Exchange Rate Modeling: The Case of Ruble*

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Abstract. The model of the equilibrium exchange rate of ruble is under construction on the basis of streams of the balance of payments of Russia taking into account trade conditions. Export-import transactions, factors of movement of the capital, trade condition, indexes of the internal and export prices, real gross domestic product, factors of elasticity of the foreign trade operations, decisions of microagents are used as base determinants in the model. In the process of creating the model a number of key internal dynamic functional dependencies were found that allowed to put the capital flows in the model on formal logical level, and, thus, to extend the model to the case of capital mobility. We discuss the relationship results from the fundamental equilibrium exchange rate in the framework of the author's conceptual approach to the assessment of the equilibrium exchange rate based on international flows (IFEER). The technique of adjustment of model internal parameters is offered with a view of macroeconomic regulation of the exchange rate of ruble. Based on the modeling results we built the analysis of the dynamics of the nominal exchange rate of ruble in 2013–2015.

Аннотация. Модель равновесного валютного курса рубля строится на основе движения средств по счетам платежного баланса России с учетом условий торговли. В качестве базовых детерминант в модели используются экспортно-импортные операции, факторы движения капитала, условия торговли, индексы внутренних и экспортных цен и реального ВВП, коэффициенты эластичности внешнеторговых операций, межвременные решения микроагентов. В процессе создания модели был обоснован ряд ключевых внутренних динамических функциональных зависимостей модели, что позволило включить на формально-логическом уровне потоки капитала в модель и таким образом расширить модель на случай мобильности капитала. Обсуждается связь результатов с фундаментальным равновесным курсом в рамках разработанного авторского концептуального подхода к оценке равновесного валютного курса на основе международных потоков (IFEER). В результате была выведена многофакторная формула динамики валютного курса рубля. Предлагается методика настройки внутренних параметров модели в целях макроэкономического регулирования курса. На основе результатов моделирования проведен анализ динамики номинального курса рубля в 2013–2015 гг.

Key words: Equilibrium exchange rate, exchange rate of ruble, balance of payments, trade condition, macroeconomic policy, capital streams.

Conceptual approaches to modeling the dynamics of the exchange rate of the national currency have fluctuated in recent years widely. One of the first studies that can be considered a model was by Y. Lukashin and A. Lushin (1994) of the formation of the exchange rate USD/RUR on MICEX. In the framework of the classical pricing model of P. Samuelson based on current supply and demand, the authors statistically modeled the exchange rate of the ruble. However, the short-term nature and the lack of analytical explanation of the genesis of monetary flows restrict the use of the model. Later model of A. Pervozvansky (1998) was applicable in the medium and long term, but had one significant drawback: it was based on the theory of purchasing power parity (in its non-equilibrium interpretation). And here it should be emphasized that the concept of purchasing power parity fails in general at least in the medium term, as shown in the author's works (Kuzmin, 2014a, 2010b).

There were carried out some parallel researches of the factor systems determining the exchange rate. In particular, the concept specific efficiency of foreign trade operations has been successfully applied to study of the equilibrium dynamics of ruble by L. Strizhkova and others (2001). A multifactor model of exchange rate dynamics of ruble was developed by the author in 1998–99 (Kuzmin, 1999). Also research of S. Dubovsky (2002) was based on the optimization problem, the results of which were applied to the analysis of the behavior of the ruble during 1996–1999.

* Моделирование курса рубля.

Further simulation of currency pricing on the basis of supply and demand was found in the model proposed by A. Kugaenko (2005). A number of issues of modeling of exchange rate dynamics in modern conditions were studied by M. Dmitrieva and S. Suetin (2012), by B. Putko, A. Didenko, M. Dubovikov (2014). However, to construct a mathematical model of the ruble in the medium term further developments are necessary based on the study of the movement of funds on accounts of the balance of payments of Russia and taking into account the terms of trade as the most important determinants.

Thus, along with the importance of conducting long-term analysis of the behavior of the exchange rate of ruble (e.g., the author's work: Kuzmin, 2014b, 2010a), greatly increases the need to study the medium-term equilibrium dynamics of the ruble and its fundamental determinants.

