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Causality Relationship among Oil Price, Stock Index and Exchange Rate: Evidence from Russia*

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1. Introduction

The international oil price fell below 20 US dollar per barrel in November 1997 and remained stagnant in 1998. However, after it hit bottom at 10.72 US dollar per barrel in December 1998, it rose to 140 US dollar by June 2008.[1] High oil prices contributed to the rapid development of the Russian economy, which grew at 7.3 percent per annum from 2003 through 2007 on average.[2] As Russia is one of the largest oil producers in the world, Russian financial and economic indicators could have strong correlations with international oil prices.

Numerous articles argue that there is a relation between oil prices and financial indicators. As for the relations between oil prices and exchange rates, Bloomberg and Harris explain how exchange rates could affect oil prices, assuming commodities to be subject to the law of one price.[3] If the dollar weakens relative to other currencies, all else being equal, commodity consumers outside the United States should be willing to pay more dollars for commodity inputs. On the other hand, Krugman argues how oil price movements could affect exchange rates, proposing a model with speculation the dollar may either appreciate or depreciate in the short-run when the price of oil increases.[4] However, in the long-run the dollar depreciates because of the adverse terms of trade effects and expectations of a depreciating dollar. Among empirical

* This work was supported by JSPS KAKENHI Grant Number 24530311.

1 Daily futures prices of New York Mercantile Exchange light sweet crude oil at Cushing, Oklahoma, Contract 1 (near month).

2 Oil price increases enabled Russia to achieve rapid economic growth, but Russia is claimed to suffer from Dutch Disease because of the increase of oil prices. See World Bank, *Russian Economic Report* 11 (Washington: World Bank, 2005); S. Ollus and S. Barisitz, *The Russian Non-Fuel Sector: Signs of Dutch Disease?: Evidence from EU-25 Import Competition* (Helsinki: Bank of Finland, BOFIT Online, 2/2007, 2007). On the other hand, Oomes and Kalcheva claim that although they find evidence of Dutch Disease, that is, real appreciation, a declining manufacturing sector, an expanding service sector, and rapid real wage growth, more research is needed to determine whether these symptoms are caused by other factors. See N. Oomes and K. Kalcheva, *Diagnosing Dutch Disease: Does Russia Have the Symptoms?* (Washington: IMF, IMF Working Paper, 07/102, 2007).

3 S. B. Bloomberg and E. S. Harris, "The Commodity-consumer Price Connection: Fact or Fable?" *Federal Reserve Board of New York, Economic Policy Review* (October 1995), pp. 21–38.

4 P. Krugman, "Oil Shocks and Exchange Rate Dynamics," in J. A. Frankel, ed., *Exchange Rates and International Macroeconomics* (Chicago: University of Chicago Press, 1983), pp. 259–284.

studies, Lizardo and Mollick found that increases in real oil prices led to a significant depreciation of the US dollar against net oil exporter currencies, such as Canada, Mexico, and Russia, whereas the currencies of oil importers, such as Japan, depreciated relative to the US dollar when the real oil price rose.[5] On the other hand, Akram claims that oil prices rose when the real value of the dollar depreciated.[6] Zhang et al. also suggest that the US dollar depreciation was a key factor in driving up the international crude oil price.[7]

As for the relations between oil prices and stock prices, Basher et al. indicate that oil prices can affect stock prices by impacting future cash flows.[8] On the other hand, stock prices in oil-producing countries can affect oil prices because the increase in oil companies' profits, which is reflected in their stock price rise, could lead to the growth of oil companies' investment and oil supply. Hammoudeh and Huimin found that there is a negative bi-directional dynamic relationship between the oil futures price growth and the return of the world capital market, and that the oil price growth has a positive impact on oil-related stocks.[9] The results of Park and Ratti show that oil price shocks have a statistically negative significant impact on real stock returns contemporaneously and/or within the following month in the United States and 12 European countries whereas Norway, as an oil exporter, shows a statistically significantly positive response of real stock returns to an oil price increase.[10]

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5 R. A. Lizardo and A. V. Mollick, "Oil Price Fluctuations and US dollar Exchange Rates," *Energy Economics* 32 (2000), pp. 399–408.

6 Q. F. Akram, "Commodity Prices, Interest Rates and the Dollar," *Energy Economics* 31 (2009), pp. 838–851.

7 Y. F. Zhang, Y. Fan, H. T. Tsai, and Y. M. Wei, "Spillover Effect of US Dollar Exchange Rate on Oil Prices," *Journal of Policy Modelling* 30 (2008), pp. 973–991. As for other studies on this topic, see R. A. Amano and S. van Norden, "Oil Prices and the Rise and Fall of the US Real Exchange Rate," *Journal of International Money and Finance* 17 (1998), pp. 299–316; A. Bénassy-Quéré, V. Mignon and A. Penot, "China and the Relationship between the Oil Price and the Dollar," *Energy Policy* 35 (2007), pp. 5795–5805; S. S. Chen and H. C. Chen, "Oil Prices and Real Exchange Rates," *Energy Economics* 29 (2007), pp. 390–404; P. Sadorsky, "The Empirical Relationship between Energy Futures Prices and Exchange Rates," *Energy Economics* 22 (2000), pp. 253–266.

8 S. A. Basher, A. A. Haug and P. Sadorsky, "Oil Prices, Exchange Rates and Emerging Stock Markets," *Energy Economics* 34 (2012), pp. 227–240.

9 S. Hammoudeh and L. Huimin, "Oil Sensitivity and Systematic Risk in Oil-sensitive Stock Indices," *Journal of Economics and Business* 57 (2005), pp. 1–21.

10 J. Park and R. A. Ratti, "Oil Price Shocks and Stock Markets in the U.S. and 13 European Countries," *Energy Economics* 30 (2008), pp. 2587–2608. As for other studies on this topic, see S. A. Basher and P. Sadorsky, "Oil Price Risk and Emerging Stock Markets," *Global Finance Journal* 17 (2006), pp. 224–251; S. Hammoudeh, S. Dibooglu and E. Aleisa, "Relationships among US Oil Prices and Oil Industry Equity Indices," *International Review of Economics and Finance* 13 (2004), pp. 427–453; S. Ono, "Oil Price Shocks and Stock Markets in BRICs," *The European Journal of Comparative Economics* 8 (2011), pp. 29–45; E. Papapetrou, "Oil Price Shocks, Stock Markets, Economic Activity and Employment in Greece," *Energy Economics* 23 (2001), pp. 511–532.

