

## МИРОВАЯ ЭКОНОМИКА И МЕЖДУНАРОДНЫЕ ФИНАНСЫ

JEL: F31, C15, C53

### Analyzing dynamics and forecasting real effective exchange rates for BRICS countries (1994–2016)

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**For citation:** Shavshukov V. M., Vorontsovsky A. V., Vyunenko L. F. Analyzing dynamics and forecasting real effective exchange rates for BRICS countries (1994–2016). *St Petersburg University Journal of Economic Studies*, 2018, vol. 34, issue 4, pp. 568–590. <https://doi.org/10.21638/spbu05.2018.405>

This article analyses the behavior of real effective exchange rates of BRICS countries and Eurocurrencies (USD & GBP). The obtained data reveals regularities in the behavior of BRICS currencies during the period of 1994–2016 and confirms that rates in the export-focused economy depend on the structure of the international market of real and financial assets. It also demonstrates high currency volatility (on average 50 % in the group) in the zone reaching the level of BIS real effective exchange rate (REER) = 100 (CPI-base 2010). The fundamental analysis shows that in the long-term (1994–2017), BRICS currencies demonstrate stable growth and the fixed rate regime (as Yuan) proved to be the most efficient in the formation of the national segment of global economy. Downward trends in Forex reflect debut difficulties BRICS economies and finances experienced in the process of integration into the global financial and economic environment. High turbulence and volatility of the REER in the range of 60–130 % was the result of the global crisis of 2008–2009 and oil shocks in 2014–2015. The REER below 100 % reflects low corporate and global competitiveness of BRICS economies and weaknesses in public and corporate finance, not the stability of currencies. This research provides a long-term forecast for the strengthening of currencies, as a result of growing efficiency of national economies and the creation of BRICS financial infrastructure (New Development Bank [capital \$100 bln] and Pool Contingent Reserve Arrangement [startup capital \$100 bln]), as well as an increase in the share of national currencies in mutual payments. The possibility for constructing a short-term forecast, based on the polynomial residues model and statistical modeling, is demonstrated in the case of BRICS currencies. The results of the short-term BIS REER forecast can also be used for forecasting the behavior of currencies, hedging by participants of foreign trade transactions, and currency policy of central banks.

**Keywords:** BRICS countries, currencies, real effective exchange rates, BIS REER, fundamental analysis, volatility, short-term forecasting.

## Introduction

The increasing influence of random factors on the performance of markets for real financial assets has become an essential feature of the modern world economy. These conditions demand improved methods of analyzing and forecasting, as financial markets are particularly vulnerable and easily affected by uncertainty and consequential high risks. There are various theories on financial markets, among which the market for capital, with its mechanisms and models for analyzing and forecasting the profitability of certain financial assets and market performance, plays the most important role [Attaly, 2009, p. 45–65]. These theories provide a complex analysis of financial assets, taking into account time and risk factors. The market value of assets changes with time, and is influenced by such classical factors as supply and demand, government and corporate bond interest rates, and so on. This article examines the possibilities of a comparative analysis applied to models of exchange rate behavior in BRICS countries: Real (BRL), Ruble (RUB), Rupee (INR), Chinese Renminbi (RMB, CHY), and South Africa Rand (ZAR), along with Eurocurrencies (USD, GBP).

Currently, much attention is paid to general issues of economic coordination and prospects for development of BRICS countries [Vinnitskiy, 2018; Avdokushin, Zharikov, 2013; Mindreci, Mihai, 2013; Ardzinba, 2014; Sadovnichy et al., 2014]. The role and importance of BRICS countries in multipolar globalization is emphasized [Pieterse, 2018], and problems of personnel management in BRICS countries [Jürgens, Krzywdzinski, 2013] and social security features [Ghai, 2015] are being studied. Particular attention is drawn to financial flows to African countries under the influence of BRICS countries [Wamboye, Tiruneh, 2017]. The national characteristics of countries participating in the BRICS group are considered in the context of their interaction and collaboration [Wulf, Tobias, 2015; Glinkina et al., 2014]. General problems and peculiarities of the REER analysis are also under consideration [Chinn, 2006; Maeso-Fernandez, Osbat, Schnatz, 2002, 2005; Anderson, Karamouzis, Skaperdas, 1987]. Other topics of study include: the impact of exchange rates on prospects for economic growth [Dosse, 2007; Eichengreen, 2007]; exchange rates under conditions of open economy models, given global prices for raw materials [Manzur, 2018], including oil [Volkov, Yuhn, 2016]; predicting dynamics of exchange rate indices using ARMA models [Rout et al., 2014], including continuous ARMA models [Arratia, Cabana A., Cabana E., 2016] and GARCH models with modifications [Gupta, Kashyap, 2016; Barunik, Krehlik, Vacha, 2016]; applying neural networks for forecasting exchange rates [Liu, Hou, Liu, 2017; Zhenhua, Zezheng, Chao, 2016]; using the Support Vector Machine method and genetic algorithms to forecast daily exchange rates [Özorhan, Toroslu, Sehitoğlu, 2017] or including panel data analysis, taking into account macroeconomic indicators and market volatility [Morales-Arias, Moura, 2013]. Some scholars draw attention to uncertainty in forecasting exchange rates [Kouwenberg, Markiewicz, Verhoeks, 2017; Detken, 2002], while others propose using cointegration methods and random processes models [Moosa, Vaz, 2016] predict exchange rates, including models taking into account incomplete information [Juselius, 2017]. It is worth noting the use of simulation, based on the Support Vector Machine method [Yuan, 2013] to improve the quality of forecasts based on random processes [Moosa, 2013].

To take into account effects of external shocks, we propose introducing special noise variables [Gali, Rabanal, 2004; Woodford, 2007] and using stochastic differential equa-

tions to simulate dynamics of macroeconomic indicators [Turnovsky, 2000, p.547–558; Vorontsovsky, Vyuneneko, 2014], including the REER [Vorontsovsky, Vyuneneko, 2017].

In this paper we introduce the hypothesis that a comparative analysis of BIS REER, based on internal and external economic factors, makes it possible to identify regularities. The second aim is to assess the possibility of forecasting short-term REER dynamics by applying a simulation based on a discrete approximation of the stochastic equation describing BIS REER evolution.

## **1. Effective exchange rate as an indicator of stability and reliability of currency**

The object of the analysis is the effective exchange rate (EER), calculated by the Bank for International Settlements (BIS) in Basel, Switzerland. The EER covers 61 countries, including the Eurozone. The BIS provides estimates of nominal and real EER. Nominal EER is the geometrically weighted expected value of bilateral exchange rates. The real effective exchange rate (REER) is another weighted expected value of bilateral exchange rates, calculated as a weighted sum of the real exchange rate during a specified year in relation to 2010 as the base year. This reflects mutual foreign trade (multiplied by the relative weight of the sum of trading countries in export-import transactions) and the country's inflation rate. The standard procedure for calculating the real exchange rate is based on the correlation of consumer price indices in the country and abroad, weighted proportionally to the share of each country in foreign trade. The measurement of EER has been carried out since 1994 and is based on two baskets, broad and narrow. The broad basket represents indices of 61 economies, and the narrow represents 27 countries. The EER is a monthly average. An increase in EER indicates an increase in the value of the currency, and vice versa.

It appears that REER most adequately reflects the exchange rate of national currencies, as it takes into account rates of the main trading partners and inflation. Figures 1, 2, and 4 compare real effective exchange rates in BRICS countries and the main issuers of Eurocurrencies (USD and GBP) from January 31, 1994 until December 27, 2015. It is possible to see changes (increases and decreases) and trends in REER that have a variable character, volatility, and fluctuation margins.

The period under analysis (1994–2016) is characterized by global economic growth (1994–1997, 1999–2001, 2002–2007, 2010–2016) and crises in global finance for various segments: Mexico in 1994, SEA countries in 1997, Russia in 1998–1999, Turkey, Brazil, and Argentina in 1999–2000, the USA in 2001, the global crisis of 2008–2009, and recession in the EU in 2010–2014 and in Russia in 2014–2016. Recurrence of the global economy caused changes in nominal and real exchange rates. Currency volatility and fluctuation margins are accounted for by the state of fundamental world markets, by stability, balance and competitiveness of national economies, and corporate and public finance. In the end, a country's balance of payments reflects cash flows and determines supply and demand of currencies, as well as their rates.

