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Transmission of United States Monetary Policy Shocks to Oil Exporting Countries: A Vector Error Correction Approach to Mundellian Trilemma

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ABSTRACT

In this article we test the hypothesis of oil price channel of United States (US) monetary policy transmission to oil-exporting countries under floating exchange rate regime and free capital mobility. On the example of Russia, using quarterly data for the period from 2000 to 2016, we study the long-term and short-term relations between the US effective federal funds rate, world oil prices (Brent) and the Bank of Russia's key rate. The results of the vector error correction model show that the system of variables corrects its previous period disequilibrium at a speed 61.24% in one quarter. Based on the results of the Wald test, we find statistically significant causality running from world oil prices to interest rate policy of the Bank of Russia with the rate of adaptation to equilibrium by 10.21%. The results also show presence of causality running from US monetary policy to Bank of Russia's key rate with the speed of adjustment towards equilibrium at 25.69%. Overall results of the study show that a negative shock in US rate leads to decline in oil prices (Brent), which in turn leads to an increase in Russia's key rate. Revealed oil price transmission channel serves also as an additional argument against Mundell-Fleming trilemma, according to which under floating exchange rate and free capital mobility, monetary policy of the country may be independent.

Keywords: World Oil Prices, Transmission Channel, Mundell-Fleming Trilemma, Monetary Policy
JEL Classifications: E50, E58, F40, Q41, Q43

1. INTRODUCTION

The modern world's geopolitical and financial turbulence broke many basic laws relied on the established connections, relationships on world markets for goods, services and capital. Ensuring financial stability becomes the main leitmotif of the monetary policy of many national economies of the world. The financial stability, unlike price stability, allows to ensure stability in the markets of goods and services, capital markets, prevents the formation of bubbles on the credit markets, stock markets, asset markets. Since achievement of financial stability is put at the forefront of many central and reserve banks of the countries of the world, establishing optimal monetary policy becomes one of the priority tasks. To date, the activities of many of the central and reserve banks of the world fit into the dominant paradigm of the mainstream, according to which the control over the level of prices in the national economy is a key priority of their activities.

However, the price stability is far from a guarantor of financial stability, since, in the current context, the majority of crisis events is happening on asset markets, stock markets. In this regard, it is necessary to consider that the policy of monetary authorities may be optimal when and only when it is independent in nature. This implies the existence of tools and methods of central banks to respond to a set of exogenous and endogenous shocks.

Thus we can assume that the monetary policy of the national economy needs to be sensitive as well as relatively rigid. In other words, the monetary authorities must be able to respond to shocks both inside the country and outside. Among the exogenous shocks one can point out changes in the global trade and monetary flows, international capital flows, shifts in output of competing countries, the international flow of capital, changes in interest rate policy and the terms of refinancing on the international capital markets by monetary authorities in other countries. Endogenous shocks include changes in the level of prices for goods and services in the national economy, changes in the volume of investment, changes in marginal propensity to consume and savings behavior of households and business entities. Long-term factors represent just a partial list of those forces, including drastic ones which can lead to less effective monetary policy.

Since the main objective of monetary authorities of most countries is price stability, it is necessary to consider that each of these factors can influence effectiveness of monetary policy. The last decade was marked by the shift of majority of both developed and developing countries, to inflation targeting regime. It is the price stability that has been put at the forefront to ensure sustainable economic growth: Sustainable economic development. This belief is rooted in classical theoretical postulates linking the stability of prices of goods and services and employment in the economy. This relationship, established empirically, is called the Phillips curve. The essence of this relationship is reduced to the description of the inverse proportional relationship between the level of inflation in the national economy and the level of inflationary pressure in the markets for goods and services: The higher the inflation, the lower the unemployment and vice versa. The mechanism of the Phillips curve can be described in the following way: A positive price shock changes expectations of economic entities and implies the expectation of rising prices in short-medium term. In terms of labor-intensive growth of demand for manufactured goods and services leads to an increased demand for labor force, which leads to additional pressure on the labor market. This in turn leads to an increase in demand for labor force, increased employment, increased final consumption of households, ceteris paribus. The unwinding of this helix leads to an additional positive shock in demand for goods and services which in turn, in the short term, leads to higher prices for goods and services, due to shortages in supply in the short term. Monetary policy of most developed and developing countries of the world is empirically identify the relationship between the level of employment in the national economy and inflation. Thereby, controlling inflation of the national economy allows to indirectly influence the level of employment, and, consequently, the level of welfare of population. This, in turn, affects economic growth. Thus, the basis of monetary policy, interest rate policy of the central bank, is the belief about the ability to influence the level of prices in the national economy by changing the discount rate. Policies of hard and free money allow to cool or heat up the economy to the required level for dualistic control of inflationary processes and economic growth.

