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Borivoje D. Krušković *

* E-mail:
bkruskovic@gmail.com

Exchange Rate and Interest Rate in the Monetary Policy Reaction Function

Abstract: In recent years there has been a particular interest in the relation between exchange rates and interest rates both in developed countries and emerging countries. This is understandable given the important role that these variables have in determining the movement of nominal and real economic variables, including the movement of domestic inflation, real output, exports and imports, foreign exchange reserves, etc. To realized the importance of the given instruments selected macroeconomic indicators, data analysis (monthly data) relating to Serbia was made on the basis of the Transfer Function Model, a data analysis (annual data) relating to emerging countries was done on the basis of the Stepvise Multiple Regression model. In the transfer function model we used the Maximum Likelihood method for assessing unknown coefficients. In the gradual multiple regression model we used the Least Square method for the evaluation of unknown coefficients. All indicator values were used in the original unmodified form, i.e. there was no need for a variety of transformations. Empirical analysis showed that the exchange rate is a more significant transmission mechanism than the interest rate both in emerging markets and Serbia.

Key words: exchange rate, interest rate, monetary policy

JEL Classification: E31, E41, E52.

1. Introduction

The exchange rate is an important transmission mechanism of monetary policy because, depending on the nature of shocks, it affects inflation and aggregate demand, especially in a small and open economy. In recent years there has been a particular interest in the relation between exchange rates and interest rates both in developed countries and emerging countries. This is understandable given the important role that these variables have in determining the movement of nominal and real economic variables, including the movement of domestic inflation, real output, exports and imports, foreign exchange reserves, etc. Among emerging economies, this interest is further fueled by the fact that many of the countries have introduced changes in their monetary policies and exchange rate policies, adopting inflation targeting, which involves floating exchange rate regime. The variability of the exchange rate has increased in recent years compared to the previous periods when we had much more rigid exchange rate regimes.

The purpose of the quantitative analysis of empirical data on macroeconomic developments in Serbia, as well as in emerging countries (Russia, China, Brazil, India, Singapore, Argentina and Chile), is to prove theoretical assumptions and explanations. The analysis will show the real impact of interest rate and foreign exchange rate on macroeconomic indicators: the budget surplus/deficit, consumer prices (inflation), industrial production, employment, trade balance, and foreign exchange reserves. The analysis of data pertaining to Serbia covers macroeconomic indicators on monthly basis. The analysis included the macroeconomic indicators of the nine emerging countries in the period from 2000 to 2008.

To realized the importance of the given instruments selected macroeconomic indicators, data analysis (monthly data) relating to Serbia was made on the basis of the Transfer Function Model, and data analysis (annual data) relating to emerging countries was done on the basis of the Stepwise Multiple Regression model. In the transfer function model we used the Maximum Likelihood method for assessing unknown coefficients. In the gradual multiple regression model we used the Least Square method for the evaluation of unknown coefficients. All indicator values were used in the original unmodified form, i.e. there was no need for a variety of transformations.

2. Literature Review

Kun (2008) showed that the exchange rate plays an important role in the monetary policy during the fixed exchange rate regime periods. However, the influence disappears after these countries have moved to the flexible regimes. Hoffmann, Sondergaard & Westelius (2007) showed that the interest rate reduction, necessary to achieve the new inflation target, is less pronounced in a more open economy. The muted interest rate response leads to a decrease in the magnitude of the overshooting result for both the nominal and real exchange rate. Additionally, since the inflation response is greater in a more open economy, the cumulative effect on the price level is larger and the long-run nominal exchange rate is higher. A higher long-run nominal exchange rate gives rise to a delayed overshooting of the nominal relative to the real exchange rate. Leith & Wren-Levis (2007) showed that monetary policy acts to reduce the excessive real appreciation of the exchange rate that would emerge under flexible prices, but it dose not do so completely (the consumption gap remains negative) as to do so would fuel inflation. As a result, monetary policy cannot completely offset these shocks for two reasons: they generate inflation and move consumption in both sectors, in different directions. The last effect is aggravated when the prices in non-tradable goods sector are more rigid than the prices in the tradable goods sector. Therefore, a policy that would attempt to hold the terms of trade or the real exchange rate constant would be significantly suboptimal, as would be a policy that does not attempt to offset the shock at all. Hyder & Khan (2007) showed that the extent to which exchange rate changes affect inflation depends on many factors such as: exchange rate pass-through, market structures, elasticities of imports, exports, consumption and investments with respect to the exchange rate. Chang (2007) showed that the exchange rate overreacts when with no major change in its main determinants (e.g. terms of trade, conditions for accessing international financing) a substantial appreciation is followed by a similar depreciation in a relatively brief period of time. For example, a sharp depreciation could generate inflation that would be necessary to compensate for with monetary policy tightening. However, if the exchange rate movement was large, the monetary tightening would unnecessarily deepen the economic cycle.

Williams (2006) showed that in addition to fundamental economy characteristics, the level of foreign exchange reserves is influenced by interest rates as well. Interest rates should be kept competitive in order to prevent capital outflows and low enough as not to adversely affect the cost of operations of business or precipitate outflows and hence a loss of foreign exchange reserves. Holland (2005) showed that as for emerging countries, one should consider the specificity of these economies regarding the movement of interest rates and exchange rates. There are several significant differences between developed economies and emerging economies. These differences include: liability dollarization, credibility issues, high degree of exchange rate transmission, and inflationary process instability. Economists refer to this specificity of emerging markets, accountable for a relatively low level of exchange rate flexibility, as a “fear of floating”. One direct way to assess whether a central bank has suffered from the fear of floating is by estimating the reaction functions of the central bank on inflation pressure. In this case, a central bank cares more about inflation rather than it cares about exchange rate volatility. Sanchez (2005) showed that balance sheet effects that raise the domestic-currency real value of external liabilities have in recent years particularly attracted the attention of analysis who look for mechanisms through which a weakening in domestic currencies could lead to contractions in economic activity, i.e. "contractionary devaluations". Depreciations are defined to be contractionary when real exchange rates have an overall negative effect on output in the aggregate demand schedule. The result of contractionary depreciations means that, faced with adverse shocks of the risk premium, monetary authorities in economies that show contractionary depreciations increase interest rates to a point that will lead to the strengthening of the domestic currency value. Interest rates also increase in response to the shock of negative net exports in the economies in which there is contractionary depreciation and they decrease in the case of expansionary depreciation. Net exports shocks generate a clear prediction that both interest rates and exchange rates should be increased in response to the shock of negative net exports in cases of contractionary depreciations and reduced in the cases of expansionary depreciations. Menner & Mendizabal (2005) showed that a positive demand shock persistently raises output whilst reducing prices and the interest rate. A positive demand shock increases output, prices and the interest rate. A positive monetary shock raises the interest rate and lowers output and prices.