Analyzing exchange rates using REER, economic cycles of national economies, and the global financial and economic environment made it possible to identify certain regularities. Observations of the Forex market for the Republic of South Africa over 21 years (1994–2016) identified certain stable movements: three downward trends (1994–2001, 2006–2009, 2011–2016) and two upward (2000–2006, 2009–2010). The first downward

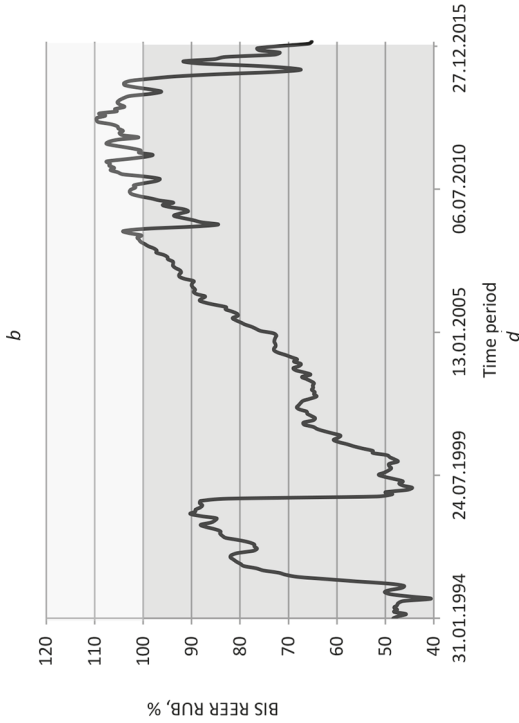
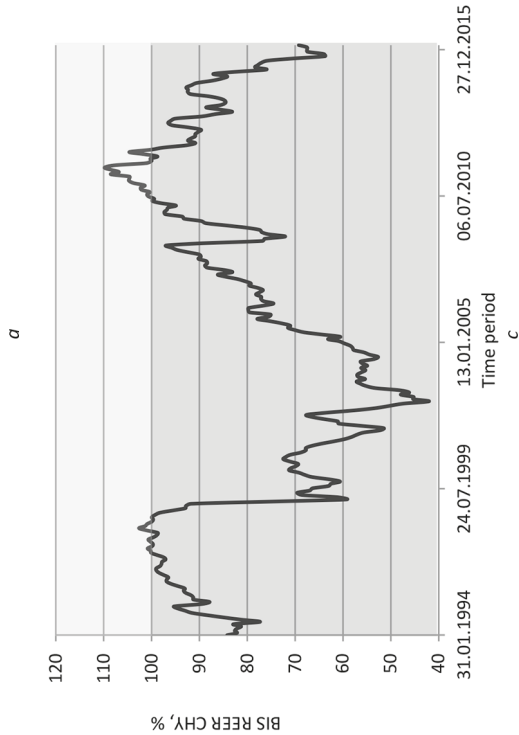
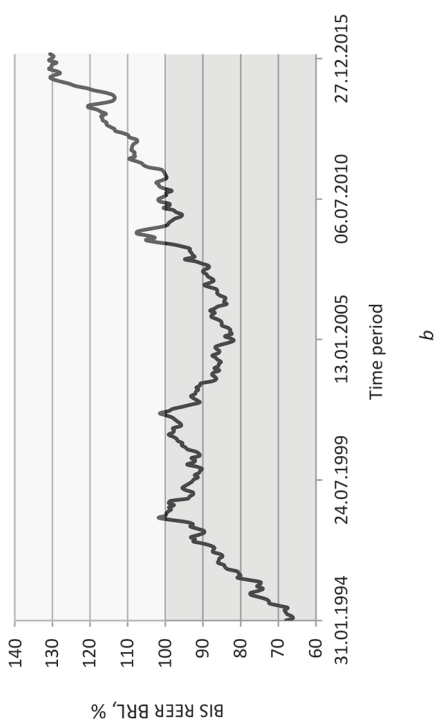
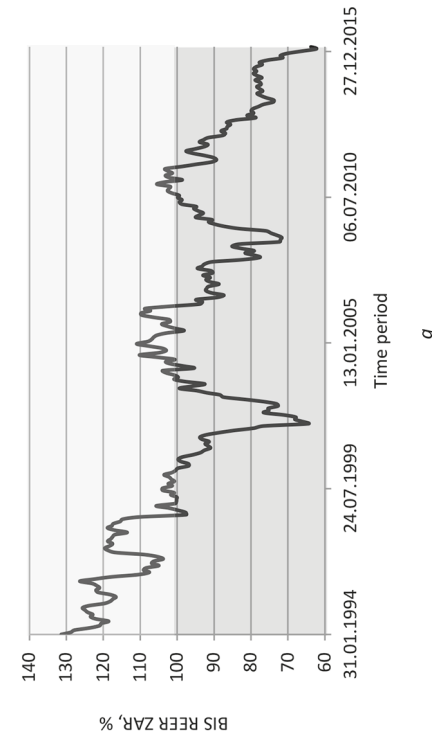


Fig. 1. BIS real effective exchange rates (REER) of ZAR (a), BRL (b), CHY (c), RUB (d) (CPI-base 2010, monthly average), 31.01.1994–27.12.2015. Note: the figure is based on the data provided by the source: BIS. Effective exchange rate indices. URL: <https://www.bis.org/statistics/eer.htm?m=6%7C381%7C676> (accessed: 15.08.2018).

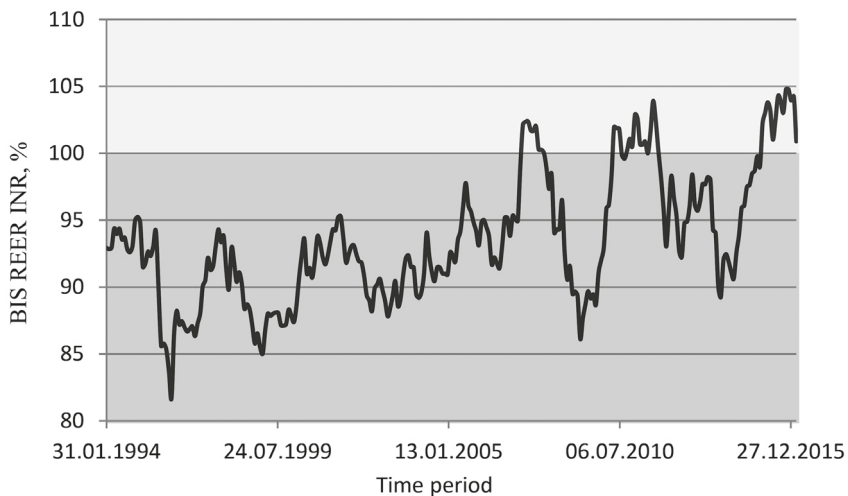


Fig. 2. BIS real effective exchange rates (REER) of INR (CPI-base 2010, monthly average) in 31.01.1994–27.12.2015

Note: the figure is based on the data provided by the source: BIS. Effective exchange rate indices. URL: <https://www.bis.org/statistics/eer.htm?m=6%7C381%7C676> (accessed: 15.08.2018).

trend was connected with debut difficulties of the emergent of the South African segment in the global financial and economic system. The second was caused by the global crisis; the third resulted from the worldwide post-crisis recession and an imbalance in the national economy. The upward trends reflect economic adaptation in the global environment and overcoming the crisis. Exchange rate volatility, ranging from 130 to 60 % from base of 2010, created additional obstacles for foreign direct investment (FDI).

Brazilian real exchange rates (BRL) during the same 21-year period are also highly volatile (60–130 %), but over short-term intervals of 5 years were relatively small (10 %). Therefore, medium-term investment projects were characterized by discounted rates of 10–12 %, reasonable for developing economies. The Brazilian currency demonstrated two upward and two downward trends. The first short-term upward trend ran from 1994 to 1998, during the formation of the Brazilian segment of the global economy. Currency shocks of 1998–1999 and 2008–2009 were caused by national and global crises. Over the long term, there was a stable strengthening of the BRL, characterized by small volatility in short-term periods. Since 1994, Brazil seems to have strengthened its national economy and currency.