However, it is important to understand that the success of inflation targeting regime, according to the Taylor rule, ensuring price stability in the national economy, is based on a number of critical assumptions, namely the observance of which can be attributed to the following: First, the level of domestic consumption as a share of gross domestic product (GDP) should be at least 70%. This assumption is intended to reflect one of the key tenets that ensure the success of the inflation targeting regime-control of demand inflation. In case of dominance of demand inflation in the economy, changes in inflation under the influence of a positive shock in demand from households and business entities, central bank can successfully use interest rate policy to cool or warm up the market for goods and services. In case, when national economy is dominated by the export sector, or a substantial proportion of public expenditure in the structure of GDP, it's difficult to talk about efficiency of inflation regime. The reason lies in the increased dependence of the national economy on the inflows and outflows of capital, international capital flows. In case of a substantial dependence of the national economy on export-import operations, dependence of the national economy from fluctuations in the exchange rate is of increased nature. Provided flexible and floating exchange rate there is a risk of importing inflation. In this case, it is possible to speak about dominance in the national economy of cost-push inflation, under the assumption of the dependency from the exported goods and services, as well as imported foreign parts on the one hand, and imported finished goods. Thus, a high export share of GDP of the national economy, as well as the high degree of dependence of national economy on import of goods and services, lead to a sharp decrease of the effectiveness of the inflation targeting regime.

Second, the effectiveness of inflation targeting can be questioned in case of oil producing countries. High dependence on export revenues related to the sale of resources leads to increased pressure on the exchange rate of the country: Export revenue flowing into the national economy gives birth to importing of inflation on the domestic markets for goods and services. In other words, national economies, actively using oil and gas revenues are jeopardizing the possibility of applying inflation targeting framework to ensure price stability in the national economy. A successful example of using inflation targeting regime in case of oil exporter's status is Norway. The application of the inflation targeting regime in the country shows significant success. This success is a consequence of limiting the impact of export earnings on the national economy: More than 95% of the income from the oil rent doesn't flow in the national economy, and is stored in sovereign funds.

Thus, potential of monetary policy in the country, dependent on oil and gas rents, in ensuring price stability can be questioned. The active use of oil and gas revenues in the national economy, a sharp shock in oil prices could lead to a significant change in income of economic entities and the state budget. A sharp negative shock in oil prices leads to a sharp deterioration of the national currency, and, the case of dependence on import, to a significant increase in the price of goods and services in the national economy. This in turn leads to a sharp increase in inflation on the domestic market for goods and services. From the point of view of inflation targeting regime, monetary policy must be accompanied by a change in interest policy for the purpose of cooling the overheating in the national economy. In other words, the logical reaction of monetary authorities to the demand inflation shock must be an increase in the key rate to cool the economy which leads to the rise in the cost of loanable funds in order to increase the costs of goods and services, and, provided the elasticity of demand for goods and services, with the exception of Giffen goods, to reduce final demand for goods and services, which is one way of cooling the economy and achieving short-term price stability. As can be seen, the application of inflation targeting regime in oil-producing countries is a very, ceteris paribus, controversial decision. The ambiguity of the use of this regime, for example in Russia, is exacerbated by the fact that in addition to short-term factors, affecting dynamics of oil prices (one of them can be attributed to changes in volumes of production, number of commissioned rigs, changing global and national oil reserves), one should also highlight changes in monetary policy by one of the key players of the global oil market-the United States (US). It is known that changes in monetary policy by the US of America can have a significant impact on national markets and international liquidity markets.

Today, the international transmission of shocks of US monetary policy are investigated sufficiently. However, the question of influence of positive and negative shocks of US monetary policy, in terms of changes in effective interest rates by the Fed, on monetary policy in oil producing and exporting countries remains open. In this regard, the study of long-term and short-term relationship between changes effective funds rate on changes in key interest rates of oil-producing countries seems very relevant and timely research question. According to our belief, positive or negative shock in effective funds rate can have a significant impact on the changes in the key rates of central banks of oil producing countries through one of the channels of international transmission, and, namely, through the transmission channel of oil prices. The negative shock in the Federal Reserve System (FRS) rate leads to a significant appreciation of the world's dollar supply, which in turn leads to a reduction in quotations of oil on world markets, which in turn leads to additional negative shock on the local currencies of the petroleum exporting countries, that in turn leads to a significant strengthening of inflationary processes in the national economy. This empirical regularity is of well-known character.

However, in this study we are interested in the question of whether there is a dependence of the reaction of monetary authorities of the oil-producing countries to shocks in U.S. monetary policy. From the Mundell-Fleming paradigm view, such a dependence must exist.

2. LITERATURE REVIEW

To date, the question of the international transmission of shocks in US monetary policy on emerging markets was investigated sufficiently. But mostly these studies focus on identifying channels of impact of monetary policy on stock markets, capital markets, output, changes in the risk premium in the national securities and so on. Conventionally, the existing literature on the issue can be divided into several blocks. However, almost all the research is dedicated to finding evidence of the conformity or discrepancy between empirical realities and the Mundell-Fleming-Dornbusch paradigm. Within this paradigm of research are issues of elasticity of international movements of capital, goods and services.