Kim (2003) showed that monetary policy of foreign exchange interventions and monetary policy of setting interest rate (or money) interact with each other. For example, foreign exchange intervention may affect interest rate (or money) setting monetary policy if it is not fully sterilized. In addition, foreign exchange intervention may also signal future changes in monetary policy stance. Monetary policy of setting interest rate (or money) affects foreign exchange intervention since monetary policy affects the exchange rate and foreign exchange intervention may respond to it in order to stabilize the exchange rate. Edwards (2000) showed that if the nature of external shocks is not independent of the exchange rate regime, the countries with more credible exchange rate regimes face milder shocks as well. Benassy-Quere & Chauvin (1999) showed that insufficient growth of domestic money market frequently reduces the possibility of central bank sterilization. In that case, the expansion of monetary base is inflationary and can create a price bubble in the domestic assets market. This occurs in various developing economies where, due to inflation suppression, the interest rates are maintained at higher levels than the foreign interest rates, attracting portfolio investments. Koray & McMillin (1998) showed that according to exchange rate overshooting models, a contractionary monetary policy shock causes a large initial appreciation followed by depreciation in nominal and real exchange rate. This view is not supported by the findings that a contractionary shock to U.S.

monetary policy leads to persistent appreciations in nominal and real U.S. exchange rates.

3. Modeling of macroeconomic indicators related to Serbia

The macroeconomic indicators that will be modeled are: budget surplus/deficit, consumer prices (inflation), industrial production, employment, trade balance, and foreign exchange reserves. Modeling indicators, based on the exchange rate and interest rate models using a transfer function. One of the characteristics of the transfer function model is that it does not include the model explanatory variable (Predictor), which is not statistically significant.

$$\Delta\left(f\left(Y_t\right)\right)=\mu+\left(\sum_{i=1}^{k}\frac{Num_i}{Den_i}\Delta_i B^{b_i} f_i\left(X_{it}\right)\right)+\frac{MA}{AR}a_t$$

Yt - a variable which is modeled; MA and AR - variable parameters to be modeled; Xit - predictor model; Num and Den - predictor model parameters; at - the process of “white noise” that has a normal distribution; - Difference operator; Bb - operator of default or delays.

3.1. Modeling of the budget surplus/deficit

Modeling of the budget surplus/deficit was made using non-seasonal ARIMA (0,0,0) model (Table 4.1) because the data series has no pronounced seasonal character. From the explanatory variables (predictors), only one variable and the exchange rate were included (Tables 1. and 2.). Table 1 shows that the data series that is modeled has no extreme values (outlier number is 0).

For the model to be statistically significant, it is necessary that the residuals of the model represent the process of “white noise”. This is checked on the basis of Ljung-Box statistics. If the statistical significance is greater than 5%, then the residuals collectively represent the process of “white noise”. Individual checks of the autocorrelation function on each arrears shall be made by plotting the given autocorrelation (Charts 1. and 2.). It is also necessary that the residuals have a normal distribution model, which was tested using the Kolmogorov-Smirnov test (Table 4.). Based on the given test (if statistical significance is greater than 5%) it is concluded that the given residuals have a normal distribution.

Applying the model of the transfer function leads to the conclusion that the budget deficit / surplus can be explained by the exchange rate over the next model (series Y - budget deficit / surplus; X series - the exchange rate):

$$Y_t = 43315,385 + \frac{-1918,300 - 2879,537 \cdot B + 1400,264 \cdot B^2}{1 - 0,822 \cdot B + 0,602 \cdot B^2} \cdot X_{t-1} + a_t$$

Table 1: Model Description

			Model Type
Model ID	Budget_S_D	Model_1	ARIMA (0,0,0)

Table 2: Statistics Model

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
Budget_S_D-Model_1	1	,521	18,537	18	,421	0

Table 3: ARIMA Model Parameters

					Estimate	SE	t	Sig.
Budget_S_D-Model_1	Budget_S_D	No Transformation	Constant		43315,385	14814,487	2,924	,007
	Exchange rate	No Transformation	Delay		1			
			Numerator	Lag 0	-1918,300	392,428	-4,888	,000
				Lag 1	-2879,537	778,062	-3,701	,001
				Lag 2	1400,264	523,283	2,676	,013
			Denominator	Lag 1	,822	,236	3,476	,002
				Lag 2	-,602	,182	-3,304	,003

Figure 1: Autocorrelation (AFC) and the partial autocorrelation (PACF) residual coefficients

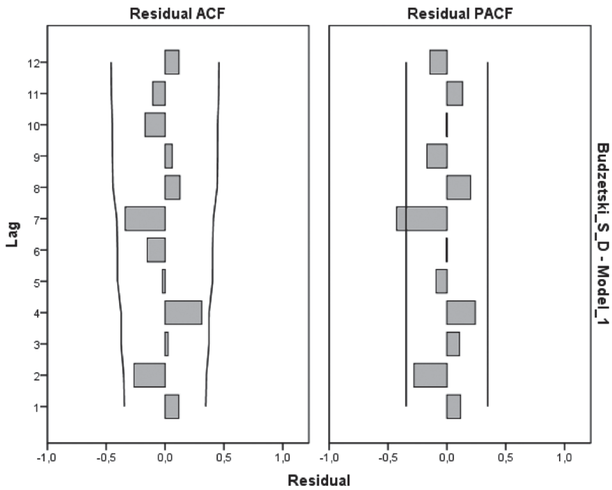

Figure 2: Actual and estimated value of the time series

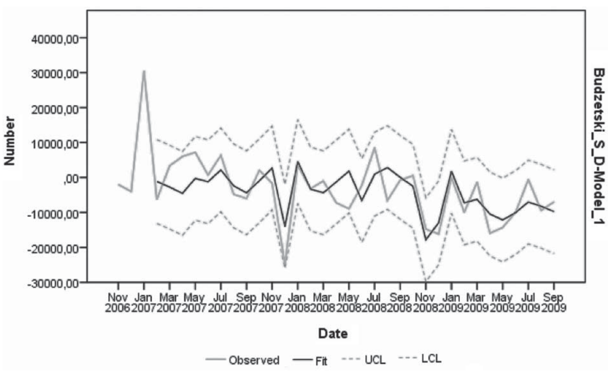

Table 4: Kolmogorov-Smirnov test of normality residual

		Noise residual from Budget_S_D-Model_1
N		32
Normal Parameters[a,b]	Mean	,6604
	Std. Deviation	5338,44116
Most Extreme Differences	Absolute	,107
	Positive	,060
	Negative	-,107
Kolmogorov-Smirnov Z		,604
Asymp. Sig. (2-tailed)		,859

a. Test distribution is Normal.
b. Calculated from data.