The relations between stock prices and exchange rates are mainly explained by the goods market approach of Dornbusch and Fischer[11] and the portfolio balance approach of Frankel.[12] The former claims that exchange rate changes affect the competitiveness of a firm, which in turn influences the firm's earnings and its stock price. On the other hand, the latter claims that a rising stock market would attract capital flows, which increases the demand for the domestic currency and causes the appreciation of exchange rates. Hatemi-J and Irandous,[13] and Ajayi et al.[14] found unidirectional causality from stock prices to exchange rates. Abdalla and Murinde indicate unidirectional causality from exchange rates to stock prices.[15] Bahmani-Oskooee and Sohrabian,[16] and Granger et al.[17] found bidirectional causality between stock prices and exchange rates. The empirical results of Pan et al.[18] show a causal relation from exchange rates to stock prices during the Asian crisis for all analyzed countries except Malaysia, which cannot be explained by the goods market approach, but in part by investors' herding behavior.

Furthermore, Basher et al.,[19] and Śmiech and Papież[20] examined the relations between oil prices, exchange rates and stock prices. Basher et al.[21] showed that, in the short run, positive shocks to oil prices tend to depress emerging market stock prices and US dollar exchange rates. Śmiech and Papież[22] found various causalities, but the only stable relationship appeared for Brent oil price, which consistently influenced the US dollar-euro exchange rate.

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11 R. Dornbusch and S. Fischer, "Exchange Rates and Current Account," *American Economic Review* 70 (1980), pp. 960–971.

12 J. A. Frankel, "Monetary and Portfolio-balance Models of the Determination of Exchange Rates," in J. A. Frankel, ed., *On Exchange Rates* (Cambridge: MIT Press, 1993), pp. 95–116.

13 A. Hatemi-J and M. Irandoust, "On the Causality between Exchange Rates and Stock Prices: A Note," *Bulletin of Economic Research* 54 (2002), pp. 197–203.

14 R. Ajayi, J. Friedman and S. Mehdian, "On the Relationship between Stock Returns and Exchange Rates: Tests of Granger Causality," *Global Finance Journal* 9 (1998), pp. 241–251.

15 I. S. A. Abdalla and V. Murinde, "Exchange Rate and Stock Price Interactions in Emerging Financial Markets: Evidence on India, Korea, Pakistan, and Philippines," *Applied Financial Economics* 7 (1997), pp. 25−35.

16 M. Bahmani-Oskooee and A. Sohrabian, "Stock Prices and the Effective Exchange Rate of the Dollar," *Applied Economics* 24 (1992), pp. 459–464.

17 C. Granger, B. Huang and C. Yang, "A Bivariate Causality between Stock Prices and Exchange Rates: Evidence from Recent Asian Flu," *The Quarterly Review of Economics and Finance* 40 (2000), pp. 337–354.

18 M. Pan, R. C. Fok and Y. A. Liu, "Dynamic Linkages between Exchange Rates and Stock Prices: Evidence from East Asian Markets," *International Review of Economics and Finance* 16 (2007), pp. 503–520.

19 Basher et al., "Oil Prices, Exchange Rates."

20 S. Śmiech and M. Papież, "Fossil Fuel Prices, Exchange Rate, and Stock Market: A Dynamic Causality Analysis on the European Market," *Economics Letters* 118 (2013), pp. 199–202.

21 Basher et al., "Oil Prices, Exchange Rates."

22 Śmiech and Papież, "Fossil fuel prices."

This paper implements estimations, including the international oil price, the Russian stock index and the Russian roble exchange rate in the model, and examines the causality among them. As mentioned above, the oil industry plays an essential role in Russian economic growth while there are arguments that Russia is suffering from Dutch Disease. Using these three series helps us to examine whether the oil price exerts an influence on the roble exchange rate and economic conditions, and determine the peculiarities of the Russian economy. Furthermore, causality between stock prices and the roble exchange rate can be investigated to determine whether the exchange rate affects Russia's economic conditions or whether Russia's economic conditions influence international capital flows and the exchange rate. In connection with this argument, the causality between stock prices and the exchange rate during the Russian financial crisis in 1998 is compared with that of the global financial turmoil in 2008.

Moreover, unlike former studies, this paper divides the analyzed period into seven sub-periods because causality among the oil price and financial indicators could change depending on economic conditions. In particular, the Russian economy experienced the federal government's default and the financial crisis in 1998, the rapid output recovery after 1999, the dramatic rise of crude oil prices in international commodity markets, the global financial turmoil in 2008 and the following plunge in stock and oil prices. Therefore, this paper examines causality changes among the oil price, the stock index and the exchange rate.

In this paper, Section 2 presents a short history of the Russian foreign exchange system. Section 3 describes the data sources for the analysis and methodological issues. Section 4 presents the empirical results. The last section summarizes the conclusions of this paper.

2. Short History of the Russian Foreign Exchange System

Russia's foreign exchange system has changed depending on macroeconomic conditions. A short history of the currency exchange scheme is as follows. The roble exchange rate depreciated following the Russian transition to a market economy. However, the exchange rate began to stabilize and accordingly, the Russian government and the Central Bank of Russia introduced a fixed exchange rate of 4.3–4.9 robles per US dollar on July 6, 1995. Although the authorities introduced a crawling band from the second half of 1996, the fixed exchange rate band was adopted again after January 1, 1998, and was set within 5.25–7.15 robles per US dollar.[23]

Although macroeconomic indicators showed favorable values in 1997, crisis was near at hand. During the first half of 1998, about 50 percent of federal tax revenue was needed to service the debt, and just before the crisis all federal

23 For details, see Organisation for Economic Co-operation and Development, (OECD), *OECD Economic Surveys 1997–1998: Russian Federation* (Paris: OECD Publishing, 1998).

tax revenue was so used.[24] Government bond prices began to plummet in early August 1998, and many banks attempted to sell their government bond portfolios in order to meet their current obligations on foreign loans, which caused a further fall of government bond prices and the depreciation of the Russian ruble. On August 17, 1998, the Russian authorities announced a series of measures, including a new exchange rate band of 6–9.5 rubles per US dollar, and Russia moved to a freely floating exchange rate regime on September 2, 1998.[25]

Russian exporters had been required to convert a certain share of export earnings into the Russian ruble in accordance with the currency market regulations of the Central Bank of Russia. The share of the mandatory sale of export revenues was lifted from 50 percent to 75 percent at the beginning of 1999. It was gradually decreased, and the regulations were abolished on May 7, 2006.[26] Furthermore, the deposit requirements for foreign investors by the Central Bank of Russia were eliminated on July 1, 2006, leading to the liberalization of capital movement.[27]