Mundell-Fleming trilemma admits that at the same time it is impossible to maintain the fixed exchange rate, full and free mobility of capital, and ensure the independence of the monetary policy of the national economy. Only two of three components can coexist in one and the same time. The assumption of a trilemma based on the elasticity and absence of barriers to international capital movement, absence of possibility to obtain arbitrage income, as well as ensuring interest rate parity in the world that equates the bond yield under the classic assumptions of a perfect capital market.

No doubt that in the conditions of rigid exchange rate and free flow of capital, monetary authorities of the national economy set interest rates at a level that would be sufficient to ensure price stability and other goals of the national economy. In case of transition to floating exchange rate, the central bank of the country appears to have an additional degree of freedom of action. According to the Mundell-Fleming paradigm, transition to a floating exchange rate eliminates the problem of the inflow of speculative capital, and allows the monetary authorities to use interest rate policy to achieve national goals, particularly, to curb inflation, and to ensure the optimum level of output in the national economy.

The majority of studies on the international transmission of monetary policy shocks is reduced to studies of interest rates behavior on subject of mundell-fleming paradigm viability. For example, studies of Obstfeld et al. (2005), Klein and Shambaugh (2015), Goldberg (2013) and Obstfeld (2015) show that short-term interest rates of developing countries are to a lesser extent correlated with the rates of the core countries (e.g., the USA) in case of a floating exchange rate. On the other hand, a study by Rey (2015) shows that in case of using alternative variables to measure the independence of monetary policy, viability of the Mundell-Fleming paradigm may be questioned. For example, a study by Kim (2001), is devoted to the research of the international transmission of shocks of US monetary policy, also shows that a positive shock to US monetary policy leads to a boom in developing countries, as reflected in the change in US trade balance with partner countries. The study by Takáts and Vela (2014) also showed that under a floating exchange rate, a change in monetary policy in developed countries leads to a change in monetary policy in developing countries, confirming the international interest rate channel of transmission, and this, in turn, is an element of criticism of the Mundell-Flemming. The study by Adjemian and Paries (2008), devoted to research of influence of oil-price shocks on monetary policy, shows that oil price shocks significantly affect consumer price index and wages and to counteract the consequences of such a shock, monetary authorities need to develop additional tools, other than interest rate policy to curb inflation. The same results of oil price shock's influence on inflation are presented in the study by Jacquinot et al. (2009). They show that in the short-term oil price shocks are vital for short-term inflation in transmitted countries. Unexpected oil shocks are treated by contractionary monetary policy in case of G7, which was empirically tested by Cologni and Manera (2008). In the study by Burakov (2016), effect of oil price shocks on migration flows was studied: A decline in oil prices leads to emigration from oil-exporting countries due to decline in wages. A study, devoted to influence of oil shocks on real exchange rate, by Ozturk et al. (2008), shows significant Granger causality.

It is important to note that research of the indirect impact of US monetary policy on monetary policies of oil producing countries through the channel of oil prices is absent.

In our understanding, testing this hypothesis is significant, because it allows to test the Mundell-Fleming paradigm. According to the trilemma, the presence of a floating exchange rate permits the coexistence of free capital mobility and independence of action of the monetary authorities. According to our hypothesis, a negative shock to key rates, US FED should force monetary authorities of oil exporting countries to change its monetary policy in order to counteract the effect of imported inflation.

3. MATERIALS AND METHODS

3.1. Research Methods

To test the hypothesis about relationship between shocks in US monetary policy, oil prices transmission to monetary policy of oil exporting countries, we use econometric techniques to analyze time series. The algorithm of the ongoing study is determined by several key stages. First and foremost, one should test sampled variables on stationarity or order of cointegration, since the time series must have the same order, as can be seen from equation (1) secondly, it is necessary to determine presence/absence of correlation in long term between the variables in the equation. To check this assumption, we use a Johansen cointegration test. In a case of a long-term relationship on the one hand and condition of stationarity of sampled time series in the first order I(1) on the other, it is possible to use vector error correction model (VECM). In case of confirmation of presence of cointegration between the variables of the sample, residuals of the equilibrium regression can be used to estimate error correction model (ECM). Also based on VEC model it is possible to identify short-term relationships between sampled variables. For this purpose, we use the Wald test. To determine causal linkages between variables we use Granger causality test. The final stage of constructing a model is to conduct diagnostic tests to determine validity of the model. These include testing for heteroscedasticity, serial correlation, normality and stability of the model.