3.2. Modeling of Consumer Prices

Modeling of consumer prices was made using the seasonal ARIMA (0,0,2), (0,1,0) model (Table 5). From the explanatory variables (predictors), only one variable and the exchange rate were included (Tables 6 and 7). Table 6 shows that the data series that is modeled no extreme values. Based on the Kolmogorov-Smirnov test (Table 8) it is concluded that the given residuals have a normal distribution. Applying the model of the transfer function leads to the conclusion that consumer prices can be explained by the exchange rate, over the next model (series Y - consumer prices; X series - the exchange rate):

$$\left(1-B^{12}\right)Y_t = \frac{-0,010}{1-1,864\cdot B-0,941\cdot B^2}\cdot\left(1-B^{12}\right)X_{t-1}+\left(1-0,488\cdot B^2\right)a_t$$

Table 5: Model Description

			Model Type
Model ID	Consumer Prices (month rate)	Model_1	ARIMA(0,0,2)(0,1,0)

Table 6: Statistics Modem

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
Consumer Prices (month rate) Model_1	1	,564	20,515	17	,249	0

Table 7: Parameters ARIMA Model

					Estimate	SE	t	Sig.
Consumer Prices (month rate)-Model_1	Consumer Prices (month rate)	No Transformation	MA	Lag 2	,488	,226	2,161	,042
			Seasonal Difference		1			
	Exchange rate	No Transformation	Delay		4			
			Numerator	Lag 0	-,010	,002	-4,084	,000
			Denominator	Lag 1	1,864	,050	37,559	,000
				Lag 2	-,941	,047	-20,210	,000
			Seasonal Difference		1			

Figure 3: Autocorrelation (AFC) and the partial autocorrelation (PACF) residual coefficients

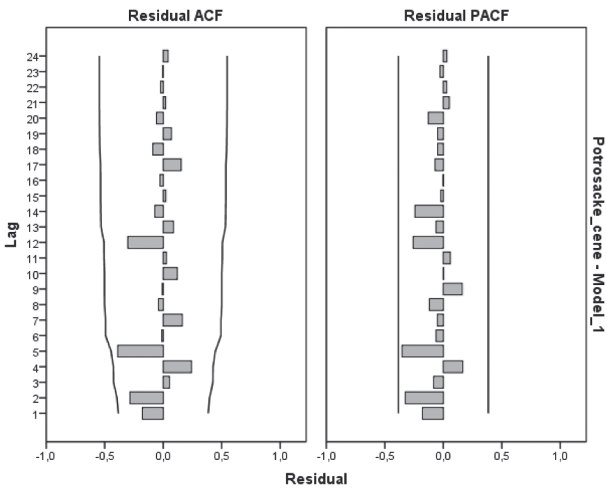

Figure 4: Actual and estimated value of the time series

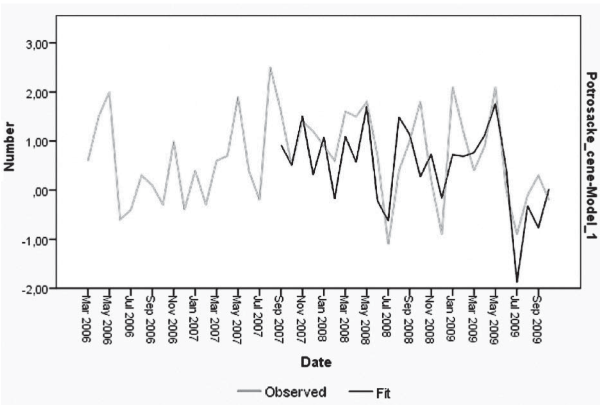

Table 8: Kolmogorov-Smirnov test of normality residual

		Noise residual from Consumer Prices-Model_1
N		26
Normal Parameters[a,b]	Mean	,2417
	Std. Deviation	,68583
Most Extreme Differences	Absolute	,118
	Positive	,118
	Negative	-,096
Kolmogorov-Smirnov Z		,600
Asymp. Sig. (2-tailed)		,865

a. Test distribution is Normal.
b. Calculated from data.

3.3. Modelling of industrial production

Modelling of industrial production was performed using seasonal ARIMA (0,1,0), (0,1,0) model (Table 9). From the explanatory variables (predictors), only one variable and the exchange rate were included (Tables 10 and 11). Table 10 shows that the data series that is modeled has no extreme values. Based on the Kolmogorov-Smirnov test (Table 12), it is concluded that the given residuals have a normal distribution. Applying the model of the transfer function leads to the conclusion that industrial production can be explained by the exchange rate over the next model (series Y - industrial production, a series of X - the exchange rate):

$$(1-B)\left(1-B^{12}\right)Y_t = 0,753\cdot(1-B)\cdot\left(1-B^{12}\right)X_{t-8} + a_t$$

Table 9: Model Description

			Model Type
Model ID	Industrial production	Model_1	ARIMA(0,1,0)(0,1,0)

Table 10: Statistics Model

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
Industrial production-Model_1	1	,361	.	0	.	0

Table 11: Parameters ARIMA model

					Estimate	SE	t	Sig.
Industrial production-Model_1	Industrial production	No Transformation	Difference		1			
			Seasonal Difference		1			
	Exchange rate	No Transformation	Delay		8			
			Numerator	Lag 0	,753	,255	2,951	,010
			Difference		1			
			Seasonal Difference		1			

Figure 5: Autocorrelation (ACF) and partial autocorrelation (PACF) residual coefficients

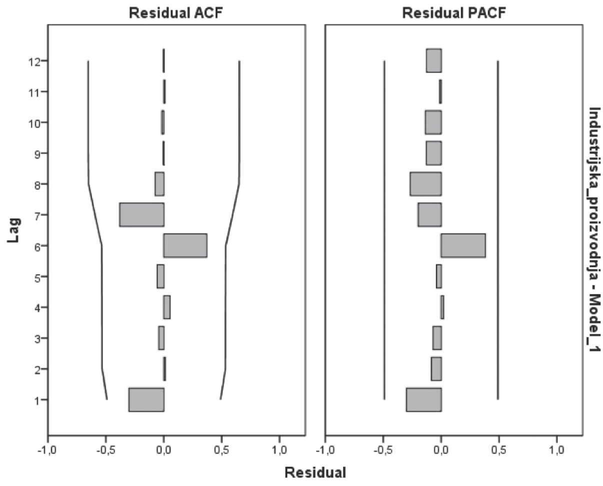

Figure 6: Actual and estimated value of the time series

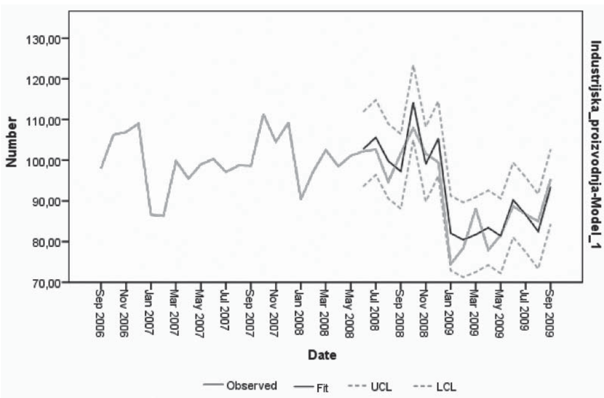

Table 12: Kolmogorov-Smirnov test of normality residual

		Noise residual from Industrial production-Model_1
N		16
Normal Parameters[a,b]	Mean	-1,2118
	Std. Deviation	4,12660
Most Extreme Differences	Absolute	,139
	Positive	,139
	Negative	-,081
Kolmogorov-Smirnov Z		,555
Asymp. Sig. (2-tailed)		,917

a. Test distribution is Normal.
b. Calculated from data.