In January 2009 the Central Bank of Russia set a wide exchange rate corridor at 26–41 rubles for the US dollar-euro basket.[28] Furthermore, a sliding narrow exchange rate corridor was introduced to complement the wide corridor, the width of which was initially set at two rubles. The Central Bank of Russia intervenes to keep the ruble exchange rate within the band, but the limits of the band are automatically readjusted if the amount of interventions exceeds a certain pre-set level.[29] The band was widened from six rubles to seven rubles in July 2012[30] and the intervention volumes that trigger an automatic shift of the band's limits were set to be 500 million US dollars in December 2011.[31]

3. Data and Methodology

This study applies a vector autoregressive (VAR) model with Russian data from the beginning of November 1997 through the end of 2012. Weekly average data of the oil price, the stock index and the ruble exchange rate are

24 P. Sutela, *The Financial Crisis in Russia* (Helsinki: Bank of Finland, BOFIT Online, 11/1999, 1999).

25 For details, see OECD, *OECD Economic Surveys 1999–2000: Russian Federation* (Paris: OECD Publishing, 2000).

26 *Vedomosti*, March 28, 2006; *Kommersant*, May 31, 2006.

27 *Kommersant*, May 31, 2006; Central Bank of Russia (CBR), *Annual Report for 2006* (Moscow: Prime-TASS, 2007).

28 The bi-currency basket was composed of 55 percent US dollar and 45 percent euro. This wide corridor was abolished in October 2010.

29 The Central Bank of Russia also conducts so-called "targeted" interventions, which are not part of the intervention volumes that trigger an automatic shift of the band's limits. These "targeted" interventions aim to neutralize market expectations regarding exchange rate movements that might be formed on a basis of terms-of-trade trends. OECD, *OECD Economic Surveys: Russian Federation 2011* (Paris: OECD Publishing, 2011).

30 *Vedomosti*, July 25, 2012.

31 CBR, *Annual Report for 2011* (Moscow: Prime-TASS, 2012).

used instead of daily data to avoid possible problems regarding time differences between Russia and the United States. Weekly average series are preferred over monthly series due to the greater number of observations, which is significant in evaluating the Russian currency crisis.

This paper applies a modified version of the Granger causality test proposed by Toda and Yamamoto.[32] Their method is applicable regardless of whether the VAR's are stationary, integrated of an arbitrary order, or cointegrated of an arbitrary order. After a lag length k is chosen, this paper estimates a $(k+d)$ th-order VAR using the data in their levels where d is the maximal order of integration. The coefficient matrices of the last d lagged vectors in the model are ignored (since these are regarded as zeros), and restrictions on the first k coefficient matrices can be tested.

The VAR model of order $k+d$ can be written as:

$$\begin{aligned} OIL_t = \alpha_0 &+ \sum_{i=1}^{k} \alpha_{1i} OIL_{t-i} + \sum_{j=k+1}^{d} \alpha_{2j} OIL_{t-j} + \sum_{i=1}^{k} \alpha_{3i} ST_{t-i} + \sum_{j=k+1}^{d} \alpha_{4j} ST_{t-j} \\ &+ \sum_{i=1}^{k} \alpha_{5i} FX_{t-i} + \sum_{j=k+1}^{d} \alpha_{6j} FX_{t-j} + \varepsilon_{1t} \end{aligned} \tag{1}$$

$$\begin{aligned} ST_t = \beta_0 &+ \sum_{i=1}^{k} \beta_{1i} OIL_{t-i} + \sum_{j=k+1}^{d} \beta_{2j} OIL_{t-j} + \sum_{i=1}^{k} \beta_{3i} ST_{t-i} + \sum_{j=k+1}^{d} \beta_{4j} ST_{t-j} \\ &+ \sum_{i=1}^{k} \beta_{5i} FX_{t-i} + \sum_{j=k+1}^{d} \beta_{6j} FX_{t-j} + \varepsilon_{2t} \end{aligned} \tag{2}$$

$$\begin{aligned} FX_t = \gamma_0 &+ \sum_{i=1}^{k} \gamma_{1i} OIL_{t-i} + \sum_{j=k+1}^{d} \gamma_{2j} OIL_{t-j} + \sum_{i=1}^{k} \gamma_{3i} ST_{t-i} + \sum_{j=k+1}^{d} \gamma_{4j} ST_{t-j} \\ &+ \sum_{i=1}^{k} \gamma_{5i} FX_{t-i} + \sum_{j=k+1}^{d} \gamma_{6j} FX_{t-j} + \varepsilon_{3t} \end{aligned} \tag{3}$$

where OIL_t is the log of futures prices of New York Mercantile Exchange light sweet crude oil, ST_t is the log of MICEX Index, and FX_t is the log of the Russian ruble exchange rate per US dollar at time t,. In Eq. (1) if $\alpha_{3i} \neq 0 \ \forall_i$, there is Granger causality from the stock index to the oil price, and if $\alpha_{5i} \neq 0 \ \forall_i$, the exchange rate Granger causes the oil price. In Eq. (2) Granger causality from the oil price to the stock index implies $\beta_{1i} \neq 0 \ \forall_i$, and there is Granger causality from the exchange rate to the stock index if $\beta_{5i} \neq 0 \ \forall_i$. Similarly, in

32 H. Y. Toda and T. Yamamoto, "Statistical Inference in Vector Autoregressions with Possible Integrated Processes," *Journal of Econometrics* 66 (1995), pp. 225–250.

Eq. (3) if $\gamma_{1i} \neq 0 \; \forall_i$, Granger causality from the oil price to the exchange rate is indicated, and if $\gamma_{3i} \neq 0 \; \forall_i$, there is Granger causality from the stock index to the exchange rate.

This paper divides the period analyzed in the research into seven sub-periods. In dividing the period into sub-periods this paper implements a test for the structural stability of VAR models. The VAR models of this paper are expressed as follows:

$$A(L)X_t = u_t \tag{4}$$

where $A(L) = I - A_1 L - \cdots - A_p L^p$ is a pth order lag polynomial, $LX_t = X_{t-1}$ and u_t is a 3×1 vector of serially uncorrelated disturbances with a mean zero and a covariance matrix Σ_u.[33]

When implementing the test for the structural stability, this paper applies the procedure used by Christiano,[34] Cecchetti and Karras,[35] and Miyao,[36] which is a test of whether overall parameter values are unchanged between the two periods before and after a given possible break date. Thus the null hypothesis that all the model parameters are the same is tested against the alternative of a structural shift.