3.1.1. Unit root test

For the analysis of long-term relationships between the variables, Johansen and Juselieus (1990) admit that this form of testing is only possible after fulfilling the requirements of stationarity of the time series. In other words, if two series are co-integrated in order d (i.e., I (d)) then each series has to be differenced d times to restore stationarity. For d = 0, each series would be stationary in levels, while for d = 1, first differencing is needed to obtain stationarity. A series is said to be non-stationary if it has non-constant mean, variance, and auto-covariance over time (Johansen and Juselius, 1990). It is important to cover non-stationary variables into stationary process. Otherwise, they do not drift toward a long-term equilibrium. There are two approaches to test the stationarity: Augmented Dickey and Fuller (ADF) test (1979) and the Phillips-Perron (P-P) test (1988). Here, test is referred to as unit-root tests as they test for the presence of unit roots in the series. The use of these tests allows to eliminate serial correlation between the variables by adding the lagged changes in the residuals of regression. The equation for ADF test is presented below:

$$\Delta Y_t = \beta_1 + \beta_2 t + aY_{t-1} + \delta_3 \sum \Delta Y_{t-1} + \varepsilon_t \tag{1}$$

Where ε_t is an error term, β_1 is a drift term and $\beta_2 t$ is the time trend and Δ is the differencing operator. In ADF test, it tests whether a = 0, therefore the null and alternative hypothesis of unit root tests can be written as follows:

H_0: a = 0 (Yt is non-stationary or there is a unit root).

H_1: a < 0 (Yt is stationary or there is no unit root).

The null hypothesis can be rejected if the calculated t value (ADF statistics) lies to the left of the relevant critical value. The alternate hypothesis is that a <0. This means that the variable to be estimated is stationary. Conversely, we cannot reject the null hypothesis if null hypothesis is that a =0, and this means that the variables are non-stationary time series and have unit roots in level. However, normally after taking first differences, the variable will be stationary (Johansen and Juselius, 1990). On the other hand, the specification of P-P test is the same as ADF test, except that the P-P test uses nonparametric statistical method to take care of the serial correlation in the error terms without adding lagged differences (Gujarati, 2003). In this research, we use both ADF and P-P test to examine the stationarity of the sampled time series.

3.1.2. Johansen co-integration test

To test for presence of cointegration we apply the Johansen test using non-stationary time series (values in levels). If between variables does exist a cointegration, the first-best solution would be using VEC methodology (VECM) model. An optimal number of lags according to Akaike information criterion for providing Johansen test is determined in vector autoregressive (VAR) space. To conduct Johansen test, we estimate a VAR model of the following type:

$$y_t = A_1 y_{t-1} + .. + A_p y_{t-p} + Bx_t + \epsilon_t \tag{2}$$

In which each component of y_t is non-reposeful series and it is integrated of order 1. x_t is a fixed exogenous vector, indicating the constant term, trend term and other certain terms. ε_t is a disturbance vector of k dimension.

We can rewrite this model as:

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{p-1} V_i \Delta y_{t-1} + Bx_t + \epsilon_t \tag{3}$$

Where,

$$\prod = \sum_{i=1}^{p} A_i - I, \qquad \vee_i = -\sum_{j=i+1}^{p} A_j \tag{4}$$

If the coefficient matrix $\prod$ has reduced rank r < k, then there exist k × r matrices α and β each with rank r such that $\prod = \alpha\beta'$ and β′yt is I(0). r is the number of cointegrating relations (the cointegrating rank) and each column of β is the cointegrating vector. The elements of α are known as the adjustment parameters in the VEC model. Johansen's method is to estimate $\prod$ matrix from an unrestricted VAR and to test whether we can reject the restrictions implied by the reduced rank of $\prod$ (Johansen, 1991).

3.1.3.VECM

Granger (1988) suggested the application of VECM in case if the variables are cointegrated in order to find short-run causal relationships. VECM, therefore, enables to discriminate between long-run equilibrium and short-run dynamics. In this sense, we employ following VECMs to estimate causal linkages among the variables:

$$\Delta \ln l = a_0 + \sum_{i=1}^{k} a_1 \Delta \ln l_{t-i} + \sum_{i=1}^{n} a_2 \Delta \ln s_{t-i} + \sum_{i=1}^{m} a_3 \Delta \ln y_{t-i} + \lambda ECT_{t-1} + v_1$$

$$\Delta \ln s = \beta_0 + \sum_{i=1}^{k} \beta_1 \Delta \ln s_{t-i} + \sum_{i=1}^{n} \beta_2 \Delta \ln l_{t-i} + \sum_{i=1}^{m} \beta_3 \Delta \ln y_{t-i} + \phi ECT_{t-1} + v_2$$

$$\Delta \ln y = \eta_0 + \sum_{i=1}^{k} \eta_1 \Delta \ln y_{t-i} + \sum_{i=1}^{n} \eta_2 \Delta \ln l_{t-i} + \sum_{i=1}^{m} \eta_3 \Delta \ln s_{t-i} + \chi ECT_{t-1} + v_3$$

Where, l – effective federal funds rate, s – international oil prices (Brent), y – key rate of the Bank of Russia (Granger, 1988).

Providing regression analysis of the sampled variables by modeling VECM allows us to determine the existence of substantial and statistically significant dependence not only on the values of other variables in the sample, but also dependence on previous values of the variable.