The efficiency of the fixed rate regime is demonstrated by twenty years' history of the Chinese Yuan (RMB). This currency regime does not exclude de- or re-valuation. Exchange rate dynamic reflects the international monetary policy of the National Bank of China and an attempt to establish currency advantages in international commodity market competition. During the twenty-year period, the exchange rate was above the base index of 2010 only in 2008 and 2010–2011. During all other periods of observation, the rate was within the corridor of 40–100 %. Further, it was deliberately devaluated during the crisis of SEA countries and Russia (1998–1999), the global crisis of 2008–2009, and the sluggish recession of 2010–2016. Controlled devaluation remains an effective instrument of international monetary policy for competition in the international markets of real

assets. The fixed currency regime, unlike floating rates, prevents high volatility to limit currency risks and to retain foreign investors, thus making the Chinese economy more attractive and transforming it into an effective and cheaper producer of world brands.

In Russia, the Central Bank began to use REER in 2000. In its calculations of REER, the Bank considers currencies of those trading partners whose weight in foreign trade constituted no less than 0.5 %. The number of such countries in 2006 was 35 (87 % total foreign trade of Russia), led by Germany, Belarus, Ukraine, China, Italy, the Netherlands, and the USA. In the REER index, the share of the currency for each of these countries accounted for more than 4 % and in the cumulative goods turnover for 51.3 % [Kudrin, 2006].

REER for the Russian ruble is also quite variable. It is necessary to note the significant decrease in the exchange rate to the level of 40 % after the default in 1998. Until then, a similar trend had only been observed in early in the transition to the market economy, in August 1994. Until 2012, growth in the ruble exchange rate was stable, except for some decrease at the end of 2008 and beginning of 2009, when it exceeded 100 %. The REER had been falling until early 2015, with a slight increase during 2015, followed by collapse to nearly 60 % at the beginning of 2016. Since 2009, the Russian Central Bank had been pursuing a policy (within the ruble corridor) of binding the rate to a bi-currency basket, and in August 2013 adopted the flexible exchange rate (based on Article IV of the IMF report during the Russian Federation 2013 consultations<sup>1</sup>). However, the national currency was bound to the export of hydrocarbons, and its returns failed to withstand the collapse of oil prices in 2014.

Oil shocks, the halt in economic growth, and introduction of economic sanctions by the EU, USA, and Canada in December 2014 resulted in ruble devaluation by 45 %, but due to efficient anti-recessionary measures undertaken by the Central Bank, the basket returned to the 53–54 ruble corridor in April 2015.

Figure 2, demonstrating the dynamics of the effective exchange rate for the Indian rupee, makes it obvious that its rate is more stable than those of South Africa, Brazil, China, and Russia. The general interval of fluctuations during the period under consideration was within the range of 80 to 105 %, but for other BRICS countries this was much wider. However, it seems that within the specified period, the rupee exchange rate was characterized by higher turbulence. Its value did not drop below 80 % (February 1996), but the value of 100 % was exceeded only in July 2007 and late 2014 — early 2015. It should also be noted that in 2015–2016, the effective exchange rate exceeded 100 %.

Thus, during the post-crisis period of 2010–2014 ZAR (9.5 %), CHY (7.8 %), and BRL (7 %) demonstrated the highest level of volatility, while USD (2.5 %) and CHF (2.3 %) exhibited the lowest. Other currencies (EUR, GBP, INR, RUB, and ZAR) were within the average zone of turbulence (4–6 %). Statistics on volatility and effective exchange rate reflect a steady increase in stability of BRICS currencies, but the figures have not yet achieved threshold values that would promote further business development (2–3 % annual volatility, 2–3 % and 1–1.5 % exchange rate for strengthened currencies), and in 2014–2015 the currency market continued to demonstrate high turbulence due to international commodity markets, conditions of national economies, geopolitical shocks, and macroeconomic policies of developed economies. BRICS currencies suffered from oil shocks and strengthening of the USD, which began in the last quarter of 2014. Strengthening the re-

<sup>1</sup> URL: <https://www.imf.org/en/Publications/CR/Issues/2016/12/31/Russian-Federation-2013-Article-IV-Consultation-40995> (accessed: 15.08.2018)

serve currency resulted from the “Shale gas revolution,” an increase in the extraction and gas supply from the USA for international markets, as well as the Federal Reserve policy of “quantitative easing” (QES).

In this changing environment the Chinese Yuan maintained its traditional stability, while INR devaluated by 9.5 %, ZAR by 20 %, and BRL by 38 %. There are reasonable grounds to expect further strengthening and stabilization of all BRICS currencies in the near future as a result of strengthening economies within the bloc and its own “financial safety net” created by the *New Development Bank* and *Pool Contingent Reserve Arrangement*. An analog of the European Stability Mechanism (ESM), the Pool of Contingent Reserve Arrangement (CRA) is a BRICS Equalization Currency Fund (July 15, 2014) with a startup capital of \$100 bln and a capital structure (%) of: China — 41 %, Brazil, Russia, and India 18 % each, and South Africa 5 %. The fund was established to support balances of payments within the bloc.

The New Development Bank for BRICS (July 15, 2014) had its headquarters in Shanghai, with K. Ramath as its President. The aims of the Bank included funding (in local currencies) of infrastructure projects and projects for sustainable development of BRICS and other developing countries. In 2016 the Bank carried out 7 projects (at a total cost \$ 2.5–3 bln): two hydroelectric power plants in Karelia, Russia (\$100 mln); one hydroelectric power plant in Brazil (\$911 mln); one hydroelectric power plant in India (\$250 mln); one solar power plant in China (\$81 mln); one electric power line in South Africa (\$180 mln); and an issue of “Green bonds” in China (\$450 mln. coupons 3.07 %, 30 investors, Bank of China as the bookrunner). Another model used for the Pool is SWIFT. There are also plans to introduce a joint aggregated currency in the future. Both models open way for more intensive transactions in CHY and RUR and grounds for a positive forecast. First, the average daily trade turnover of CHY in the Forex in 2013 amounted to \$120 bln, versus \$85 bln for RUR. These two currencies were in the top 10 most used currency pairs: USD/CHY (daily turnover of \$113 bln, 2.1 % market share, 8<sup>th</sup> place), USD/RUR (turnover \$79 bln, 1.5 % market share, 10<sup>th</sup> place). In 2013 the share of the Yuan in the world currency trade accounted for 2.2 % (9<sup>th</sup> place), while the ruble was in 12<sup>th</sup> place at 1.6 % [Triennial Central Bank Survey, 2013].

One BRICS strategy was to carry out transactions in national currencies for companies involved in intensive export-import operations. In 2010–2014, bilateral trade between Russia and China increased by 50 % to \$88 bln, and China’s share of foreign trade with Russia reached 10 %. In 2014 the volume of trans-border payments from Russia in Yuan increased to 9.95 bln and amounted to 38 % of China’s foreign trade. Considering the size of China’s economy, the dynamics of the Yuan in Forex, and the character and cooperation between Russia and China, in 2011 the Russian Central Bank and the National Bank of China signed an agreement on the transition to settlements in national currencies. In 2010 the pairs CHY/RUR started trading in the Chinese Foreign Exchange Trade System (CFETS, Shanghai) and the Moscow Stock Exchange. In 2014 the total volume of transactions on both platforms reached \$1.9 bln, with 75 % operations carried out at the Moscow Exchange. The only deterrent for an increase in operations in national currencies is limited investment opportunities for financial instruments denominated in Yuan. Creating conditions for new investments might stimulate an increase in operations in national currencies.

Since 2000 BRICS balances of payments have been positively reacting to the new trading and investment policy developed by the bloc (see Table 1). In 2002–2014 developed countries had negative balances of payments, unlike developing countries, whose positive balances of payments were more attractive for foreign investors, which in its turn stimulated the strengthening of national currencies. Balance of current operations as a share of GDP (%) in 2010–2014 was also positive in the Eurozone, Japan, China, Russia and negative in the USA, Brazil, India, and South Africa (RSA). The first group was economies with export oriented strategies, while the second focused on foreign investments and domestic markets.