3.4. Modelling of the number of employees

Modelling of the number of employees was carried out using non-seasonal ARIMA (0,1,0) model (Table 13). From the explanatory variables (predictors), two variables were included: the exchange rate and the interest rate (Tables 14 and 15). Table 14 shows that the data series that is modeled has two extreme values. Based on the Kolmogorov-Smirnov test (Table 17), it is concluded that the given residuals have a normal distribution. Applying the model of the transfer function leads to the conclusion that the number of employees can be explained by the exchange rate and interest rate over the next model (series Y - number of employees; X1 series - the exchange rate; X2 Series - the interest rate):

$$(1-B)Y_t = -2,287 + 1,388 \cdot (1-B)X_{1,t-4} + \frac{1,962 + 2,322 \cdot B}{1 - 0,700 \cdot B}(1-B)X_{2,t} + a_t$$

Table 13: Model description

			Model Type
Model ID	Number of employees	Model_1	ARIMA(0,1,0)(0,0,0)

Table 14: Statistics model

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
Number of employees-Model_1	2	,982	10,278	18	,922	2

Table 15: ARIMA model parameters

					Estimate	SE	t	Sig.
Number of employees-Model_1	Number of employees	No Transformation	Constant		-2,287	,696	-3,285	,003
			Difference		1			
	Exchange rate	No Transformation	Delay		4			
			Numerator	Lag 0	1,388	,259	5,362	,000
			Difference		1			
	Interest rate	No Transformation	Numerator	Lag 0	1,962	,567	3,463	,002
				Lag 1	-2,322	,666	-3,485	,002
			Difference		1			
			Denominator	Lag 2	-,700	,096	-7,296	,000

Table 16: Extreme values of the time series

			Estimate	SE	t	Sig.
Number of employees-Model_1	Sep 2007	Level Shift	13,394	3,840	3,488	,002
	Apr 2009	Level Shift	-136,850	4,406	-31,060	,000

Figure 7: Autocorrelation (ACF) and partial autocorrelation (PACF) residual coefficients

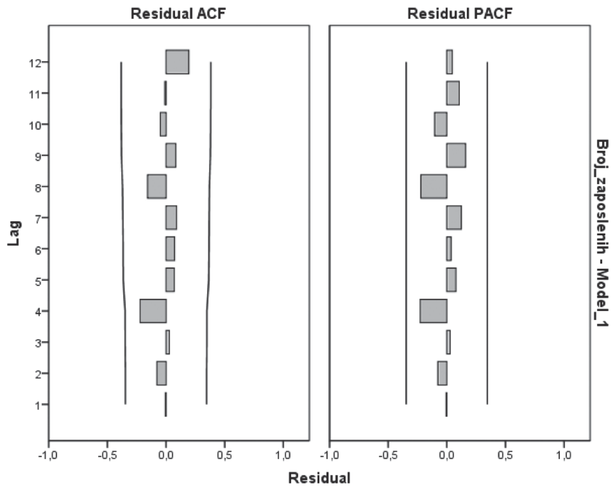

Figure 8: Actual and estimated value of the time series

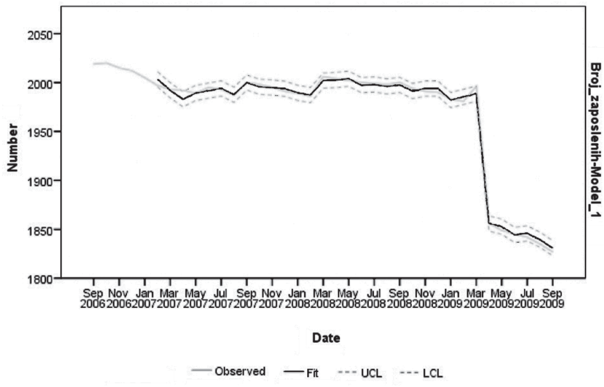

Table 17: Kolmogorov-Smirnov test of normality residual

		Noise residual from Number of employees-Model_1
N		32
Normal Parameters[a,b]	Mean	,00
	Std. Deviation	3,381
Most Extreme Differences	Absolute	,084
	Positive	,084
	Negative	-,068
Kolmogorov-Smirnov Z		,472
Asymp. Sig. (2-tailed)		,979

a. Test distribution is Normal.
b. Calculated from data.

3.5. Modelling trade balance

Modelling trade balance was performed using seasonal ARIMA (1,1,0), (0,1,0) model (Table 18). From the explanatory variables (predictors), no variable was included (Table 19 and 20). Table 20shows that the data series that is modeled has no extreme values. Based on the Kolmogorov-Smirnov test (Table 21), it is concluded that the given residuals have a normal distribution. Applying the model of the transfer function leads to the conclusion that the balance of trade can be explained by the following model (series Y - trade balance):

$$(1-B)(1-B^{12})Y_t = \frac{1}{1+0,622\cdot B}a_t$$

Table 18. Model description

			Model Type
Model ID	Trade balance	Model_1	ARIMA(1,1,0)(0,1,0)

Table 19: Statistics Model

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
Trade balance-Model_1	0	,297	7,690	17	,973	0

Table 20: Parameters ARIMA model

					Estimate	SE	t	Sig.
Trade balance-Model_1	Trade balance	No Transformation	AR	Lag 1	-,622	,171	-3,634	,001
			Difference		1			
			Seasonal Difference		1			

Figure 9: Autocorrelation (ACF) and partial autocorrelation (PACF) residual coefficients