However, VEC model must meet the requirements of serial correlation's absence, homoscedasticity of the residuals and to meet the requirement of stability and normality. Only in this case the results can be considered valid.

3.1.4. Granger causality test

The last stage to determine the relationship and its direction is the use of Granger causality test. So, rejection of the null hypothesis of Granger test (H_0), according to which:

$$b_1 = b_2 = ... = b_p = 0 \quad (5)$$

in favor of the alternative hypothesis (H_1) suggests that in US monetary policy Granger cause changes in world oil prices and Russian Monetary Policy (Granger, 1969).

3.2. Materials and Data Processing

We test a hypothesis of international transmission of US monetary policy shocks to monetary policy of oil exporting countries through oil prices' channel on example of Russian data for the period 2000-2016. The base period is 1 month. Unfortunately, use of monthly and daily values of variables for the analysis is hindered due to availability of only monthly data on Bank of Russia's key rate. Moreover, for Brent oil prices we use aggregate monthly values. Using VECM, we set ourselves a task to determine sensitivity of Russian's interest policy to shocks in US monetary policy.

Data on key rate of Bank of Russia is obtained from the statistical database of the Central Bank of Russia (www.cbr.ru). Data for world prices of oil is obtained from the statistical database of NASDAQ (www.nasdaq.com). Data effective federal funds rate is obtained from the statistical database of the Federal Reserve Bank of St. Louis (www.stlouisfed.org).

To conduct time-series analysis, all variables were transformed into logarithms. To identify and formally assess the relationship between variables, we use simple correlation analysis. To study sensitivity and causal linkages between the variables in the sample in short-and long-run, we turn to regression analysis, which involves the construction of VEC model of certain type based on stationary time series, testing the model for heteroscedasticity of the residuals, autocorrelation as well as stability and normality. Based on the model, we study causal linkages between variables in the short run by applying Granger causality test in VEC domain.

4. RESULTS AND DISCUSSION

The first step in testing the hypothesis is to test the variables for the presence of correlation. We use simple correlation analysis and imply Pearson statistical significance test. Results of correlation analysis ate presented in Table 1.

As can be seen from the results of the correlation analysis, the relationship between US monetary policy and world oil prices has a statistically significant ($P < 5\%$), and the value of the correlation coefficient tends to one. This suggests that the empirically observed dynamics of world oil prices from US monetary policy exists. Thus, the increase in the effective Federal funds rate leads to higher money supply denominated in US dollars and to a reduction in the availability of the US dollar in the global capital market. This, in turn, leads to a rise in the cost of a barrel of oil. The results of the analysis of the relationship between world oil prices and monetary policy the Bank of Russia are ambivalent. At a 95% confidence interval, the dependence of monetary policy of Russia from the world price of oil is statistically insignificant in nature. However, expanding the confidence interval, albeit with a certain loss of quality of model calibration, the relationship becomes significant. In such a case, the dependence of monetary policy of Russia from the world price of oil allows for the existence of dependence. So, the rise in world oil prices leads, assuming a floating exchange rate, to strengthening of the Russian ruble, which is disadvantageous for the other export sectors. In this case, the Bank of Russia reacts by the reduction of the key rate to reduce the cost of the national currency in order to balance the profitability of

Table 1: Results of correlation analysis

Variable	US federal funds rate	Oil prices (Brent)	Bank of Russia's key rate
US federal funds rate	1		
Oil prices (Brent)	−0.861511 (0.0101)	1	
Bank of Russia's key rate	0.009509 (0.4320)	0.46584 (0.0981)	1

currency on the global capital market. It is important to note that the index of correlation (0.46584) is uncertain. In other words, the dependence is manifested in an implicit form, which implies the need for more detailed research.

Regarding the dependence of Russia's monetary policy from US monetary policy it can be noted that statistically significant relationship identification in the framework of the correlation analysis has failed. The P value is more than 5% and the value of correlation coefficient is also uncertain. However, unconditional acceptance of the results of correlation analysis is impossible due to possible existence of serial correlation, problem of multicollinearity. In this regard, it is necessary to turn to more qualitative techniques of analysis.

The second step in testing hypotheses is to test variables for the presence of unit root. For this purpose, we use standard tests-ADF and P-P test. Results of unit root testing are presented in Table 2.

As can be seen from the test results of the variables for the presence of unit root in their differentiation to the first order, we can reject the null hypothesis of unit root in each of the variables. Thus, the condition of stationarity at I(1) is performed, which gives us reason to test variables for cointegration. However, it is necessary to determine the optimal time lag.