Positive dynamics of BRICS economic development in 2001–2011 was reflected by their rating histories. Since 2007 all BRICS countries were included into investment ratings (Fig. 3). The rating agency S&P, having commended the anti-recessionary policy of the group, in the second half of 2010 raised China's rating to AA- and in 2008 and later kept the ratings of the RSA (BBB+), Russia (BBB), and Brazil and India (BBB-) at a permanent level.

In 2010–2015 China, India, and Brazil had stable sovereign ratings of credit status as they managed to prevent any significant fall in GDP and maintained rather high growth of 5–7%, which was undoubtedly attractive for domestic and foreign investors. Russia and South Africa in 2012–2014 demonstrated negative GDP dynamics (in Russia GDP fell by 3.7%, and in South Africa by 3.9%), which was immediately reflected by the current account of the balance of payments and exchange rate (33.49% RUR and 31.15% ZAR devaluation from January 2010 to April 2015). This negative trend was noted by S&P: in 2013 ratings were lowered to BBB- and BB+ respectively.

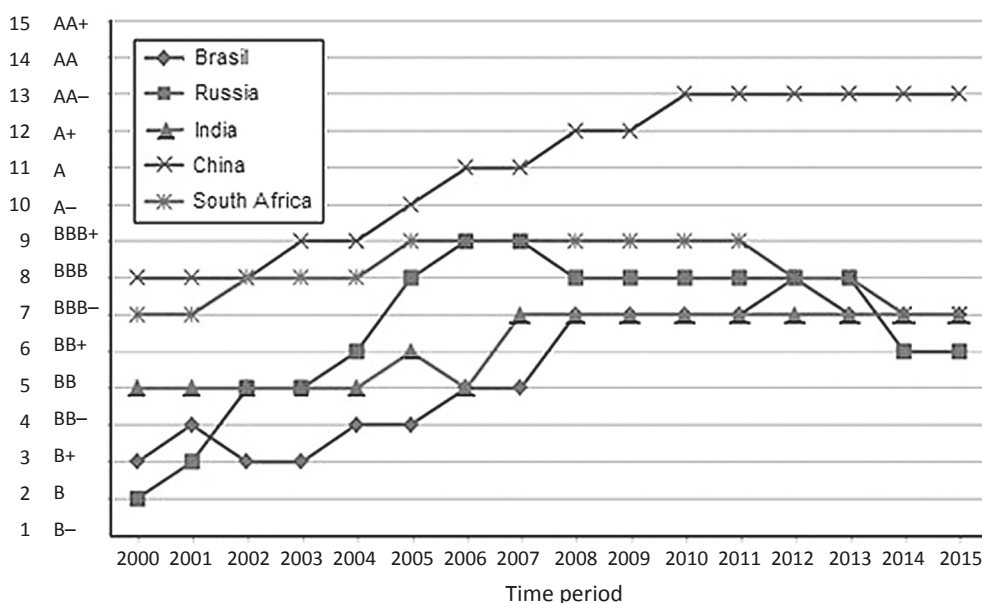


Fig. 3. BRICS ratings in 2000–2015 by S&P, long-term ratings in foreign currency

Note: lines 1–15 present rating levels. Line 13 AA- (average reliability), lines 7 BBB- 8 BBB, 9 BBB+ (reliability below average), line 6 BB+ (speculative category). The figure is based on the data provided by the source: Standard & Poor's. S&P Global Ratings. URL: [https://www.standardandpoors.com/en\\_US/web/guest/home](https://www.standardandpoors.com/en_US/web/guest/home) (accessed: 15.08.2018).



In the 80s there were two ongoing major processes taking place in the global economy: globalization and the beginning of modernization for Brazil, Russia, India, and China. In spite of the fact that Russia and China moved away from a command economy and Brazil and India retained their market economies, all four countries began reforms towards mixed economies.

Though reforms in BRICS countries were different in their content, forms, stages, and national specificity, they were all aimed at creating competitive national economies and businesses with new centers of power in the world geo-economy and geo-politics and improving living standards.

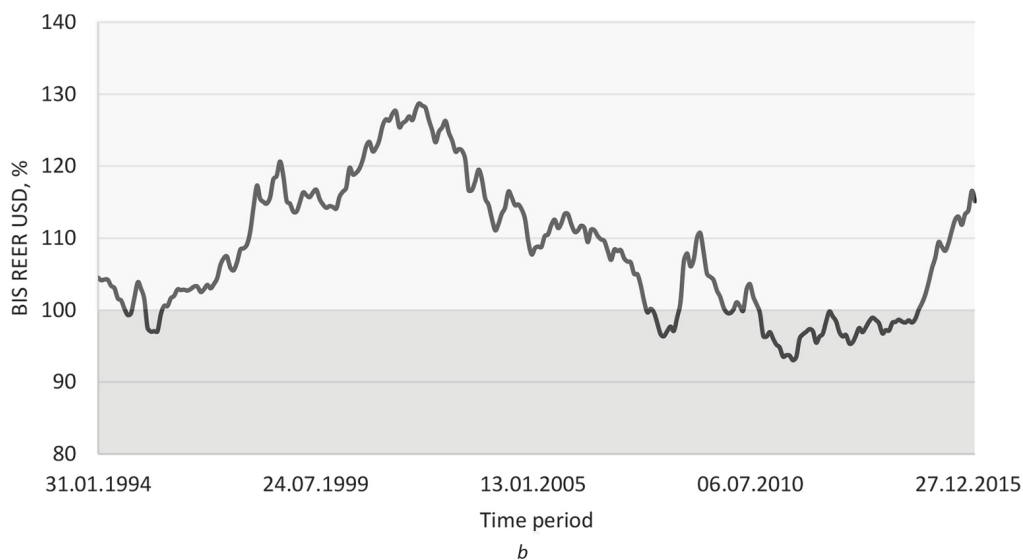
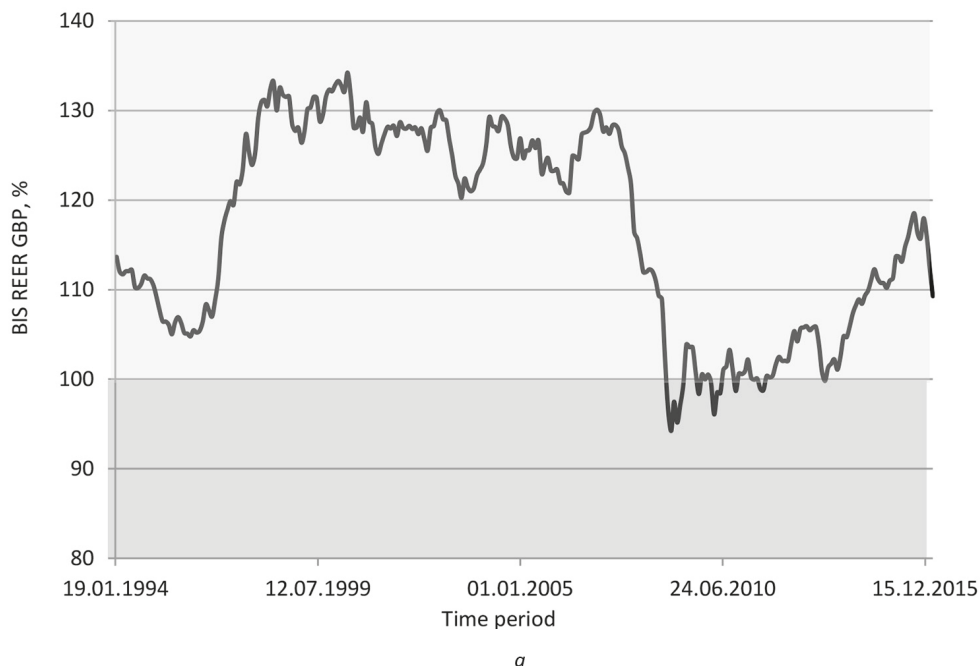
The strategies developed by BRICS countries intended to use advantages of globalization. These included: manufacture transferred from the Financial Centre to the Financial Periphery; transformation of national markets into a segment of the global; liberalization of currency legislation to allow for a considerable increase in capital flows between developed and developing countries; hi-tech connection of markets in the global economy. All these advantages made it possible to attract foreign capital, and to create hi-tech enterprises with modern systems of management and manufacturing cultures, opening the way to the international markets and to create their own MNCs.