In this method, the following system is estimated:

$$A(L)X_t + B(L)X_t d_t = \eta_t \tag{5}$$

where $B(L) = I - B_1 L - \cdots - B_p L^p$, d_t is a dummy variable that is set to be one after a given break date and η_t is a 3×1 vector of serially uncorrelated disturbances with a mean zero and a covariance matrix Σ_η.

The test statistics are equal to $(T - k)\left[\log|\Sigma_u| - \log|\Sigma_\eta|\right]$, where T is the number of observations, and k is the number of coefficients in Eq. (5). The test statistic is asymptotically Chi-squared with degrees of freedom equal to the total number of constraints, which is $(k/2)$ times the number of equations.

4. Empirical Results

This paper divides the period of analysis into seven sub-periods: before, during and after the 1998 financial crisis and the 2008 global financial turmoil. Furthermore, trend changes of the exchange rate are also taken into account in order to examine the validity of the goods market approach and the portfolio balance approach.

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33 In the argument here, constant terms are omitted for simplification.

34 L. J. Christiano, "Money and the U.S. Economy in the 1980s: A Break from the Past?" *Federal Reserve Bank Minneapolis Quarterly Review* (Summer 1986), pp. 2–13.

35 S. G. Cecchetti and G. Karras, "Sources of Output Fluctuations during the Interwar Period: Further Evidence on the Causes of the Great Depression," *Review of Economics and Statistics* 76 (1994), pp. 80–102.

36 R. Miyao, "The Role of Monetary Policy in Japan: A Break in the 1990s?" *Journal of the Japanese and International Economies* 14 (2000), pp. 366–384.

Specifically, Sub-period 1 is from the beginning of November 1997 through the Russian government's default in August 1998. Sub-period 2 is until the stabilization of the Russian financial markets in late 1998. Sub-period 3 is until the trend change of the ruble exchange rate in 2002. Sub-period 4 is until the beginning of the global financial turmoil in 2008. Sub-period 5 is the period during the global financial turmoil. Sub-period 6 is until the stabilization of the financial market in mid-2011. Sub-period 7 is the period of growing uneasiness of EU fiscal problems.

4-1. Sub-period 1

Sub-period 1 is set to be from November 1997 through the Russian government's default in August 1998. Data after November 1997 is used in the analysis because the period around this month can be regarded as the beginning of the Russian financial crisis. Specifically, Russian stock prices plunged on October 27–28, 1997 and the interest rates of the Russian government bonds began to soar around the beginning of November 1997.

Figure 1: Dynamics of the oil price, the stock index and the exchange rate for Sub-period 1

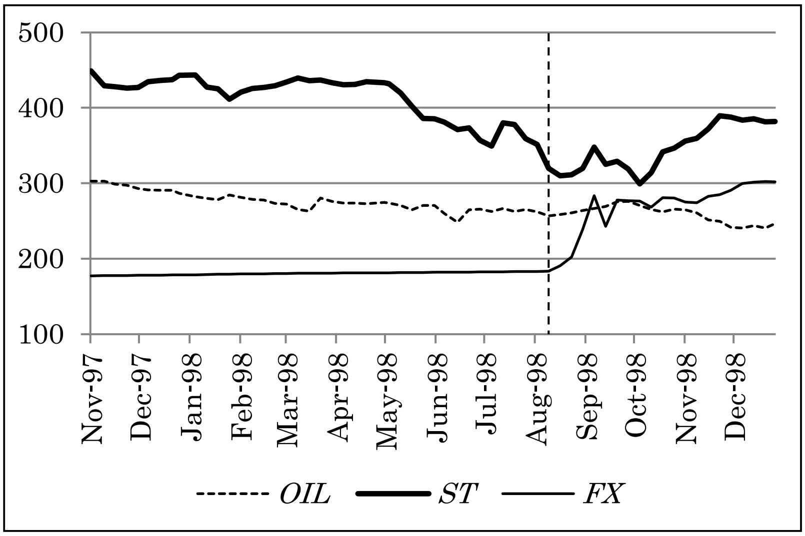


Table 1: Structural stability test results for Sub-period 1

Possible break	Chi-squared statistics	Sample period
August 14, 1998	22.89 (0.006) ***	November 6, 1997–December 31, 1998

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

This paper begins the analysis by implementing the structural break test to verify whether the Russian government's default shows a statistically appropriate break using data from the week ending on November 6, 1997 through the week ending on December 31, 1998 (Fig. 1). Table 1 presents results for a possible structural break related to the August 1998 financial crisis. According to the test results, the week of the Russian government's default declaration is shown to be a statistically significant structural break. Therefore, setting the first sub-period for the above-mentioned period (November 6, 1997–August 14, 1998) can be regarded as being appropriate.

Next, the order of integration of the variables is tested by the Augmented Dickey-Fuller unit root test (Table 2).[37] In the first sub-period *OIL* is stationary in its levels because it can reject the null hypothesis of the existence of a unit root. On the other hand, *ST* cannot reject the null hypothesis in its levels, but it is stationary in its first differences. *FX* cannot reject the null hypothesis both in its levels and first differences while it is stationary in its second differences. These results suggest that *OIL*, *ST* and *FX* can be characterized as $I(0)$, $I(1)$ and $I(2)$ in the first sub-period, respectively. In the estimation of the VAR model, the Schwarz information criterion (SIC) indicates the optimal lag length is one. As the maximums order of integration of the series is two, a third order of VAR is estimated.

Table 2: Augmented Dickey-Fuller unit root test results for Sub-period 1

Periods	Variables	Constant & trend		
		Log level	1st log difference	2nd log difference
Nov. 6, 1997–Aug. 14, 1998	*OIL*	–3.573 (0) **	–6.984 (1) ***	–6.425 (3) ***
	ST	–0.654 (0)	–4.974 (0) ***	–7.365 (1) ***
	FX	–1.665 (2)	–2.701 (1)	–4.880 (2) ***

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 3: Toda-Yamamoto non-causality test results for Sub-period 1

		Dependent variables		
		OIL	*ST*	*FX*
Independent variables	*OIL*	–	0.613	0.536
	ST	0.307	–	0.003
	FX	0.091	4.620**	–

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

The Toda-Yamamoto non-causality test results in Table 3 indicate that there is Granger causality from the exchange rate to the stock index in the first sub-period. Pan et al. also indicate the causality from the exchange rate to the stock index during the Asian financial crisis in 1997 in the cases of Hong Kong,

37 D. A. Dickey and W. A. Fuller, "Distributions of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association* 74 (1979), pp. 427–431.