Table 2: Results of individual unit root test

Variables	ADF		PP	
	Statistic	P**	Statistic	P**
Levels				
Intercept	4.85493	0.3923	4.90101	0.5566
Intercept and trend	2.74693	0.8160	2.72891	0.8420
First-difference				
Intercept	34.2189	0.0000**	38.6515	0.0000**
Intercept and trend	19.5621	0.0012**	35.6748	0.0000**

**Denotes statistical significance at the 5% level of significance. ADF: Augmented Dickey and Fuller, PP: Phillips-Perron

Table 3: Results of unrestricted VAR model diagnostic testing

Type of test	Results		
	Lags	LM-Statistics	P value
VAR residual serial correlation LM test	1	14.13409	0.1195**
	2	34.81144	0.0031
	3	43.08531	0.0002
Stability condition test	All roots lie within the circle. VAR satisfies stability condition		
Heteroscedasticity (White test)	0.3244*		
VAR residual cross correlation test	No autocorrelation in the residuals		

**Denotes acceptance of null hypothesis (H_0: There is no serial correlation). *Denotes acceptance of null hypothesis of homoscedasticity. VAR: Vector autoregressive

Building a VAR model involves determining the optimal number of lags. In our case, the Akaike information criterion equals 1. Consequently, we built models based on the use of time lag of 1 year to determine the relationship in the short run. The results of the diagnostic testing of VAR model for heteroscedasticity of residuals, autocorrelation, serial cross-correlation, and stability are presented in Table 3. As can be seen from Table 3, the model is stable, heteroscedasticity and serial correlation of residuals in the model are absent.

The model is used to determine the level of sensitivity of control variables to shocks in US monetary policy in the short run and we use it to test for stable long-run relationship, applying Johansen cointegration test. Results of Johansen co-integration test are presented in Table 4.

Johansen test results show the presence of cointegration between a numbers of equations, which allows presuming the existence of a long-term relationship between them. Starting from the results of the cointegration test, we can proceed to the construction of VECM model to reveal presence or absence of long-term and short-term relations between variables.

The first model shows the relationship between Bank of Russia's key rate and explanatory variables (oil prices and US effective federal funds rate).

The results of the model, showing the relationship between Bank of Russia's key rate, oil prices and US effective federal funds rate are presented in Table 5. As can be seen from the Table, the value of error correction term C(1) is negative in sign and statistically significant. This suggests the existence of long-run relationship between the variables of the sample. In other words, we can assume that Bank of Russia's key rate, oil prices and US effective federal funds rate have similar trends of movement in the long term.

The C(1) shows speed of long run adjustment. In other words, this coefficient shows how fast the system of interrelated variables would be restored back to equilibrium in the long run or the disequilibrium would be corrected. Given statistical significance at 5% level (P-value being < 5%) and negative meaning, the system of variables corrects its previous period disequilibrium at a speed of 61.24% in one quarter (given optimal lag meaning of one quarter for ECM). It implies that the model identifies the sizeable speed of adjustment by 61.24% of disequilibrium correction in 1 quarter for reaching long run equilibrium steady state position.

High speed of adjustment of relations between variables towards equilibrium is quite understandable. This is due to the high elasticity in the global capital market in the absence of barriers to its penetration into the national markets on the one hand. On

Table 4: Results of Johansen co-integration test

Hypothesized number of CE(s)	Eigenvalue	Trace statistics	Critical value 0.05	P*
None*	0.624421	34.80952	29.79707	0.0122*
At most 1	0.300230	11.30667	15.49471	0.1933
At most 2	0.107838	2.738575	3.841466	0.0979

Trace statistics indicate 1 cointegrating equation at the 0.05 level. *Denotes statistical significance at the 5% level of significance the other hand, this is due to the high international mobility of capital under floating exchange rates. This result indirectly refutes the Mundell-Fleming-Dornbusch paradigm, according to which under the conditions of floating exchange rates, coexistence of free capital mobility and independent monetary policy is possible. Results of long-run dependence between variables show that in Russia, given floating exchange rate and free capital mobility, monetary policy is dependent on the actions of the FRS, albeit indirectly–through the oil prices channel, given that oil export revenue being the largest source of income for the federal budget.

To identify short-term relationship between the variables we refer to the Wald test results. This test allows to determine the interrelationship between variables in the short term. In other words, under the null hypothesis of this test, the response of error correction term to explanatory variables equals zero, i.e., the sensitivity of resulting variable to changes (shocks) in explaining are not observed. Results of Wald test for the model are presented in Table 6.

As can be seen from the results of the Wald test in the short term there is a relationship between changes in the key rate of Bank of Russia and world oil prices. Moreover, this relationship is opposite. Based on the results of the Wald test, we can detect statistically

Table 5: Results of VECM

Coefficient number	Coefficient meaning	Standard error	t-statistic	P
C (1)	−0.612479*	0.184302	−2.192954	0.0410*
C (2)	0.065589	0.235092	0.278992	0.7833
C (3)	−0.102111	0.001022	−2.065126	0.0378*
C (4)	−0.256902	3.08E-08	1.401057	0.0279*
C (5)	0.006457	0.010912	0.591686	0.5352

*Denotes statistical significance. VECM: Vector error correction model

Figure 1: Response of Russia's key rate to a shock in United States effective federal funds rate