The model of dynamics of the equilibrium exchange rate of ruble proposed in this paper is a development of previous research of the author and takes into account the medium-term period, the terms of trade, flow of funds of the balance of payments, including export-import operations and, in part, capital flows with the preferences of investors. Thus, this exchange rate balances the balance of payments and, as a consequence, the demand and supply of currency on the monetary market. The main objective of the model is to identify the dependence of the dynamics of the exchange rate of ruble from the consumer price indices and export price and real GDP. During the construction of the model the other factors were eliminated.

This approach has been used consistently by the author (Kuzmin, 2014a, 2014b, 2011, 2010b, 1999) and in the context of this work it would be productive. It is also supported by other researchers: for example, L. Krasavina: "To improve the effectiveness of exchange rate policy, in our view, it is necessary: — to use the technique of determining the exchange rate of ruble on the basis of multifactor but not unifactor concept, mainly taking into account the dynamics of oil prices... — when forecasting the exchange rate, on the basis of the balance of payments, it is advisable to consider not only the current account, but the account of the international movement of capital and financial instruments, whose role have increased in conditions of financial globalization" (Krasavina, 2014).

BASIC ASSUMPTIONS OF THE MODEL

For analysis of the ruble it is necessary to highlight the characteristics of the Russian currency market, used in further constructions:

- The mode of conducting monetary policy is a managed float of the national currency ("too controlled", according to opinion of many economists),
- There are no serious restrictions on current account transactions (which corresponds to Art.VIII of the IMF Charter),
- There are restrictions on settlements between residents in foreign currency,
- The quality and the cost of currency exchange services comply with the global standards.

One must first consider several exchange rates existing in the country:

- Centrally set rate (the rate of the Central Bank of Russia),
- The rate of interbank market,
- The rate of the currency exchanges,
- The exchange rate of foreign banknotes.

The choice of synthetic value, which continues to be the exchange rate directly depends on the magnitude of mismatch between each of above-mentioned rates.

This choice has the following advantages:

- As a rule, the rate of the interbank market slightly deviates from a centrally set rate,
- In case of legal prohibition or restriction of settlements between residents in foreign currency interbank market is the only source of market calculations and the rate of sale and purchase by customers at banks currency differs from the interbank quotations on the value of the bank's commission. In this case, the interbank market becomes a kind of intermediary, accumulating and satisfying the requests of all participants in foreign exchange trading,
- Constant presence of the Central Bank and the possibility of currency interventions consistent with the internationally accepted standards of market regulation,
- In many cases, the interbank rate slightly deviates from the rates of currency exchanges because of the ease of spatial arbitrage and high degree of interconnectedness of these segments of the currency market,
- The exchange rate of foreign banknotes directly determined by the interbank rate, with the "cost principle: the interbank rate plus the cost of cashing out".

For medium-term studies of the equilibrium dynamics of exchange rate of ruble it is possible to apply the principles of modeling of the international flows equilibrium exchange rate (IFEER), developed in the aforementioned works of the author. Even more revealing must be the comparison of the approaches and results of assessments that identify the exchange rate mechanism on the basis of economic-mathematical modeling of crisis processes.

To study the dynamics of the ruble (and also other currencies with varying degrees of floating we propose a definition of the exchange rate *e* as the average weighted on volumes of foreign currency value rate *N* market transactions $e_i, i \in (1, N)$ for a certain period of time. The earlier result (Kuzmin, 2014a, 2014b) of a conceptual level shows that the exchange rate e_t is equal to the aggregate amount of funds in national currency divided by the aggregate amount of funds in foreign currency traded on the foreign exchange market during a given period *t*. Briefly, after disaggregating flows resulting dynamic dependence has the form that is the basic result for further analysis:

$$e_t = (I_t + K^-) \Big/ (E_t + K^+), \quad (1)$$

where *I* is the demand in the national currency on foreign imports, *E* is the offer of foreign currency from exports, K^-, K^+ — respectively, the amount of capital outflow (demand in national currency in foreign) and capital inflow (the supply of foreign currency).