For purposes of this study, it seems important to compare schedules of the real effective exchange rate (REER) of BRICS currencies and free used currencies of other countries that are the most attractive for Forex. Let us consider the Eurocurrencies as a peer group (Fig. 4), with particular attention to the USD and GBP. The graphs of REER of these currencies demonstrate that exchange rates during the period 1994–2016 steadily exceed the index of 2010 = 100 %.

The exchange rate for GBP showed a dynamic increase in 1995–1999 (35% for the period and 7% per year), slower growth of 3% a year in 2010–2016, and a 15% increase for the period. The falling trend, with a significant drop height of 35%, was short-term and could be linked to the global crisis and difficulties of the crisis-exit period (2007–2009). What attracts attention is a long eight-year period of rate stability (1999–2007) with a very small volatility of 10–11%. Thus, monetary and credit policies by the Bank of England demonstrated stability for such a device as Eurocurrency. The policy of floating rates from 1978 proved the ability of a free market currency to provide low volatility, reliability, and to appeal to participants in markets of financial assets. London maintained its position as the center of Eurocurrencies; the GBP maintained its status as a free used currency and SDR basket currency. However, during the global crisis the GBP provided no currency harbor for central banks and participants in Forex. Now, in preparation for Brexit, the future of the British currency is uncertain.

Great Britain, having lost its status as a world power in the 1930s, managed to benefit from globalization, having created in the 1970–1980s the global financial center for Eurocurrencies, which was extremely attractive for investors, transactions, and capital, providing high standards of competitiveness for national economy, and force and stability of currency.

Dynamics of REER for the USD during our 21-year period demonstrates two trends: one upwards (1994–2001, 2009, 2011–2015) and another downwards (2001–2008, 2010–2011). While downward movement was an adequate reaction of the currency to crises in the national and world economies, the opposite reaction within 12 years reflected the quality of economy and finance, and benefits received from the status of being a leading



*Fig. 4.* BIS real effective exchange rates (REER) of GBP (*a*) and USD (*b*) (CPI-base 2010, monthly average) in January 1994 — January 2015

Note: the figure is based on the data provided by the source: BIS. Effective exchange rate indices. URL: <https://www.bis.org/statistics/eer.htm?m=6%7C381%7C676> (accessed: 15.08.2018).

economy and USD as a reserve currency. It is not coincidental that the rate fell below 100% only during the global crisis and post-crisis recession (2008–2009 and 2010–2014), with volatility being small. In 1999–2005 it was 25% (5% a year), in 2005–2010 — 12% (2% a year on average), and in 2010–2016 20% (4% a year). As a whole, over 19 years the mid-annual volatility was at 3.3%.

What factors laid the foundation for the stability of the USD as a reserve currency and a benchmark? The USA, one of the main architects of globalization, reaped its benefits. In the 1980s the USA made its stock market attractive for foreign banks and investors. As a result, net capital inflow to the country increased from about \$19.4 billion in 1980 to \$153 billion in 1987. This strengthened the position of the United States in the global economy in the end of the 20<sup>th</sup> century, having increased the country's share of global GDP from 25 % to 30 %, with market capitalization from 30 % to 50 % (\$12.5 bln) [Rogovsky, Vasilev, 2008].

The American economy, besides already possessing available competitive advantages (ability to expand and diversify capital, manage human resources, and manufacture new production), also gained additional benefits from globalization. From the 1980s until 2011, the inflow of foreign investments to the USA steadily exceeded the outflow. In spite of the fact that since 1991 the current account balance-of-payments was in deficit (it increased from about \$12 bln in 1982 to \$856 bln in 2006), it did not pose a threat to the financial safety of the country.

This deficiency was covered by foreign investment, first of all from China and oil-producing countries, as can be seen from indicators from pre-crisis 2005. The amount of foreign assets of American residents was \$9.6 bln, while the amount of assets of foreign nationals in the USA accounted for \$12.5 bln, with a net international investment position of \$2.8 bln. Thus, direct foreign investments into the USA in 2006 amounted to \$184 bln, and the list of direct investors was headed by Great Britain and Germany [Stiglitz, 2012]. After the Second World War, the United States exploited the status of the dollar as the world's reserve currency, receiving not only issue income, but also additional income. The US mid-annual issue income is estimated at about \$500 bln.

## 2. Forecasting short-term dynamics of BIS REER for BRICS countries

The main problem in forecasting results is due to effects of external factors or shocks, which can be temporary or permanent. The former affect dynamics of the indicator only in the short term and do not change general trends; any fluctuations will be temporary. In contrast, external shocks will be persistent if their influence on the dynamics of indicators continues for a long period of time [Campbell, Mankiw, 1987], and result in significant changes of the previously calculated growth trajectory, preventing any possibility for it to revert in the future. Permanence corresponds directly to the nonstationary behavior of a time series, which is widely used in econometrics [Gujarati, 2009; Dougherty, 2016]. When making a forecast, it is necessary consider the current value of the indicator as the most important factor determining macroeconomic prospects. The increasing impact of an uncertainty factor and risks to the economy necessitates using specific mathematical methods of analysis and simulations to analyze random processes and to project the trajectory of growth.

This article considers composing a discrete approximation of stochastic equations that would describe the exchange rate, and applying the Monte-Carlo method, based on the expected trajectory determined from estimations by a simulation, to forecast the BIS REER of the currency. The authors use the approximation equation; how well it complies with real economic development requires a separate analysis.

The composition of relevant stochastic equations relies on the premise that changes in the BIS REER (hereinafter REER) have an irregular pattern. This approach includes

Table 1. Current account balance of developed and developing countries, 1997–2014, \$ bln., %/GDP<sup>1,2</sup>

Countries	1997	2002	2006	2007	2008	2009	2010	2011	2012	Current Account Balance, % GDP			
										2010	2012	2013	2014
Developed countries, including:	71	-223	-499	-344	-71.8	-01.1	-95.5	-26	-37		-0.1	NA	NA
USA	-41	-475	-805	-718	-68.9	-78.4	-470.2	-94	-440		-2.9	-2.3	-2.3
Euro Zone	96	49	18	15	-96.9	-69.4	-77	4	227		1.9	NA	NA
Japan	97	113	141	211	157.1	141.8	194.8	134	60		1.0	NA	NA
Emerging markets	-85	86	494	647	704	327	378	647	381		1.4	NA	NA
BRICS:											0.44	-2.6	-2.2
Brazil											-2.2	-2.4	-3.6
Russia											1.9	3.7	1.6
India											-4.2	-4.8	-2.5
China											5.1	2.3	2.0
RSA											-2.8	-6.4	-5.8
													-5.6

Note: the table is based on the data provided by the sources: World Bank Open Data. URL: <https://data.worldbank.org> (accessed: 15.08.2018); International Monetary Fund. IMF country information. URL: <https://www.imf.org/en/countries> (accessed: 15.08.2018).

models where indices are determined by a random diffusion process, which generally can be described by the following stochastic differential equation:

$$dr_t = a(t, r_t)dt + b(t, r_t)dw_t, \quad (1)$$

where  $r_t$  is currency REER at a time  $t$ ;  $dw_t$  is an increment of the standard Wiener process;  $a(t, r_t)$  and  $b(t, r_t)$  are functions of time and current value of REER, respectively. We assume that variables  $a(t, r_t)$  and  $b(t, r_t)$  are such that equation (1) has a unique solution, i.e. for every Wiener process  $w_t$  there is a single function  $r_t$  satisfying condition (1).

The forecast, following the above approach, is of an interval nature and includes the trend determined by the expected trajectory and the confidence band, determined so that the actual REER trajectory during the reference period was within this interval. The quality of the forecast depends on how much the REER dynamics within the reference period correspond to the established trend and whether the actual values of REER are within the determined confidence band.