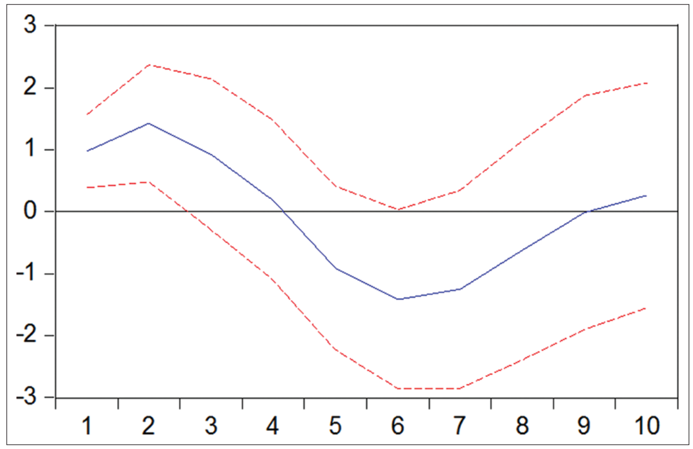


Figure 2: Response of the Bank of Russia's key rate to a shock in world oil prices

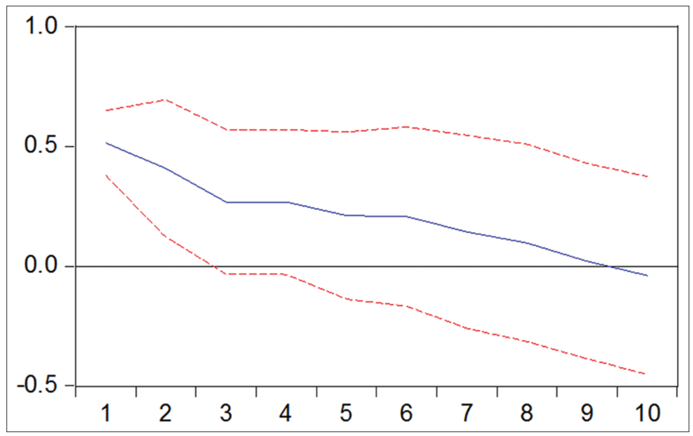


Table 6: Wald test results for short run relationship

Test statistic	Value	Df	P	Test statistic	Value	Df	P
t-statistic	−2.0651	19	0.0317*	t-statistic	1.401057	19	0.0312
F-statistic	4.2647	(1,19)	0.0317*	F-statistic	1.962960	(1,19)	0.0312
Chi-Square	4.2647	1	0.0212*	Chi-Square	1.962960	1	0.0138
Null hypothesis: C(3)=0 (world oil prices)				Null hypothesis: C(4)=0 (effective federal funds rate)			

*Denotes statistical significance and rejection of H_0: No short-run relationship

Table 7: Results of diagnostic testing

Test type	Value	Probability characteristic		P value
Heteroscedasticity test: Breusch-Pagan-Godfrey				
F-statistic	8.327663	P F (6,17)		0.3365
Obs*R^2	7.368774	P Chi-square (6)		0.2912
Scaled explained SS	4.564749	P Chi-square (6)		0.7853
Heteroskedasticity test: ARCH				
F-statistic	2.296783	P F (1,21)		0.9452
Obs*R^2	0.012844	P Chi-square (1)		0.9193
Breusch-Godfrey serial correlation LM test				
F-statistic	2.145953	Prob. F (1,18)		0.7345
Obs*R^2	0.130683	Prob. Chi-Square (1)		0.7541
Autocorrelation/partial correlation				
Lag	AC	PAC	Q-statistics	P
1	−0.015	−0.015	0.0065	0.936
2	0.151	0.151	0.6548	0.721