Figure 2: Dynamics of the oil price, the stock index (left axis) and the exchange rate (right axis) for Sub-period 2

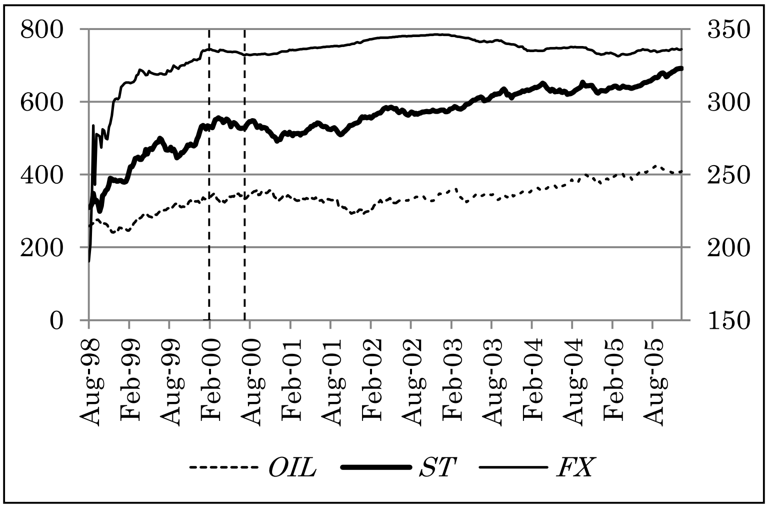


Table 4: Structural stability test results for Sub-period 2

Possible break	Chi-squared statistics	Sample period
February 18, 2000	77.54 (0.020) **	August 21, 1998–December 30, 2005
July 28, 2000	59.96 (0.269)	August 21, 1998–December 30, 2005

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 5: Augmented Dickey-Fuller unit root test results for Sub-period 2

		Constant & trend	
Periods	Variables	Log level	1st log difference
Aug. 21, 1998–Feb. 11, 2000	*OIL*	–2.292 (1)	–6.577 (0) ***
	ST	–1.891 (0)	–7.943 (0) ***
	FX	–7.740 (0) ***	–

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 6: Toda-Yamamoto non-causality test results for Sub-period 2

		Dependent variables		
		OIL	*ST*	*FX*
Independent variables	*OIL*	–	3.345*	0.012
	ST	0.188	–	0.056
	FX	0.058	4.409**	–

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Korea, Singapore, Taiwan and Thailand.[38] However, the depreciation of the exchange rate and the fall of stock prices cannot be explained by the goods market approach because the ruble depreciation is supposed to exert a favorable influence on both export-oriented industries and companies related to import substitution. According to the OECD, the Russian government's failure to finance its budget deficit properly caused a plunge of government bond prices, which stimulated banks to rush to sell government bonds in order to meet their obligations on foreign loans and protect themselves from exchange rate risk.[39] On the other hand, by July 1998 a number of banks had already defaulted on their forward contracts signed with foreign investors for the hedging of exchange rate risk.[40] These economic circumstances exerted a negative impact on Russian economic growth. Therefore, the causality from *FX* to *ST* can be explained by the evolution of the financial crisis.

4-2. Sub-period 2

The structural break test is implemented to determine a statistically appropriate break using data from the week ending on August 21, 1998 through the week ending on December 30, 2005 (Fig. 2). Table 4 presents results for possible structural breaks related to the stabilizing period after the Russian government's default. According to the test results, February 18, 2000, when the sharp depreciation of the ruble exchange rate receded, is shown to be a statistically significant structural break while July 28, 2000, when the slow appreciation trend of the ruble exchange rate ended, does not show statistical significance. Based on the results, Sub-period 2 is set to be from the week ending on August 21, 1998 through the week ending on February 11, 2000.

Next, the order of integration of the variables is tested by the Augmented Dickey-Fuller unit root test. Table 5 shows that in the second sub-period *OIL*, *ST* and *FX* can be treated as $I(1)$, $I(1)$ and $I(0)$, respectively. In the estimation of the VAR model, the SIC indicates the optimal lag length is one. As the maximum order of integration of the series is one, a second order of VAR is estimated.

The Toda-Yamamoto non-causality test results in Table 6 indicate that the exchange rate and the oil price have Granger causality with the stock index with statistical significance.

Persistent fiscal imbalances and structural weaknesses in the enterprise and banking sectors eventually compelled the Central Bank of Russia and the Russian government to implement a series of measures on August 17, 1998: a new exchange rate band, the cessation of payments on government bonds with maturities before the end of 1999, pending a restructuring of this debt, and a

38 Pan et al., "Dynamic Linkages."

39 OECD, *OECD Economic Surveys* (2000).

40 OECD, *OECD Economic Surveys* (2000).

90-day moratorium on payments by Russian banks and private firms on obligations to non-residents.[41]

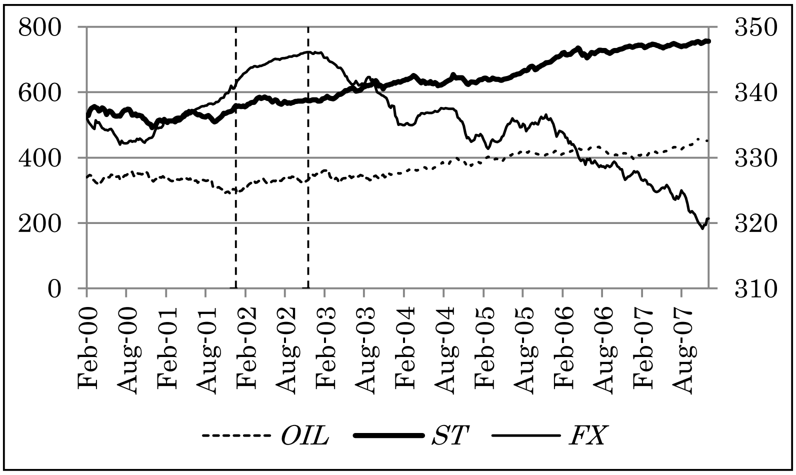
As a result of the financial crisis, the output of industrial production and services continued to decrease at the beginning of 1999. However, it turned positive in May and showed an increasing tendency thereafter. This rapid economic recovery is attributed to the treble depreciation of the Russian ruble, which provided Russian exporters with price competitiveness, and also prompted import-substitution in the domestic industries. Moreover, companies did not fall into a liquidity shortage caused by the financial difficulties of banks because of the low dependence of firms on banks in raising funds (for details see OECD, 2000). The causality from the exchange rate to the stock index can be explained by this context.

On the other hand, the causality from the oil price to the stock index implies that oil price increases improved Russian economic conditions. In fact, the international oil price bottomed out at $11.31 per barrel in December 1998, and showed an increasing tendency.

