852)	0.0999** (0.0440)	0.1276* (0.0718)	0.0520 (0.0389)
β_1	-0.9900*** (0.0123)	-0.2872 (0.5467)	0.9010*** (0.0450)	-0.9184*** (0.1019)	0.9443*** (0.0208)	0.9938*** (0.0114)	0.9949*** (0.0127)	0.9977*** (0.0099)
ω	-21.2437*** (0.1479)	-10.8444** (4.5988)	-0.9065** (0.4120)	-17.0974*** (0.9332)	-0.4579** (0.1808)	-0.0439 (0.0859)	-0.0275 (0.0923)	-0.0101 (0 .0688)
GED parameter	0.4207*** (0.1107)	0.0465 (0.0640)	0.5720*** (0.1146)	0.3414*** (0.0820)	0.4801*** (0.1284)	0.5823*** (0.1134)	-0.0419 (0.0942)	0.2297** (0.0981)
Diagnostic								
$Q(10)$	0.0346 (1.0000)	17.1712 (0.0707)	10.0416 (0.4368)	10.6406 (0.3862)	8.7267 (0.5582)	2.9099 (0.9835)	16.6888 (0.0815)	5.4004 (0.8629)
$Q^2(10)$	0.0295 (1.0000)	6.4490 (0.7762)	7.8647 (0.6420)	1.8604 (0.9973)	6.9114 (0.7338)	16.1049 (0.0967)	2.7957 (0.9858)	3.2445 (0.9751)

Notes:

The numbers in parentheses are standard errors.

Q (10) is the Ljung–Box Q statistics for the null hypothesis that states that there is no autocorrelation up to orders 10 for standardized residuals.

The *, ** and *** mean significance at the 10%, 5% and 1% levels.

Similar estimations for causality-in-mean and variance from stock market demonstrate that roubles exchange rates returns and their volatility were influenced also by RTS before and during the crisis. RTS caused causality in mean to WTI, before the crisis too (Table A1).

Test statistics for causality-in-mean and variance from foreign exchange market show that before the crisis RTS returns were affected by the rouble's exchange rate returns at lag 5 and during the crisis RTS returns' volatilities were affected by volatilities of the rouble's exchange rate returns at lags 1 to 3 (Table A2).

Comparison of the estimation results in Tables 7, A1 and A2 demonstrate unidirectional causality in mean from commodity market to foreign exchange market before the crisis and unidirectional causality in variance from commodity market to foreign exchange market during the crisis. The derived results show bidirectional causality in mean between the commodity and stock markets before the crisis. There is unidirectional causality in mean from the commodity market to the stock market during the crisis. Causality-in-mean before the crisis and causality-in-variance during the crisis are bidirectional between the stock and foreign exchange markets. There is unidirectional causality in variance before the crisis and unidirectional causality in mean during the crisis from the stock market to the foreign exchange market.

Table 7. Test statistics for causality-in-mean and variance from the commodity market

Brent								
	Causality-in-Mean				Causality-in-Variance			
	Before crisis		During crisis		Before crisis		During crisis	
Lags	Rouble	RTS	Rouble	RTS	Rouble	RTS	Rouble	RTS
1	-0.0082	0.0283	-0.2522***	0.0140	-0.0342	-0.0366	0.0020	-0.0441
2	-0.0444	0.0532	-0.0117***	0.0130	-0.0158	-0.0334	-0.0090	0.0221
3	-0.1176	-0.0007	0.046***	-0.0410	0.1406**	-0.0300	-0.0025	-0.0009
4	0.1128**	-0.0173	0.0404***	0.0320	0.1172***	-0.0319	-0.0595	-0.0020
5	0.0197	-0.0199	-0.0426***	-0.0683	-0.0276***	-0.0004	-0.0848	-0.0610
WTI								
	Causality-in-Mean				Causality-in-Variance			
	Before crisis		During crisis		Before crisis		During crisis	
Lags	Rouble	RTS	Rouble	RTS	Rouble	RTS	Rouble	RTS
1	-0.0031	0.1027**	-0.3560***	0.0973**	-0.0220	-0.0178	0.0165	-0.0137
2	-0.0903	0.0764**	-0.0285***	0.0522	0.0355	-0.0434	-0.0386	0.0128
3	-0.0730	-0.0783**	0.0170***	-0.1004**	0.0194	-0.0214	-0.0008	0.0043
4	0.1170**	-0.0345	0.0205***	0.0530**	0.0805	0.0071	-0.0542	-0.0171
5	0.0056	0.0000	0.0443***	-0.0485	-0.0219	-0.0263	-0.0832	-0.0701

Notes:

The ** and *** mean significance at the 5% and 1% levels based on the standardized version of Cheung and Ng's (1996) chi-square test statistic proposed by Hong (2001).