ARCH: Autoregressive conditional heteroskedasticity

Figure 3: Results of normality test

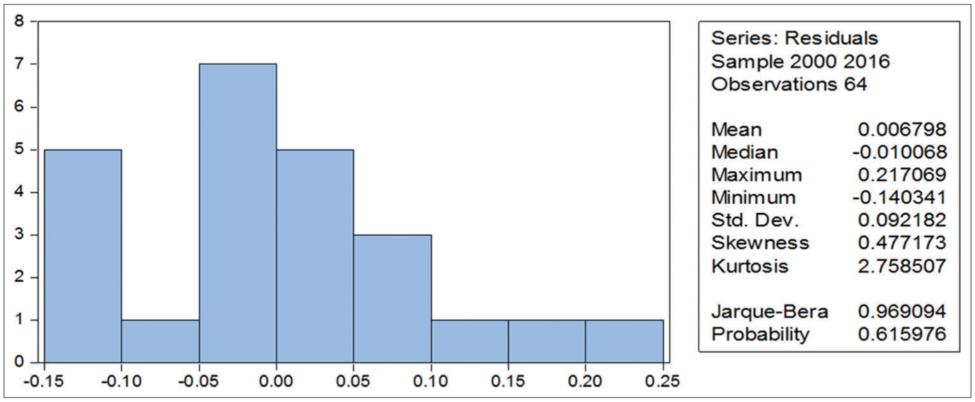


Figure 4: Results of cumulative sum test

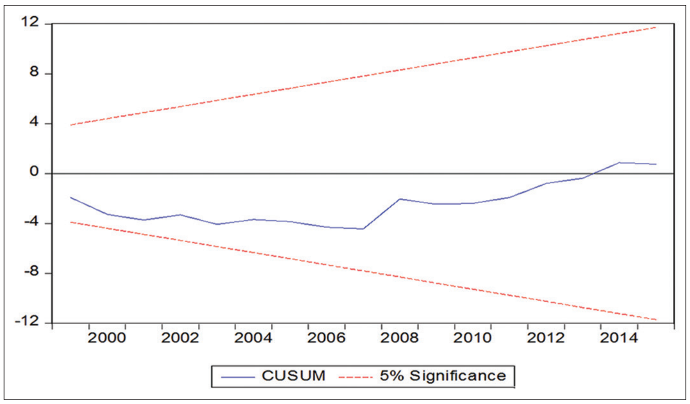
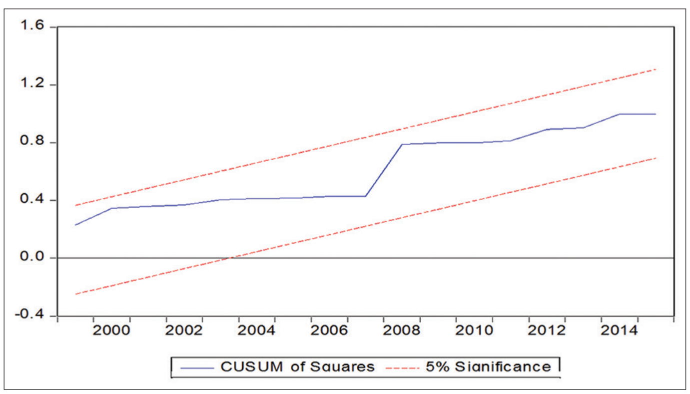


Figure 5: Results of cumulative sum square test



significant causality running from world oil prices to interest rate policy of the Bank of Russia with rate of adjustment towards equilibrium of 10.21% in t−1. In other words, a rise (decline) in oil prices leads to a decline (rise) in the key rate.

The second result shows presence of causality running from US monetary policy to Bank of Russia's key rate with the speed of adjustment towards equilibrium at 25.69%. So, the results of Wald test show that US monetary policy even in the short term has the potential to impact on monetary policy of Russia. Thus, an increase in the effective federal funds rate of the U.S. leads to an increase in the key rate of the Bank of Russia. This causality, in our view, stems from oil prices dynamics.

Overall, the obtained results are consistent with existing empirical and theoretical results of the previous studies. In order to reinforce the thesis of the existence of relationship between Russia's key rate and oil price shocks we refer to the results of impulse response functions (Figures 1 and 2).

The analysis of impulse response functions confirms existence of significant dependence of Russia's key rate to positive oil shocks, in both short and long run, as well as dependence from shocks in US monetary policy.

The final stage of the analysis of the model is to determine the extent of its validity. For this, it is necessary to conduct some diagnostic tests, including tests for heteroscedasticity of the residuals, serial correlation, stability and normality of the model. The results of these tests are presented in Table 7.

As can be seen from Table 7, the model is characterized by the fulfillment of all requirements-homoscedasticity and absence of serial, auto and partial correlation. In Figures 3-5 we present test results for normality and stability (cumulative sum [CUSUM] and CUSUM square test).

As can be seen from the data of Figures 3-5, the model meets the requirement of normality and.

5. CONCLUSION

This study examines the international transmission of US monetary policy shocks in oil exporting countries on the example of Russia. According to the hypothesis of the study, the Mundell-Fleming Trilemma, allowing the conduct of independent monetary policy under free capital movement and floating exchange rate, contrary to empirical observations in the case of the national economy, dependent on exports of energy resources, particularly oil. According to our hypothesis, there exist an international transmission channel of the effects of US monetary policy in oil-producing countries through shocks in the global oil market. So, we assume that tighter US monetary policy leads to a friction on the oil market with the attendant fall in prices. This, in turn, leads to lower export revenue earned by the oil exporters, and weakening of the national currency. The depreciation of the national currency leads to growth of inflationary pressure in the domestic market on the one hand. The reaction of the exporting country becomes tightening monetary policy to reduce pressure on the national currency and the threat of imported inflation.

To conduct the study, we used the example of Russia. To assess the validity of the transmission channel of oil price shocks we've built a VEC model. The results of the analysis of the causal relationship in both long and short term periods confirm our hypothesis about the importance of the channel of oil prices in the transmission of US monetary policy shocks to the countries-exporters of oil.

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