4-3. Sub-period 3

The ruble exchange rate against the US dollar tended to depreciate until late 2002. However, it began to show an appreciating trend on December 11, 2002 (Fig. 3). The structural break test is implemented to verify whether there is a structural break on December 11, 2002, using data from the week ending on February 25, 2000 through the week ending on December 28, 2007. The results in Table 7 indicate that there is no structural break on December 11, 2002.

Figure 3: Dynamics of the oil price, the stock index (left axis) and the exchange rate (right axis) for Sub-period 3



41 International Monetary Fund (IMF), *World Economic Outlook* (Washington D.C.: IMF, October 1999); OECD, *OECD Economic Surveys* (2000).

Table 7: Structural stability test results for Sub-period 3

Possible break	Chi-squared statistics	Sample period
January 11, 2002	34.43 (0.011) **	February 18, 2000–December 28, 2007
December 11, 2002	24.96 (0.126)	February 18, 2000–December 28, 2007

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 8: Augmented Dickey-Fuller unit root test results for Sub-period 3

		Constant & trend	
Periods	Variables	Log level	1st log difference
Feb. 18, 2000–Jan. 4, 2002	*OIL*	–1.523 (0)	–10.765 (0) ***
	ST	–3.172 (1) *	–
	FX	–1.921 (1)	–9.134 (0) ***

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 9: Toda-Yamamoto non-causality test results for Sub-period 3

		Dependent variables		
		OIL	*ST*	*FX*
Independent variables	*OIL*	–	0.089	1.262
	ST	3.125*	–	0.006
	FX	0.000	0.807	–

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

As the Russian ruble's trend change can be regarded as being important for the Russian economy, a statistically significant structural break is searched around the end of 2002. As shown in Table 7, there is a structural break with statistical significance on January 11, 2002. The international oil price hit the bottom around this week. In accordance with the statistical test results, Sub-period 3 is set to be from the week ending on February 25, 2000 through the week ending on January 4, 2002.

Next, the order of integration of the variables is tested by the Augmented Dickey-Fuller unit root test. Table 8 shows that in the third sub-period *OIL*, *ST* and *FX* can be treated as $I(1)$, $I(0)$ and $I(1)$, respectively. In the estimation of the VAR model, the SIC indicates the optimal lag length is one. As the maximum order of integration of the series is one, a second order of VAR is estimated.

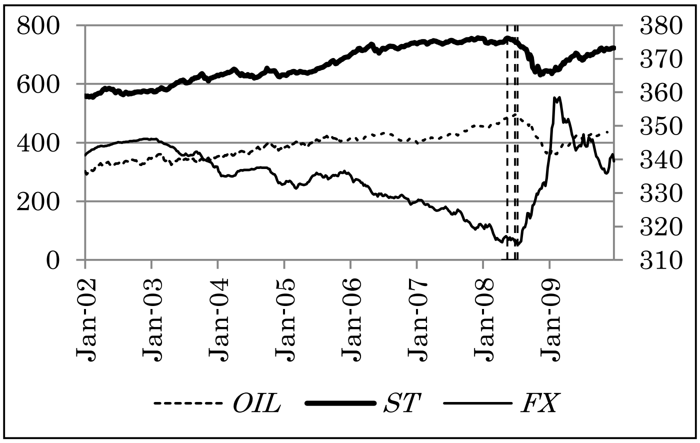
The Toda-Yamamoto non-causality test results in Table 9 indicate that there is Granger causality from the stock index to the oil price in Sub-period 3. The Russian stock index as well as the international oil price had a decreasing trend during the sub-period. Behind the decreasing tendency of Russian stock prices were negative returns in the world's stock index. Specifically, the MSCI

World Index fell from 1340.6 in February 29, 2000 to 1003.5 in December 31, 2001, which reflects the world economy's recession, partly caused by the end of the so-called dot-com bubble in the U.S. in 2000.[42] The global economic stagnation including Russia could put downward pressure on the international oil price.

4-4. Sub-period 4

The ruble exchange rate against the US dollar had a tendency to appreciate while stock and oil prices had an increasing trend before the global financial crisis in 2008.[43] The structural break tests are implemented to verify whether there is a structural break on May 23, 2008, when the stock index recorded the highest value in 2008, on July 4, 2008, when the international oil price recorded the highest value, and on July 18, 2008, when the ruble exchange rate recorded the highest value in 2008, using data from the week ending on January 11, 2002 through the week ending on December 31, 2009 (Fig. 4). The results in Table 10 indicate that the above-mentioned weeks can be regarded as statistically significant structural breaks. As the Chi-squared statistic took the largest value on July 18, 2008, Sub-period 4 is set to be from the week ending on January 11, 2002 through the week ending on July 11, 2008.

Figure 4: Dynamics of the oil price, the stock index (left axis) and the exchange rate (right axis) for Sub-period 4



42 The MSCI World Index is calculated on the basis of large and mid-cap representation across 23 developed markets countries. Data are available at the following website [http://www.mscibarra.com/products/indices/international_equity_indices/gimi/stdindex/performance.html]

43 Oil price increases and the appreciation of the ruble increased the money supply in the situation where there were insufficient sterilization instruments, which, in turn, fostered economic growth. See S. Ono, "Financial Development and Economic Growth: Evidence from Russia," *Europe-Asia Studies* 64 (2012), pp. 247–256; S. Ono, "The Effects of Monetary and Foreign Exchange Policies in Russia," *Economic Systems* 37 (2013), pp. 522–541.

Table 10: Structural stability test results for Sub-period 4

Possible break	Chi-squared statistics	Sample period
May 23, 2008	76.42 (0.00) ***	January 11, 2002–December 31, 2009
July 4, 2008	74.87 (0.00) ***	January 11, 2002–December 31, 2009
July 18, 2008	76.73 (0.00) ***	January 11, 2002–December 31, 2009

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 11: Augmented Dickey-Fuller unit root test results for Sub-period 4

		ADF	
		Constant & trend	
Periods	Variables	Log level	1st log difference
Jan. 11, 2002–Jul. 11, 2008	*OIL*	–3.001 (1)	–16.042 (0) ***
	ST	–2.490 (1)	–14.326 (0) ***
	FX	–1.948 (2)	–13.017 (1) ***

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 12: Toda-Yamamoto non-causality test results for Sub-period 4

		Dependent variables		
		OIL	*ST*	*FX*
Independent variables	*OIL*	–	0.266	5.674**
	ST	0.0562	–	2.508
	FX	0.7560	1.441	–