The polynomial residues model, based on the method of successive differences to access variance of a random variable linear trend or in evaluating the smoothness degree of a trend, can be useful for making short-term forecasts as follows. Provided that series  $dr_t$ , consisting of increments of time series  $r_t$  (in this case, a series of BIS REER values at time  $t$ ), includes a random variable  $w_t$  and deterministic (systematic) polynomial variable  $Q^p$  of degree  $p$ , then the series consisting of successive differences  $k + 1$ , calculated in accordance with the formula

$$\Delta^{k+1}dr_t = \Delta^k dr_t - \Delta^k dr_{t-1}, \quad (2)$$

would contain only random variables, because

$$\Delta^k(Q^p) = 0, \quad k = p+1, p+2, \dots \quad (3)$$

However, it is assumed that all  $w_t$  are non-correlated and have expected value  $EW_t = 0$  and dispersion  $EW_t^2 = s^2$ . The procedure to determine degree  $p$  and the value of variables of the polynomial  $Q^p$ , containing the deterministic constituent of the series, for the polynomial in a low degree and a continuous period of time is described in detail in [Anderson, 1994; Brockwell, Davis, 2016]. Provided the variables of the polynomial and  $s^2$  are determined, levels of series  $r_t$  with the specified value  $dr_1$  can be calculated according to the recursion formula:

$$r_{t+1} = r_t + Q_t^p + s\xi_t, \quad (4)$$

where  $\xi_t$  is the standard normal random variable.

Equation (4) is usually used for interpolation, but under certain conditions it can be applied to extrapolation and constructing a short-term forecast. For that purpose, the results of the imitations of a large number of REER trajectories and modeling shall be used to calculate forecast values and their probabilistic estimates.

The analysis of data on expected REER demonstrated that the polynomial residues model can rather accurately be applied to forecast short-term REER dynamics in BRICS countries for time intervals of 17–22 months. The main problem in applying the

polynomial residues model is that the degree of the trend approximating polynomial and the choice of the fragment of dynamic series (i.e. time interval) to identify parameters of the model are individual in each separate case, and it does not seem feasible to formulate general recommendations from this.

In this research the polynomial residues model (4) was used to test the hypothesis of making a short-term forecast of BIS REER for BRICS currencies, which was further used to compare the expected estimated trajectory and actual values of REER over the forecast period. To estimate the quality of the generated forecast, we used the most common metrics: Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE), calculated for errors  $e_k$  and percentage errors  $P_k$  as follows:

$$MAPE = \frac{1}{n} \sum_{k=1}^n |P_k|, \quad RMSE = \sqrt{\frac{1}{n} \sum_{k=1}^n e_k^2}.$$

Figure 5 reveals simulated REER results for BRL (5a), INR (5b), CHY (5c), and ZAR (5d) calculated on the basis of data collected during the period from January 2013 to January 2016. One thousand simulated trajectories were used to calculate the mean expected trajectory and bounds of the 50% and 30% confidence bands. The results derived demonstrate that during the forecast period (September 2015 — January 2016) the trend described by mean expected trajectories of the REER BRL (Fig. 5a) and the REER INR (Fig. 5b) corresponds to the general vector of actual dynamics of the REER, with actual values of the simulated indicator within the 30% confidence band calculated in the simulation. The values  $MAPE = 0.0530$ ,  $RSME = 8.0626$  for REER BRL and  $MAPE = 0.0058$ ,  $RSME = 1.5031$  for REER INR show that the quality of the forecast for the expected REER trajectory is rather high.

During the forecast period the actual dynamics of the REER for CHY and ZAR were in line with the trend determined by mean calculated trajectories of the REER (Fig. 5c, 5d). Actual REER values for each of the five months of the forecast period are within the 50% confidence band. Therefore, we can conclude that the established short-term trend of the nominal expected trajectory and established confidence band reflect future dynamics of the REER for CHY and ZAR, deviations from the trend being insignificant.  $MAPE = 0.0070$ ,  $RSME = 2.4792$  for the CHY REER and  $MAPE = 0.0134$ ,  $RSME = 2.7361$  for the ZAR REER indicate a satisfactory quality of the forecast. Actual REER dynamics also confirm the forecast quality.

The results of forecasting REER for RUB on the basis of the 1<sup>st</sup> order polynomial residue model for 18 months are presented in Figure 6. They show a good agreement between the forecast trend and real dynamics of the index and the high quality of the forecast, taking into account the estimates  $MAPE = 0.0419$ ,  $RSME = 8.3724$ .

For purposes of comparison, we considered the forecast for the REER USD and GBP dynamics over the same forecast period (August 2015 — January 2016). The calculated mean trajectories demonstrate that within the forecast period, actual REER USD and GBP dynamics are in line with trends established by the mean expected trajectories.

The forecasted dynamics for the BIS REER GBP is, to a large extent, supported by data. The actual value of GBP REER only once (in November 2015) went beyond the established 50% confidence band for the mean trajectory (Fig. 7b). The values of MAPE and RSME are as follows:  $MAPE = 0.0108$ ,  $RSME = 3.4060$  for USD REER,

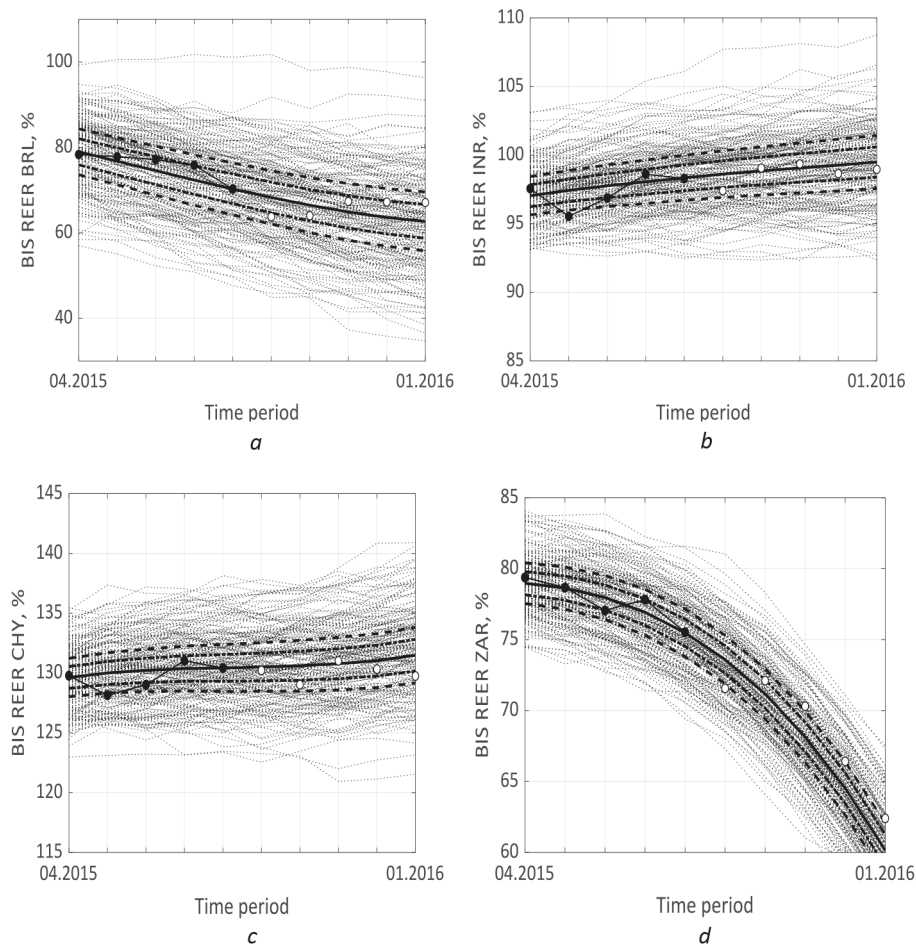


Fig. 5. BRL (a), INR (b), CHY (c), and ZAR (d) BIS REER forecast for the September 2015 – January 2016 period calculated on the basis of 2<sup>nd</sup> order polynomial residue model (for the time period of 22, 20, 17, 20 months respectively)

Note: (–) — expected mean trajectory, (– –) — bounds of the 50% confidence band, (•••) — bounds of the 30% confidence band, • — actual REER values during the reference period of April 2015 – August 2015, o — actual REER values over September 2015 – January 2016 (used for assessing the forecast quality).