5. Conclusion

In this paper, we estimated the dynamic conditional correlation, causality-in-mean and causality-in-variance among foreign exchange, stock and commodity markets for the case of Russia during and before the ongoing Russian financial crisis, which started in mid-2014. The paper has noted that the trend of the return series of the exchange rate of the rouble and RTS index were significantly affected by the oil price and that the impact on the rouble was especially significant during the crisis period. The research has also shown that the volatility in oil prices (Brent) has contributed to changes in the volatility of rouble's exchange rate returns before the crisis; however, the volatility changes in the exchange rate of the rouble and RTS index returns during the crisis were not influenced by the volatilities in oil prices. The rouble's exchange rate returns and their volatility were also influenced by RTS before and during the crisis. Before the crisis, RTS returns were affected by the rouble's exchange rate returns, and during the crisis, RTS returns' volatilities were affected by volatilities of the rouble's exchange rate returns.

The paper provides scientific elements to identify and validate the effects of oil price fall over the Russia's stock and foreign exchange markets performance. It contributes to the existing knowledge on the Russian financial crisis by providing information on the dynamic relationship between the Russian foreign exchange and stock markets from one side and the oil price – one of the main causes of the crisis – on the other side. The paper confirms previous findings (a significant effect of the changes in oil prices on Russian financial markets) and contributes additional evidence that suggests difference in dynamic conditional correlation and causality relationship among commodity, foreign exchange and stock markets during the crisis period compared to the pre crisis period.

The derived results promote a better understanding of the impact of oil prices on Russian foreign exchange and stock markets, and have important implications for policy makers and investors in Russia and the countries affected by Russian crisis. The paper raises many important questions, for example, the relationship between other important macroeconomic fundamentals that are in need of further investigation.

Appendix

Table A1. Test statistics for causality-in-mean and variance from the stock market

RTS						
	Causality in Mean			Causality in Variance		
Before crisis						
Lags	Ruble	Brent	WTI	Ruble	Brent	WTI
1	-0.0517	0.0568	0.0985**	-0.0019	-0.0697	0.0176
2	-0.0355	-0.0630	0.0477	-0.0089	0.0352	0.0154
3	0.1011	0.0236	-0.0244	0.0310	0.0214	-0.0359
4	-0.4699***	0.0057	-0.0607	0.9492***	0.0643	-0.0236
5	0.0181***	-0.0248	-0.0392	-0.007***	0.0864	0.0966
During crisis						
Lags	Ruble	Brent	WTI	Ruble	Brent	WTI
1	-0.5568***	0.0839	0.0013	0.2665***	-0.0432	0.0260
2	-0.0257***	0.0027	0.0420	0.195***	-0.0285	0.0079
3	0.0582***	-0.0392	-0.0471	-0.0356***	-0.0141	0.0166
4	0.0309***	0.0221	0.0329	0.0061***	0.0319	-0.0082
5	-0.0583***	0.0077	-0.0215	-0.0922***	-0.0217	-0.0121

Notes:

The ** and *** mean significance at the 5% and 1% levels based on the standardized version of Cheung and Ng's (1996) chi-square test statistic proposed by Hong (2001).

Table A2. Test statistics for causality-in-mean and variance from the foreign exchange market

Ruble						
Causality in Mean				Causality in Variance		
Before crisis						
Lags	RTS	Brent	WTI	RTS	Brent	WTI
1	-0.0003	-0.0002	-0.0004	0.0000	-0.0001	0.0000
2	-0.0804	-0.0185	-0.0951	0.0150	-0.0314	0.0453
3	-0.0599	-0.0157	0.0066	0.0007	-0.0320	-0.0220
4	-0.0412	0.0258	0.0299	-0.0056	-0.0265	-0.0168
5	0.1847***	-0.0518	-0.0375	0.1310	-0.0025	-0.0096
During crisis						
Lags	RTS	Brent	WTI	RTS	Brent	WTI
1	0.0024	-0.0437	-0.0401	0.1170***	-0.0025	0.0832
2	0.0313	0.0019	-0.0414	0.0864***	0.0436	0.0076
3	0.0533	0.0315	0.0284	0.0011**	0.0175	0.0547
4	0.0082	-0.0338	0.0357	-0.0030	0.0416	0.0194
5	0.0737	-0.0185	-0.0391	-0.0298	-0.0235	-0.0325

Notes:

The ** and *** mean significance at the 5% and 1% levels based on the standardized version of Cheung and Ng's (1996) chi-square test statistic proposed by Hong (2001).

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