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

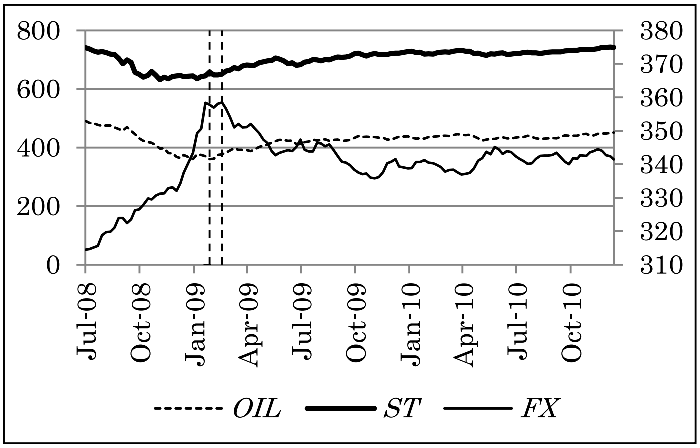
Next, the order of integration of the variables is tested by the Augmented Dickey-Fuller unit root test. Table 11 shows that in the fourth sub-period *OIL*, *ST* and *FX* can be treated as *I*(1). In the estimation of the VAR model, the SIC indicates the optimal lag length is one. As the maximum order of integration of the series is one, a second order of VAR is estimated.

The Toda-Yamamoto non-causality test results in Table 12 indicate that there is Granger causality from the oil price to the exchange rate in the fourth sub-period. This implies that the oil export revenue causes the appreciation of the Russian ruble exchange rate against the US dollar. This is the first sub-period in which a significant Granger causality from *OIL* to *FX* was detected. Hereafter, *OIL* continues to have a significant causality to *FX*, that is, from Sub-period 4 through Sub-period 7, as indicated below. It is noteworthy that the international oil price soared from 17.97 US dollars per barrel to 145.29 US dollars per barrel during the sub-period.

4-5. Sub-period 5

The ruble exchange rate against the US dollar had a depreciating trend while stock and oil prices tended to decrease during the global financial crisis. The structural break tests are implemented to verify whether there is a structural break on February 13, 2009, when the international oil price recorded the lowest value in 2009, and on March 6, 2009, when the Russian ruble exchange rate recorded the lowest value in 2009, using data from the week ending on July 18, 2008 through the week ending on December 30, 2009 (Fig. 5).

Figure 5: Dynamics of the oil price, the stock index (left axis) and the exchange rate (right axis) for Sub-period 5



The test results regarding a potential structural break on February 13, 2009 indicate statistical significance at the 1 percent level while that of March 6, 2009 is not statistically significant (Table 13). Based on the results, Sub-period 5 is set to be the period from July 18, 2008 through February 6, 2009.

Next, the order of integration of the variables is tested by the Augmented Dickey-Fuller unit root test. Table 14 shows that in the fifth sub-period *OIL*, *ST* and *FX* can be treated as *I*(1), *I*(2), and *I*(1). In the estimation of the VAR model, the SIC indicates the optimal lag length is one. As the maximum order of integration of the series is two, a third order of VAR is estimated.

The Toda-Yamamoto non-causality test results in Table 15 indicate that there is Granger causality both from the stock index and the oil price to the exchange rate in the fifth sub-period. In the context of the global financial turmoil triggered by the US subprime loan crisis, the Russian stock index plunged from about 1700 to around 550 during the sub-period whereas the international oil price fell from about 130 US dollars per barrel to below 40 US dollars per barrel. The exchange rate also plummeted from about 24 rubles per US dollar to 34 rubles per US dollar. This implies that investors sold stocks to exchange funds for the US dollar, and decreasing oil prices decelerated the Russian economy to cause the ruble depreciation. Furthermore, there is Granger causality from

Table 13: Structural stability test results for Sub-period 5

Possible break	Chi-squared statistics	Sample period
February 13, 2009	22.26 (0.001) ***	July 18, 2008–December 30, 2010
March 6, 2009	13.72 (0.133)	July 18, 2008–December 30, 2010

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 14: Augmented Dickey-Fuller unit root test results for Sub-period 5

		Constant & trend		
Periods	Variables	Log level	1st log difference	2nd log difference
Jul. 18, 2008–Feb. 6, 2009	*OIL*	–1.729 (0)	–6.098 (0) ***	–
	ST	–0.424 (3)	0.103 (2)	–10.673 (1) ***
	FX	–1.134 (0)	–4.933 (1) ***	–

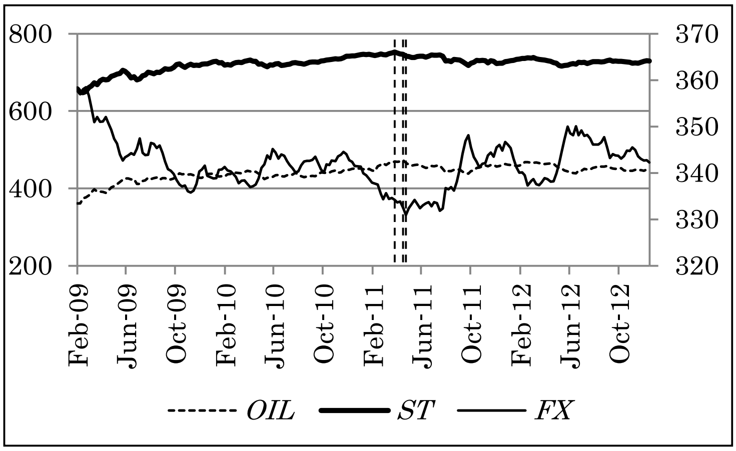
Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 15: Toda-Yamamoto non-causality test results for Sub-period 5

		Dependent variables		
		OIL	*ST*	*FX*
Independent variables	*OIL*	–	0.027	13.493***
	ST	0.407	–	13.375***
	FX	7.255***	1.693	–

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Figure 6: Dynamics of the oil price, the stock index (left axis) and the exchange rate (right axis) for Sub-period 6



the exchange rate to the oil price. This suggests that ruble depreciation reflects people's preference for hard currencies under the global economic recession, and global economic recession decreased demand for oil.

4-6. Sub-period 6

The structural break tests are implemented using data from the week ending on February 13, 2009 through the week ending on 28 December 2012 to verify whether there is a structural break on April 8, 2011, when the stock index recorded the lowest value in 2011, on April 29, 2011, when the oil price recorded the lowest value in 2011, and on May 6, 2011, when the Russian ruble exchange rate recorded the lowest value in 2011.