MAPE = 0.0186, RSME = 5.8601 for GBP REER. This means that the quality of the forecast is relatively high, even though it is difficult to foresee the significant impact of transitory shocks at the forecast stage. Thus, we can conclude that the forecast quality for dynamics of the BIS REER GBP is lower, compared to BIS REER USD or the REERs of the BRICS currencies.

Generally, the quality of the forecast is relatively high, even though it is difficult to foresee the significant impact of transitory shocks at the forecast stage. The hypothesis about the possibility of a short-term forecast of BIS REER dynamics calculated using the polynomial residue model was confirmed.

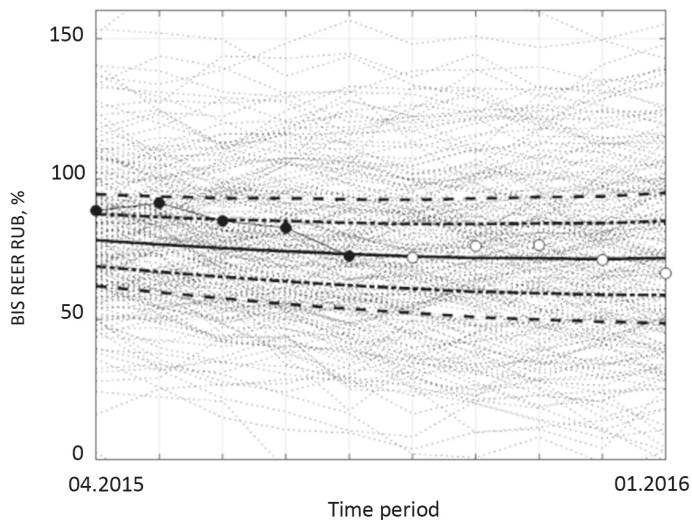


Fig. 6. RUB BIS REER forecast for September 2015 — January 2016

Note: (—) — expected mean trajectory, (---) — bounds of the 50% confidence band, (•••) — bounds of the 30% confidence band, • — actual REER values during the reference period of April 2015 — August 2015, o — actual REER values over September 2015 — January 2016 (used for assessing the forecast quality).

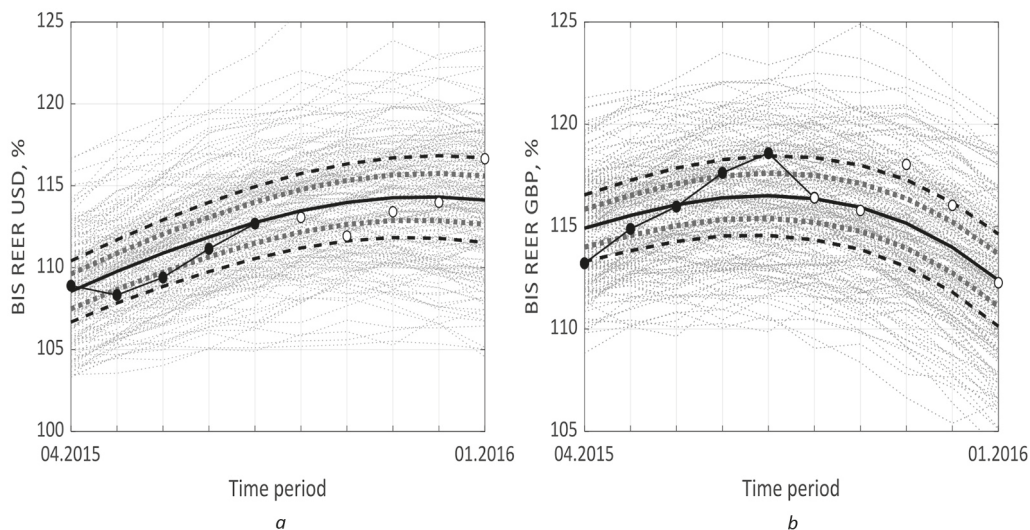


Fig. 7. Short-term BIS REER USD (a) and GBP (b) dynamics forecast for August 2015 — January 2016 calculated on the basis of the 2<sup>nd</sup> order polynomial residues model for the reference period of 19 months.

Note: (—) — expected mean trajectory, (---) — bounds of the 50% confidence band, (•••) — bounds of the 30% confidence band, • — actual REER values during the reference period of April 2015 — August 2015, o — actual REER values over September 2015 — January 2016 (used for assessing the forecast quality).



### 3. Discussion

Fundamentals of concepts suggested by economists of developed economies and by international institutes regarding BRIC (including the abbreviation) belong to J. O'Neil and to the investment bank Goldman Sachs (GS). The first fundamental and methodological study on BRIC in the West was published in 2005 [O'Neil, Wilson, 2005].

Methodologically, GS considers three groups of factors influencing scenarios of BRIC economic growth: 1) weight in the global economy and trade (a 13 % share of global trade, 8 % of world oil demand); 2) world market capitalization (3.6 % of the global share, with 1 % for each of Brazil, China, and India, and 0.6 % for Russia) and FDI inflows of 15 % (9 % for China, 3 % for Brazil, and 1.8 % for Russia); 3) GES (Growth Environmental Score) [O'Neil, Wilson, 2005, p. 14–17]. The last factor has 13 indicators: Macroeconomic Stability (Inflation, Government Deficit, External Debt), Technological Capability (PC, phones, Internet), Human Capital (Education, Life Expectancy), Political Conditions (political stability, rule of law, corruption). According to the GS, the GES Index of Developing Countries equals 4.0 (China at 5.0, Russia at 4.3, and Brazil at 3.8, taken separately).

The complex analysis of BRIC, based on earlier methodology, was carried out in 2007<sup>2</sup> focusing on economic growth in China, India, and Brazil, and infrastructure and new global markets for debt and capital (“Bonding the China and India”).

In 2011, the agenda of the GS research group [Wilson, Burgi, Carlson, 2011, a] included issues related to the size of BRICS economies in the present and future (up to 2050) and living standards. The article by Bell [Bell, 2011] considers the G6 and BRICS in terms of GDP and growth stability (sustainability of growth) with forecasts until 2050. The four factors suggested by the GS demonstrated that BRICS economic development faces a number of potential difficulties.

GS also stresses the important role of private investment capital (Private Infrastructure Spending). At present, only 20–25 % of funding for infrastructure development is by private investors [Wilson, Burgi, Carlson, 2011, b].

During the post crisis period, experts analyzed BRICS economies considering the gravity of the crisis, and carried out a comparative study of members of the bloc, for which it was important to take into account growth.

“A new world order according to BRICS” is a subject that seems no less important for a future historiography of geopolitics and geo-economy over the last decade. On this theme, Cynthia Roberts [Roberts, 2011] puts forward two propositions. *The first proposition* is that BRICS countries try to change the distribution of forces in the global economy (e.g. by changing quotas of votes in the IMF), the global economy becoming increasingly decentralized. *The second proposition* is that BRICS countries force their way into the ten largest world economies. They own more than 40 percent of global currency reserves and try to carry out coordinated currency policies to move away from using the dollar as a basic reserve and accounting currency.

BRICS countries do support diversification of global reserves as a new currency basket or regional currencies. The author rightly raises the question of “How long can the world's biggest borrower remain the World's biggest power?” [Roberts, 2011, p.7] and how to distribute the sources of that power and Responsibility [Roberts, 2011, p. 8].

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<sup>2</sup> <https://www.goldmansachs.com/insights/archive/BRICs-and-Beyond.html> (accessed 30.10.18)

Another issue is the relationship of the EU and BRICS. European Union interests in BRICS renewed after the global crisis. The Royal Institute of International Relations in Belgium [Renard, 2009] began to view BRICS through the lens of Europe's (EU) future in the world and has come to strategically important conclusions. The 21<sup>st</sup> century world is multipolar and BRICS dreams might become more realistic as China challenges the USA and events of asymmetrical multipolarity and multilateralism emerge [Renard, 2009, p. 16–19]. Works by European authors provide a comparative analysis of business transactions between BRICS countries developed economies, estimating their opportunities with regard to marketing, manufacturing innovations, and strategic alliances with western companies [Jones, 2012].