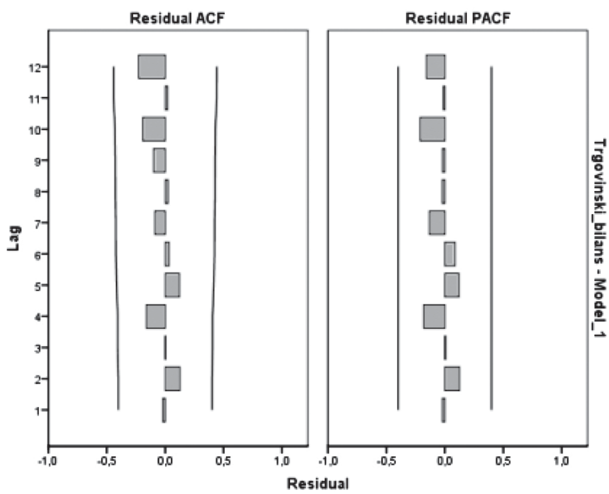

Figure 10: Actual and estimated value of the time series

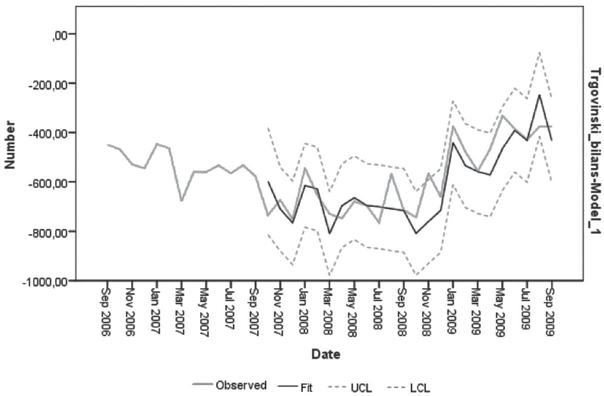

Table 21: Kolmogorov-Smirnov test of normality residual

		Noise residual from Trade balance-Model_1
N		24
Normal Parameters[a,b]	Mean	27,7935
	Std. Deviation	78,93806
Most Extreme Differences	Absolute	,110
	Positive	,089
	Negative	-,110
Kolmogorov-Smirnov Z		,540
Asymp. Sig. (2-tailed)		,933

a. Test distribution is Normal.
b. Calculated from data.

3.6. Modeling of foreign exchange reserves

Modeling of foreign exchange reserves was made using non-seasonal ARIMA (0,1,0) model (Table 22). From the explanatory variables (predictors), two variables were included: the exchange rate and the interest rate (Tables 23 and 24). Table 23 shows that the data series that is modeled has two extreme values. Based on the Kolmogorov-Smirnov test (Table 26), it is concluded that the given residuals have a normal distribution. Applying the model of the transfer function leads to the conclusion that the foreign reserves can be explained by the exchange rate and interest rate over the next model (series Y - foreign exchange reserves; X1 series - the exchange rate; X2 Series - the interest rate):

$$(1-B)Y_t = -35,619\cdot(1-B)X_{1,t-1} - 185,221\cdot(1-B)X_{2,t} + a_t$$

Table 22: Model Description

			Model Type
Model ID	Foreign exchange reserves	Model_1	ARIMA(0,1,0)(0,0,0)

Table 23: Statistics Model

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
Foreign exchange reserves Model_1	2	,668	25,881	18	,103	2

Table 24: ARIMA model parameters

					Estimate	SE	t	Sig.
Foreign exchange reserves-Model_1	Foreign exchange reserves	No Transformation	Difference		1			
	Exchange rate	No Transformation	Delay		1			
			Numerator	Lag 0	-35,619	11,067	-3,219	,003
			Difference		1			
	Interest rate	No Transformation	Delay		1			
			Numerator	Lag 0	-185,221	28,731	-6,447	,000
			Difference		1			

Table 25: Extreme values of the time series

			Estimate	SE	t	Sig.
Foreign exchange reserves-Model_1	Nov 2006	Additive	773,690	152,396	5,077	,000
	Dec 2006	Additive	563,104	151,577	3,715	,001

Figure 11: Autocorrelation (ACF) and partial autocorrelation (PACF) residual coefficients

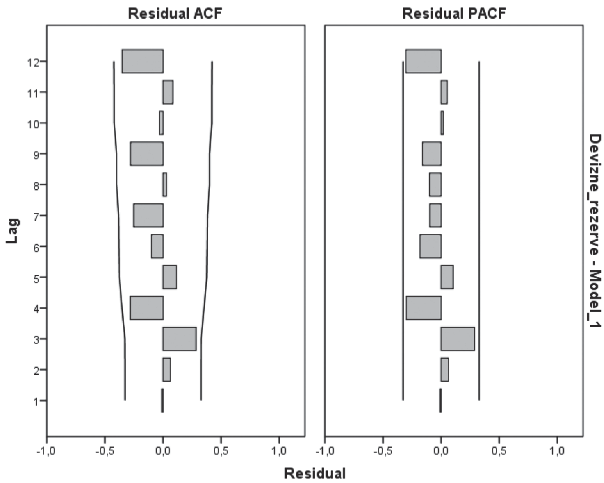

Figure 12: Actual and estimated value of the time series

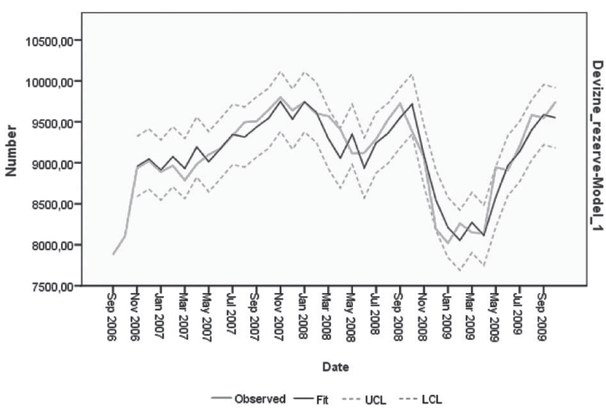

Table 26: Kolmogorov-Smirnov test of normality residual

		Noise residual from Foreign exchange reserves-Model_1
N		36
Normal Parameters[a,b]	Mean	25,4844
	Std. Deviation	170,41907
Most Extreme Differences	Absolute	,113
	Positive	,062
	Negative	-,113
Kolmogorov-Smirnov Z		,675
Asymp. Sig. (2-tailed)		,752

a. Test distribution is Normal.
b. Calculated from data.

4. Modelling of macroeconomic indicators relating to emerging countries

Macroeconomic indicators of emerging countries (Russia, China, Brazil, India, Singapore, Argentina and Chile), which will be modeled are: GDP, inflation and foreign exchange reserves. The indicators to be modelled are based on the exchange rate and interest rate models using the Stepwise Multiple Regression.

$$Y_i = \beta_0 + \beta_1 \cdot X_{1i} + \beta_2 \cdot X_{2i} + \varepsilon_i$$

Yt - a variable which is modeled; Xit - predictor model; Coefficients β - parameters of the model; - Member of the stochastic model which is assumed to have a normal schedule.

Before we start modeling, we will check the distribution of given variables that will participate in the model. Based on Table 27 it can be seen that all variables have a normal distribution because the statistical significance of the Kolmogorov-Smirnov test was greater than 5%.

Table 27: Distribution of the model variables

Statistics= Asymp. Sig. (2-tailed)

Emerging markets		GDP	Inflation	Foreign exchange reserves	Interest rate	Exchange rate
dimension0	Russia	,841	,910	,867	,587	,987
	China	,938	,922	,952	,422	,310
	Brasil	,418	,907	,279	,985	,875
	Argentina	,767	,380	,985	,211	,096
	South Africa	,745	,999	,612	,675	,789
	India	,875	,755	,983	,752	,983
	Singapur	,567	,619	,983	,675	,907
	Chile	,436	,746	,390	,824	,728
	Indonesia	,990	,874	,488	,811	1,000

a. Test distribution is Normal.
b. Calculated from data.