The structural stability test results indicate that there are structural breaks on April 8, 2011 at the 5 percent level and on April 29, 2011 at the 10 percent level. Based on the results, the sixth period is set to be from February 13, 2009 to April 1, 2011.

Next, the order of integration of the variables is tested by the Augmented Dickey-Fuller unit root test. Table 17 shows that in the sixth sub-period *OIL*, *ST* and *FX* can be treated as $I(0)$, $I(1)$, and $I(1)$. In the estimation of the VAR model, the SIC indicates the optimal lag length is one. As the maximum order of integration of the series is one, a second order of VAR is estimated.

The Toda-Yamamoto non-causality test results in Table 18 indicate that there is Granger causality from the oil price to the exchange rate in the sixth sub-period. The plunged international oil price rapidly recovered and exceeded 100 US dollars per barrel in March 2011. The causality from the oil price to the exchange rate implies that increasing oil prices caused the appreciation of the Russian ruble.

Table 16: Structural stability test results for Sub-period 6

Possible break	Chi-squared statistics	Sample period
Apr. 8, 2011	20.29 (0.016) **	February 13, 2009–December 28, 2012
Apr. 29, 2011	14.93 (0.093) *	February 13, 2009–December 28, 2012
May 6, 2011	13.93 (0.124)	February 13, 2009–December 28, 2012

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 17: Augmented Dickey-Fuller unit root test results for Sub-period 6

		Constant & trend	
Periods	Variables	Log level	1st log difference
Feb. 13, 2009–Apr. 1, 2011	*OIL*	–4.299 (1) ***	–
	ST	–2.576 (0)	–10.255 (0) ***
	FX	–2.635 (1)	–8.438 (0) ***

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 18: Toda-Yamamoto non-causality test results for Sub-period 6

		Dependent variables		
		OIL	*ST*	*FX*
Independent variables	*OIL*	–	0.495	5.956**
	ST	0.920	–	0.110
	FX	0.120	1.570	–

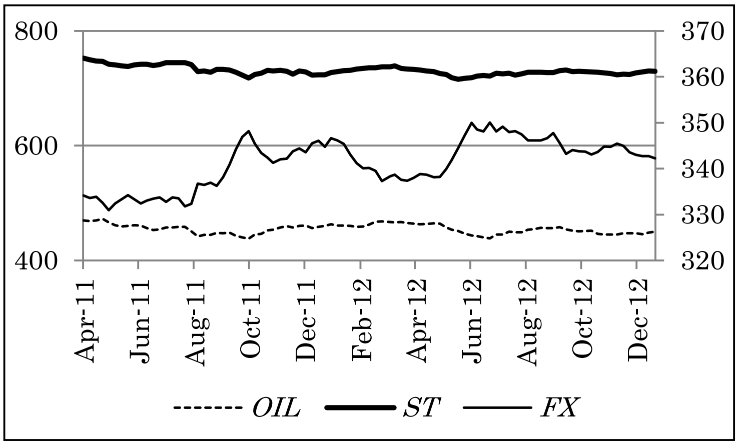
Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

4-7. Sub-period 7

Sub-period 7 is set to be the period from April 8, 2011 through the end of 2012 (Fig. 7). The order of integration of the variables is tested by the Augmented Dickey-Fuller unit root test. Table 19 shows that in the seventh sub-period *OIL*, *ST* and *FX* can be treated as *I*(1). In the estimation of the VAR model, the SIC indicates the optimal lag length is one. As the maximum order of integration of the series is one, a second order of VAR is estimated.

The Toda-Yamamoto non-causality test results in Table 20 indicate that there is Granger causality from the oil price to the exchange rate in the seventh sub-period. While the world economy's growth rate increased from –0.4 percent in 2009 to 5.2 percent in 2010, it decelerated to 3.9 percent in 2011 and 3.2 percent in 2012.[44] In this context the international oil price had a tendency to decrease. The above-mentioned Granger causality indicates that the decreasing oil price caused a depreciating trend in the ruble exchange rate.

Figure 7: Dynamics of the oil price, the stock index (left axis) and the exchange rate (right axis) for Sub-period 7



44 IMF, *World Economic Outlook* (Washington D.C.: IMF, October 2013).

5. CONCLUSIONS

This study examined the causality relations between the oil price, the stock index and the exchange rate for the period from late 1997 through 2012, using the vector autoregressive model. The analyzed period was divided into seven sub-periods based on structural break tests.

The results of the econometrical analysis are shown in Table 21. They suggest that the exchange rate leads the stock index in the 1998 Russian financial crisis, whereas the stock index leads the exchange rate in the 2008 global financial turmoil. Furthermore, the oil price leads the exchange rate from the beginning of 2002 through the end of 2012, which indicates that the ruble exchange rate is affected by international oil futures.

Future studies should address the question of whether the changes of the Russian industrial structure, which now largely depends on the oil and natural gas industry, can affect causality between the oil price and economic indicators.

Table 19: Augmented Dickey-Fuller unit root test results for Sub-period 7

		Constant & trend	
Periods	Variables	Log level	1st log difference
Apr. 8, 2011–Dec. 28, 2012	*OIL*	–2.585 (1)	–7.308 (0) ***
	ST	–2.681 (0)	–8.447 (0) ***
	FX	–2.167 (1)	–7.013 (0) ***

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 20: Toda-Yamamoto non-causality test results for Sub-period 7

		Dependent variables		
		OIL	*ST*	*FX*
Independent variables	*OIL*	–	1.042	6.088**
	ST	1.974	–	0.579
	FX	0.572	0.293	–

Note. Figures in parentheses are p-values. Superscripts ***, ** and * denote rejections of the null hypothesis by the 1, 5 and 10 percent significance levels, respectively.

Table 21: Granger causality from Sub-period 1 through Sub-period 7

	Causality from	to
Sub-period 1 Nov. 6, 1997–Aug. 14, 1998	*FX*	*ST*
Sub-period 2 Aug. 21, 1998–Feb. 11, 2000	*FX* *OIL*	*ST* *ST*
Sub-period 3 Feb. 18, 2000–Jan. 4, 2002	*ST*	*OIL*
Sub-period 4 Jan. 11, 2002–Jul. 11, 2008	*OIL*	*FX*
Sub-period 5 Jul. 18, 2008–Feb. 6, 2009	*ST* *OIL* *FX*	*FX* *FX* *OIL*
Sub-period 6 Feb. 13, 2009–Apr. 1, 2011	*OIL*	*FX*
Sub-period 7 Apr. 8, 2011–Dec. 28, 2012	*OIL*	*FX*