The official position of the EU was stated in 2009<sup>3</sup>. Prepared by the Directorate General Enterprise and Industry of the European Commission, the research was devoted to the competition and cooperation between the EU and BRICS. The present and the future of the alliances are being assessed on the basis of current potential of the BRICS (population, economic growth, economic models, openness of economy, trade structure). Particular attention is given to Chinese and Brazilian economic models, sectorial analysis of the economy of the People Republic of China, to the extraction and refining of oil and gas in Russia.

The BRICS is seen as a driving force for the world trade, an export market for the EU, while China is viewed more like a challenging force. The market of services is of a lesser importance for the alliances.

FDI flows between the EU and BRICS seem to be unilateral and tend to benefit European companies with little exception. The EU research attaches a great importance to the energy cooperation (oil, gas, biofuel) with BRICS, in particular with Russia. While trade in goods and services, FDI and knowledge flows/know-how are considered with regard to the global crisis, the Forex is mostly concerned with managing China's foreign exchange reserves.

For that reason, the research «EU and BRICS: Challenges and opportunities for European competitiveness and cooperation» includes the economic analysis of each member country of the BRICS, cooperation with the EU and between the participating countries.

The problems of macroeconomic forecasting stem from the increased uncertainty and risk factors. For the purpose of this forecast, the economics literature suggests using the increments of the Wiener random processes in the modeling of macroeconomic indicators [Tkacz, 2013], which in practice involves the use of various forms of discrete approximation. It does not always consider changes in the general trend of the indicator, unlike the polynomial residues model, and does not guarantee the reliability and quality of the forecast.

## Conclusion

The presented analysis of BIS real effective exchange rates of the BRICS and Eurocurrencies (including the USD and GBP) reveals specific characteristics of their development during the period of 1994–2016.

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<sup>3</sup> EU and BRICS: Challenges and opportunities for European competitiveness and cooperation. Industrial Policy and Economic Reform Papers. No. 13. Brussels Luxembourg: Publications Office of the European Union, 10 July 2009. URL: [http://ec.europa.eu/enterprise/newsroom/cf/itemshortdetail.cfm?item\\_id=3479](http://ec.europa.eu/enterprise/newsroom/cf/itemshortdetail.cfm?item_id=3479) (accessed: 15.08.2018).

Firstly, the analysis of the dynamics of BIS REER most precisely reflects the rate of national currency against the exchange rates of the basic trading partners.

Secondly, BIS REER is changeable in the short-term period. Thus, it is characterized by the ability to fluctuate, getting back to its previous values, which complicates a long-term forecast.

Thirdly, the analysis of the dynamics of exchange rates with regard to the REER, national and world economic cycles, global financial and economic environment reveals a number of regularities. In the long-term (1994–2017), the BRICS currencies demonstrate increasing stability, growth of correlation coefficient with Eurocurrencies from 0.3 in the 90th to 0.8 during the post crisis period. The fixed currency rate regime (see Yuan) is more effective during the period of formation of the national segment of global economy. These trends are important for the fundamental analysis.

Fourthly, in the technical short-term analysis, the «downward» trends signal of initial difficulties, when the BRICS finance and economy penetrates the global financial and economic environment. High turbulence and volatility of the REER in the BRICS countries ranging between 60–130 % resulted from the global crisis of 2008–2009 and oil shocks of 2014–2015. The REER below 100 % reflects low corporate and global competitiveness of the economy of BRICS, weaknesses of public and corporate finance, instability of currencies.

Fifthly, the research forecasts a long-term strengthening of currencies as a result of an increase in the efficiency of national economies and creation of the BRICS' financial infrastructure, with the New Development Bank (\$100 bln capital) and Pool Contingent Reserve Arrangement (\$100 bln startup capital), as well as an increase in the share of national currencies in mutual payments.

In the sixth, the representation of the BIS REER as a random process with a polynomial trend and a stochastic constituent of the Wiener type made it possible to make short-term forecasts for the REER trajectories based on discrete approximation, with a nominal expected trajectory reflecting the REER dynamics and the actual values of the BRICS' currencies being within the bounds of the 30 % confidence band during the reference period.

Seventhly, the outcomes of the short-term forecast of the BIS REER dynamics depend significantly on the reference period and forecasting horizon.

### **Research limitation and direction for further research**

Nominal and Real Exchange Rates are influenced by a large number of geo-economic and geopolitical factors, market structure, and policies of Forex participants. A complex analysis is the ideal form to consolidate authentic scientific results and estimations in future research.

Restrictions on the present research result from two different problems: the fundamental and the technical analysis. Solving these problems requires an analysis of indices over several time intervals.

The present study focused on the fundamental analysis. However, the significance of the research consists not only of analysis and synthesis of the phenomena, but also in forecasting REER, which was not an objective in this work, as it would require applying quite different tools: e.g. theories of casual processes, imitating methods of modeling, and so on.

The outcomes of forecasting short-term BIS REER dynamics for currencies of various countries using the polynomial residues model depend significantly on the choice of

the reference period and the forecasting timeframe. The degree of the polynomial and the choice of the two reference periods for each currency are determined separately for each case.

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Received: September 25, 2018

Accepted: October 4, 2018

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### **Анализ динамики и прогнозирование реальных эффективных обменных курсов валют стран БРИКС (1994–2016)**

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**Для цитирования:** *Shavshukov V.M., Vorontsovsky A.V., Vyunenko L.F. Analyzing dynamics and forecasting real effective exchange rates for BRICS countries (1994–2016) // Вестник Санкт-Петербургского университета. Экономика. 2018. Т. 34. Вып. 4. С. 568–590. <https://doi.org/10.21638/spbu05.2018.405>*

В статье проведен анализ динамики индексов реальных эффективных обменных курсов валют стран BRICS и евровалют (на примере USD и GBP). Методологической основой анализа поведения валют является модификация кейнсианской теории трех рынков с включением в нее Forex. Полученные данные выявили закономерности поведения валют BRICS за 1994–2017 гг. Подтверждена зависимость курсов экспортно-ориентированных экономик от конъюнктуры международных рынков реальных и финансовых активов. Показана высокая волатильность валют (в среднем 50 % по группе) в зоне до величины индекса BIS real effective exchange rate (REER) = 100 (CPI-Base 2010). Показано, что в долгосрочном фундаментальном анализе (1994–2017) валюты BRICS демонстрируют рост стабильности. При этом валютный режим фиксированного курса (на примере юаня) был более эффективен в период становления национального сегмента глобальной экономики. Для технического, краткосрочного анализа курсовые тренды «вниз» отражают дебютные трудности вхождения экономик и финансов BRICS в глобальную финансово-экономическую среду. Высокая турбулентность и волатильность REER стран BRICS в диапазоне 60–130 % являлась результатом влияния глобального кризиса 2008–2009 гг. и нефтяных шоков 2014–2015 гг. Нахождение REER главным образом в зоне ниже индекса 100 % отражает низкую корпоративную и глобальную конкурентоспособность экономик BRICS, слабость публичных и корпора-

тивных финансов, нестабильность валют. Исследование дает прогноз долгосрочного тренда усиления стабильности валют как результат повышения эффективности национальных экономик, создания финансовой инфраструктуры BRICS: *New Development Bank* (capital \$100 bln) and *Pool Contingent Reserve Arrangement* (startup capital \$100 bln), увеличение доли национальных валют во взаимных расчетах. На примере BIS REER для валют стран БРИКС показана возможность построения краткосрочного прогноза динамики REER, основанного на модели полиномиальных остатков и статистическом моделировании. Результаты моделирования краткосрочной динамики REER могут быть использованы для прогнозирования поведения валют, хеджирования участников внешнеэкономической деятельности и валютной политики центральных банков.

*Ключевые слова:* страны БРИКС, валюты, эффективные обменные курсы, BIS REER, фундаментальный анализ, волатильность, среднесрочное прогнозирование.

Статья поступила в редакцию 25.09.2018 г.

Статья рекомендована в печать 04.10.2018 г.

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