4.1. Modeling of GDP

Modeling of GDP, inflation and foreign currency reserves based on the predictor (exchange rate and interest rate) shows that Predictor is important if both predictors are included in the model (Tables 28, 31 and 34). A predictor, which is first included in the model, is the statistically significant predictor which is included in the model later.

Table 28: Predictors which are included in the model

Emerging markets		Model		Variables Entered	Variables Removed	Method
dimension0	Russia	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
			2	Interest rate (%)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	China	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	Brasil	dimension1	1	Interest rate (%)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	India	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	Singapur	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	Chile	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).

a. Dependent Variable: BDP (mlrd USD)

Based on Tables 29, 32, and 35, it is concluded whether the given model is significant. If the statistical significance of F-statistic is less than 5%, the model is statistically significant.

Table 29: Analysis of variance

Emerging markets		Model		Sum of Squares	df	Mean Square	F	Sig.
dimension0	Russia	1	Regression	817796,807	1	817796,807	19,680	,003[a]
			Residual	290890,119	7	41555,731		
			Total	1108686,926	8			
		2	Regression	968284,495	2	484142,247	20,689	,002[b]
			Residual	140402,431	6	23400,405		
			Total	1108686,926	8			
	China	1	Regression	4123492,754	1	4123492,754	56,159	,000[a]
			Residual	513980,500	7	73425,786		
			Total	4637473,254	8			
	Brasil	1	Regression	468080,414	1	468080,414	17,493	,004[c]
			Residual	187302,891	7	26757,556		
			Total	655383,305	8			
	India	1	Regression	240408,697	1	240408,697	6,543	,038[a]
			Residual	257204,552	7	36743,507		
			Total	497613,249	8			
	Singapur	1	Regression	6130,421	1	6130,421	92,432	,000[a]
			Residual	464,268	7	66,324		
			Total	6594,688	8			
	Chile	1	Regression	5910,261	1	5910,261	8,699	,021[a]
			Residual	4755,940	7	679,420		
			Total	10666,201	8			

a. Predictors: (Constant), Exchange rate (per USD)
b. Predictors: (Constant), Exchange rate (per USD), Interest rate (%)
c. Predictors: (Constant), Interest rate (%)
d. Dependent Variable: GDP (mlrd USD)

Based on Tables 30, 33, and 36, a model for the given dependent variable can be formed on the basis of the given predictors. The estimated coefficients in the model have a clear economic interpretation.

Table 30: Price model coefficients

Emerging markets		Model		Unstandardized Coefficients		Standardized Coefficients		
				B	Std. Error	Beta	t	Sig.
dimension0	Russia	1	(Constant)	4775,643	949,317		5,031	,002
			Exchange rate (per USD)	-148,867	33,558	-,859	-4,436	,003
		2	(Constant)	3964,450	780,896		5,077	,002
			Exchange rate (per USD)	-104,018	30,772	-,600	-3,380	,015
			Interest rate (%)	-28,099	11,080	-,450	-2,536	,044
	China	1	(Constant)	14419,390	1675,876		8,604	,000
			Exchange rate (per USD)	-1565,174	208,860	-,943	-7,494	,000
	Brasil	1	(Constant)	1942,529	288,721		6,728	,000
			Interest rate (%)	-70,544	16,866	-,845	-4,183	,004
	India	1	(Constant)	4364,249	1442,708		3,025	,019
			Exchange rate (per USD)	-81,431	31,835	-,695	-2,558	,038
	Singapur	1	(Constant)	462,517	36,891		12,537	,000
			Exchange rate (per USD)	-213,393	22,196	-,964	-9,614	,000
	Chile	1	(Constant)	316,143	74,449		4,246	,004
			Exchange rate (per USD)	-,366	,124	-,744	-2,949	,021

a. Dependent Variable: GDP (mlrd USD)

Model GDP for Russia:[1] $Y_i = 3964,450 - 104,018 \cdot X_{1i} - 28,099 \cdot X_{2i} + e_i$

Model GDP for China:[2] $Y_i = 14419,390 - 1565,174 \cdot X_{1i} + e_i$

Model GDP for Brazil:[3] $Y_i = 1942,529 - 70,544 \cdot X_{2i} + e_i$

Model GDP for India:[4] $Y_i = 4364,249 - 81,431 \cdot X_{1i} + e_i$

Model GDP for Singapore:[5] $Y_i = 462,517 - 213,393 \cdot X_{1i} + e_i$

Model GDP for Chile:[6] $Y_i = 316,143 - 0,366 \cdot X_{1i} + e_i$

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1 Y - GDP; X1 - the exchange rate; X2 - the interest rate; ei - residual model. When the exchange rate increases by 1% (provided that the interest rate constant), GDP is reduced to 104.018 billion; and if the interest rate increases by 1% (provided that the exchange rate remains constant), GDP decreased by 28,099 billion.

2 Y - GDP; X1 - the exchange rate; ei - residual model. When the exchange rate increases by 1% (appreciation), GDP is reduced to 1,565.174 billion.

3 Y - GDP; X2 - the interest rate; ei - residual model. When interest rates increase by 1% of GDP is reduced to 70.544 billion dollars.

4 Y - GDP; X1 - the exchange rate; ei - residual model. When the exchange rate rises by 1% of GDP is reduced to 81.431 billion dollars.

5 Y - GDP; X1 - the exchange rate; ei - residual model. When the exchange rate rises by 1% of GDP is reduced to 213.393 billion dollars.

6 Y - GDP; X1 - the exchange rate; ei - residual model. When the exchange rate rises by 1%, GDP decreased by 0.366 billion dollars

4.2. Modeling inflation

Table 31: Predictors which are included in the model

Emerging markets		Model		Variables Entered	Variables Removed	Method
dimension0	Russia	dimension1	1	Interest rate (%)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	Brasil	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	Argentina	dimension1	1	Interest rate (%)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
			2	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	Singapur	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	Chile	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).

a. Dependent Variable: Inflation (%)

Table 32: Analysis of variance

Emerging markets		Model		Sum of Squares	df	Mean Square	F	Sig.
dimension0	Russia	1	Regression	104,309	1	104,309	36,199	,001[a]
			Residual	20,171	7	2,882		
			Total	124,479	8			
	Brasil	1	Regression	32,891	1	32,891	7,921	,026[b]
			Residual	29,068	7	4,153		
			Total	61,959	8			
	Argentina	1	Regression	958,992	1	958,992	21,181	,002[a]
			Residual	316,927	7	45,275		
			Total	1275,919	8			
		2	Regression	1163,764	2	581,882	31,129	,001[c]
			Residual	112,155	6	18,692		
			Total	1275,919	8			
	Singapur	1	Regression	21,894	1	21,894	26,904	,001[b]
			Residual	5,697	7	,814		
			Total	27,591	8			
	Chile	1	Regression	21,162	1	21,162	8,211	,024[b]
			Residual	18,041	7	2,577		
			Total	39,203	8			

a. Predictors: (Constant), Interest rate (%)
b. Predictors: (Constant), Exchange rate (per USD)
c. Predictors: (Constant), Interest rate (%), Exchange rate (per USD)
d. Dependent Variable: Inflation (%)

Table 33: Price model coefficients

	Model			Unstandardized Coefficients		Standardized Coefficients		
				B	Std. Error	Beta	t	Sig.
dimension0	Russia	1	(Constant)	3,529	1,722		2,049	,080
			Interest rate (%)	,605	,101	,915	6,017	,001
	Brasil	1	(Constant)	-2,994	3,587		-,835	,431
			Exchange rate (per USD)	4,150	1,474	,729	2,814	,026
	Argentina	1	(Constant)	-1,200	3,245		-,370	,722
			Interest rate (%)	1,303	,283	,867	4,602	,002
		2	(Constant)	-14,707	4,583		-3,209	,018
			Interest rate (%)	1,168	,186	,777	6,263	,001
			Exchange rate (per USD)	5,586	1,688	,411	3,310	,016
	Singapur	1	(Constant)	22,844	4,086		5,590	,001
			Exchange rate (per USD)	-12,753	2,459	-,891	-5,187	,001
	Chile	1	(Constant)	16,895	4,585		3,685	,008
			Exchange rate (per USD)	-,022	,008	-,735	-2,865	,024

a. Dependent Variable: Inflation (%)

Model inflation for Russia:[7] $Y_i = 3,529 - 0,605 \cdot X_{2i} + e_i$

Model of inflation for Brazil:[8] $Y_i = -2,994 + 4,150 \cdot X_{1i} + e_i$

Model inflation for Argentina:[9] $Y_i = 14,707 + 5,586 \cdot X_{1i} + 1,168 \cdot X_{2i} + e_i$

Model inflation for Singapore:[10] $Y_i = 22,844 - 12,753 \cdot X_{1i} + e_i$

Model inflation for Chile:[11] $Y_i = 16,895 - 0,22 \cdot X_{1i} + e_i$

[7] Y - inflation; X2 - the interest rate; ei - residual model. When the interest rate increases by 1%, inflation is reduced to 0.605%.

[8] Y - inflation; X1 - the exchange rate; ei - residual model. When the exchange rate rises by 1%, inflation reduces to 4.150%.

[9] Y - inflation; X1 - the exchange rate; X2 - the interest rate; ei - residual model. When the exchange rate increases by 1% (provided that the interest rate constant), inflation increases by 5,586%; and if the interest rate increases by 1% (provided that the exchange rate constant), inflation has increased by 1,168%.

[10] Y - inflation; X1 - the exchange rate; ei - residual model. When the exchange rate rises by 1%, inflation reduces by 12,753%.

[11] Y - inflation; X1 - the exchange rate; ei - residual model. When the exchange rate rises by 1%, inflation reduces to 0.22%.

4.3. Modeling of foreign exchange reserves

Table 34: Predictors which are included in the model

Emerging markets		Model		Variables Entered	Variables Removed	Method
dimension0	Russia	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
			2	Interest rate (%)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	China	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	Brasil	dimension1	1	Interest rate (%)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	India	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).
	Singapur	dimension1	1	Exchange rate (per USD)	.	Stepwise (Criteria: Probability-of-F-to-enter <= ,050, Probability-of-F-to-remove >= ,100).

a. Dependent Variable: Foreign exchange reserves (mld USD)

Table 35: Analysis of variance

Emerging markets		Model		Sum of Squares	df	Mean Square	F	Sig.
dimension0	Russia	1	Regression	1,758E11	1	1,758E11	21,904	,002[a]
			Residual	5,618E10	7	8,026E9		
			Total	2,320E11	8			
		2	Regression	2,095E11	2	1,048E11	28,011	,001[b]
			Residual	2,244E10	6	3,740E9		
			Total	2,320E11	8			
	China	1	Regression	2,715E12	1	2,715E12	47,281	,000[a]
			Residual	4,020E11	7	5,743E10		
			Total	3,117E12	8			
	Brasil	1	Regression	2,011E10	1	2,011E10	12,527	,009[c]
			Residual	1,124E10	7	1,605E9		
			Total	3,134E10	8			
	India	1	Regression	4,175E10	1	4,175E10	12,038	,010[a]
			Residual	2,428E10	7	3,468E9		
			Total	6,603E10	8			
	Singapur	1	Regression	9,447E9	1	9,447E9	124,120	,000[a]
			Residual	5,328E8	7	7,611E7		
			Total	9,980E9	8			

a. Predictors: (Constant), Exchange rate (per USD)
b. Predictors: (Constant), Exchange rate (per USD), Interst rate (%)
c. Predictors: (Constant), Interest rate (%)
d. Dependent Variable: Foreign exchange reserves (mld USD)

Table 36: Rating model coefficients

Emerging markets		Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
dimension0	Russia	1	(Constant)	2131119,887	417193,556		5,108	,001
			Exchange rate (per USD)	-69021,447	14747,517	-,871	-4,680	,002
		2	(Constant)	1747025,714	312197,768		5,596	,001
			Exchange rate (per USD)	-47785,300	12302,469	-,603	-3,884	,008
			Interest rate (%)	-13304,603	4429,824	-,466	-3,003	,024
	China	1	(Constant)	1,096E7	1482143,515		7,394	,000
			Exchange rate (per USD)	-1270129,489	184715,267	-,933	-6,876	,000
	Brasil	1	(Constant)	326078,745	70714,546		4,611	,002
			Interest rate (%)	-14620,916	4130,952	-,801	-3,539	,009
	India	1	(Constant)	1685166,132	443230,889		3,802	,007
			Exchange rate (per USD)	-33934,394	9780,420	-,795	-3,470	,010
	Singapur	1	(Constant)	553799,817	39519,536		14,013	,000
			Exchange rate (per USD)	-264902,380	23777,403	-,973	-11,141	,000

a. Dependent Variable: Foreign exchange reserves (mld USD)

Model exchange reserves for Russia:[12] $Y_i = 1747025,714 - 47785,30 \cdot X_{1i} - 13304,603 \cdot X_{2i} + e_i$

Model for China's foreign exchange reserves:[13] $Y_i = 1,96 \cdot 10^7 - 1270129,489 \cdot X_{1i} + e_i$

Model exchange reserves for Brazil:[14] $Y_i = 326078,745 - 14620,916 \cdot X_{2i} + e_i$

Model exchange reserves of India:[15] $Y_i = 1685166,132 - 33934,394 \cdot X_{1i} + e_i$

Model exchange reserves of Singapore:[16] $Y_i = 553799,817 - 264902,380 \cdot X_{1i} + e_i$

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12 Y - foreign exchange reserves; X1 - the exchange rate; X2 - the interest rate; ei - residual model. When the exchange rate increases by 1% (provided that the interest rate constant), foreign exchange reserves are reduced to 47,785 billion; and if the interest rate increases by 1% (provided that the exchange rate constant), foreign exchange reserves are reduced to 13,304 billion dollars.

13 Y - foreign exchange reserves; X1 - the exchange rate; ei - residual model. When the exchange rate rises by 1%, foreign exchange reserves are reduced to 1,270.129 billion.

14 Y - foreign exchange reserves; X2 - the interest rate; ei - residual model. When the interest rate increases by 1%, the foreign exchange reserves are reduced by 14,620 billion dollars.

15 Y - foreign exchange reserves; X1 - the exchange rate; ei - residual model. When the exchange rate rises by 1%, the foreign exchange reserves to reduce shrink by 33,934 billion dollars.

16 Y - inflation; X1 - the exchange rate; ei - residual model. When the exchange rate rises by 1%, foreign exchange reserves are reduced to 264.902 billion dollars.

Checking the adequacy of previous modeling

For the previous three model to be statistically significant, it is necessary that the model residuals have a normal distribution and that there is no autocorrelation of the residuals of the model code.

Testing on the basis of Kolmogorov-Smirnov test (Table 37), if the residuals have a normal distribution and the statistical significance of greater than 5%, the residuals have a normal distribution. The conclusion is that all residuals have met the given hypothesis.

Table 37: Statistical significance of the normal distribution of residuals

Statistics = Asymp. Sig. (2-tailed)

Emerging markets		Unstandardized Residual for GDP	Unstandardized Residual for Inflation	Unstandardized Residual for Foreign exchange reserves
dimension0	Russia	,924	,854	,907
	China	,974		,812
	Brasil	,984	,989	,930
	Argentina		,964	
	India	,425		,967
	Singapur	,983	,937	,388
	Chile	,972	,850	

a. Test distribution is Normal.
b. Calculated from data.

A check is made whether the residuals are statistically significant autocorrelation (Tables 38, 39, and 40). Testing is conducted on the basis of Ljung-Box statistics. If the statistical significance is greater than 5%, there is no problem with the residuals autocorrelation. The conclusion is that the residuals meet this requirement as well, which means that the previous modeling was statistically valid.

Table 38: Estimated value of the autocorrelation of residuals

Series: Unstandardized Residual for GDP

Emerging markets		Lag	Autocorrelation	Std. Error[a]	Box-Ljung Statistic		
					Value	df	Sig.[b]
dimension1	Russia	1	,105	,333	,137	1	,711
		2	-,439	,337	2,864	2	,239
	China	1	,616	,333	4,699	1	,030
		2	,157	,442	5,046	2	,080
	Brasil	1	-,301	,333	1,118	1	,290
		2	,091	,362	1,236	2	,539
	India	1	-,143	,333	,252	1	,616
		2	,116	,340	,443	2	,801
	Singapur	1	-,236	,333	,687	1	,407
		2	-,305	,351	1,999	2	,368
	Chile	1	,261	,333	,841	1	,359
		2	-,235	,355	1,622	2	,444

a. The underlying process assumed is MA with the order equal to the lag number minus one. The Bartlett approximation is used.
b. Based on the asymptotic chi-square approximation.

Table 39: The estimated residual value of the auto correlation

Series: Unstandardized Residual for Inflation

Emerging markets		Lag	Autocorrelation	Std. Error[a]	Box-Ljung Statistic		
					Value	df	Sig.[b]
dimension1	Russia	1	,005	,333	,000	1	,985
		2	-,358	,333	1,811	2	,404
	Brasil	1	,371	,333	1,705	1	,192
		2	,045	,376	1,734	2	,420
	Argentina	1	,262	,333	,851	1	,356
		2	-,192	,356	1,370	2	,504
	Singapur	1	-,108	,333	,143	1	,705
		2	-,142	,337	,429	2	,807
	Chile	1	,015	,333	,003	1	,959
		2	-,293	,333	1,217	2	,544

a. The underlying process assumed is MA with the order equal to the lag number minus one. The Bartlett approximation is used.
b. Based on the asymptotic chi-square approximation.

Table 40: The estimated residual value of the auto correlation

Series: Unstandardized Residual for Foreign exchange reserves

Emerging markets		Lag	Autocorrelation	Std. Error[a]	Box-Ljung Statistic		
					Value	df	Sig.[b]
dimension1	Russia	1	,189	,333	,444	1	,505
		2	-,586	,345	5,293	2	,071
	China	1	,548	,333	3,710	1	,054
		2	,182	,422	4,180	2	,124
	Brasil	1	-,031	,333	,012	1	,913
		2	-,098	,334	,148	2	,929
	India	1	,156	,333	,302	1	,583
		2	-,184	,341	,783	2	,676
	Singapur	1	,142	,333	,250	1	,617
		2	-,014	,340	,252	2	,881

a. The underlying process assumed is MA with the order equal to the lag number minus one. The Bartlett approximation is used.
b. Based on the asymptotic chi-square approximation.

Conclusion

The exchange rate is an important transmission mechanism of monetary policy because, depending on the nature of shocks, it affects inflation and aggregate demand, especially in a small and open economy. In recent years, there has been a particular interest in the relation between exchange rates and interest rates both in developed countries and emerging countries. This is understandable given the important role that these variables have in determining the movement of nominal and real economic variables, including the movement of domestic inflation, real output, exports and imports, etc. Among emerging economies, this interest is further fueled by the fact that many of the countries have introduced changes in their monetary policies and exchange rate policies, adopting inflation targeting that involves a floating exchange rate regime. The variability of the exchange rate has increased in recent years compared to the previous periods characterized by much more rigid exchange rate regimes.

There is a certain correlation between foreign exchange reserves, exchange rate, and interest rate. The intercorrelation between the exchange rate and monetary policy can be displayed through the exchange rate volatility. Unlike developed countries, emerging countries tend to pay greater attention to achieving the exchange rate stability, as they have lower credibility to control the low inflation rate. The role of the exchange rate in the design of monetary policy rules is another way to study the correlation of the exchange rate and monetary policy. In most of the emerging countries, the monetary policy strongly responds to the exchange rate.

An increase in the domestic interest rate relative to the foreign interest rate leads to inflows of foreign capital that result in the exchange rate appreciation. Contrary to this, an increase in domestic prices relative to foreign prices leads to altered demand in favor of foreign goods, resulting in exchange rate depreciation. It has implications to the exchange rate and foreign reserves. However, high volatility of foreign exchange reserves can cause exchange rate instability. Monetary authorities discontinue the inflationary impact of foreign exchange inflows by accumulating foreign exchange reserves, reducing their effects on money supply. The aim of the central bank intervention is to reduce inflationary pressures and appreciation of the real exchange rate, and to avoid the loss of control over domestic money supply.

Foreign exchange interventions of the central bank aimed at preventing of currency depreciation, require a high level of foreign exchange reserves. It should be taken into account that there is a limit for the interventions. If weak fundamentals lead to the exchange rate depreciation, the intervention will not stabilize the exchange rate in the long run, unless the central bank increases the interest rate. But even then the stabilization is not secured. Furthermore, efforts to prevent depreciation by intervening on the foreign exchange markets might come as ineffective due to large budget deficits.

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