THE USE OF INDICATORS OF FOREIGN TRADE OPERATIONS AND THE TERMS OF TRADE WHEN ASSESSING EXCHANGE RATE

Further, at this stage, we make a few assumptions:

1. The Central Bank conducts strict regulation of capital movement restrictions, or completely satisfies the demand for foreign currency on the accounts of capital movements, depending on the situation, domestic or foreign, by sale or purchase due to changes in foreign exchange reserves. Then in the numerator and denominator of dependence (1) two last members are eliminated.

2. The current account consists of the operations of export-import of goods and services and does not account the unilateral transfers.

3. The country has only one trading partner, represented as the rest of the world.

Then (1) can be represented as

$$e = I \Big/ E.$$

Let us consider a two-period case model in times *t, t–1*. Let the resident direct consumption imports of goods and services at time *t* with proportion of their income, represented not only current income, but also income in the previous time. Assume that this function is as follows

$$I_t = k_I P_t Q_{t-1}^{1/3} Q_t^{2/3}, \quad (2)$$

where $k_1 = const$, Q_t — index of real total output (e.g., real GDP), P_t — the internal prices index (e.g., consumer), and the indices *t,t–1* indicate, respectively, the beginning and the end of the period. Method of averaging of income should not have a significant influence on the final result due to the insignificance of fluctuations in the variable *Q* in the medium term compared to possible changes in other macroeconomic indexes.

In the conditions of Russia's further integration into the world economy and WTO membership it is the expansion of Russia's participation in world trade. And here it should be emphasized that the dynamics of commodity exports largely determines the country's economic growth, as shown by several authors (e.g. Ershov, 2014; Kuzmin, 2014b; Krasavina, 2014). Amount of currency brought to the domestic market at time *t* is determined by the physical volume of exports, which depends on the terms of trade, presents a near real exchange rate value as follows

$$e^R_{t-1} = e_{t-1} P^*_{t-1} \Big/ P_{t-1},$$

and is determined by the decisions of producers-exporters at time *t–1*. Where P^*_{t-1} — export price index. The impact of real exchange rate on exports is recorded in several of the above-mentioned works.

Then the dollar amount of currency price *E* at time *t*, which came on the domestic foreign exchange market as revenue exports of goods and services, will be equal to

$$E_t = P_t^* k_E (Q_{t-1}^{1/3} Q_t^{2/3})^{1+\delta} \sqrt{e_{t-1}^R} = P_t^* k_E (Q_{t-1}^{1/3} Q_t^{2/3})^{1+\delta} \sqrt{e_{t-1} P_{t-1}^* / P_{t-1}}. \quad (3)$$

The part $k_E (Q_{t-1}^{1/3} Q_t^{2/3})^{1+\delta}$ reflects the fact that the physical export is part of total output, which is averaged for the reasons given above. Non-negative rate shows a "slightly larger" growth of exports compared to imports as a function of total output that occurs because of limited domestic demand and, thus, the need for a growing portion of total output to sell at the expense of exports.

From (1), (2), (3):

$$e_t = I_t / E_t = \frac{k_I P_t (Q_{t-1}^{1/3} Q_t^{2/3})}{P_t^* k_E (Q_{t-1}^{1/3} Q_t^{2/3})^{1+\delta} \sqrt{e_{t-1} P^*_{t-1} / P_{t-1}}} =$$

$$= = k_I / k_E \frac{P_t Q_t^{-2/3\delta}}{P_t^*} \sqrt{\frac{P_{t-1} Q_{t-1}^{-2/3\delta}}{P_{t-1}^*}} \; 1 / \sqrt{e_{t-1}}.$$

If $k = \sqrt[3]{k_I / k_E}$ we can rewrite this in the form:

$$e_t \sqrt{e_{t-1}} = k^2 \frac{P_t Q_t^{-2/3\delta}}{P_t^*} \sqrt{k^2 \frac{P_{t-1} Q_{t-1}^{-2/3\delta}}{P_{t-1}^*}}.$$

Hence, we obtain, after a temporary separation of variables:

$$e_t = k^2 \frac{P_t Q_t^{-2/3\delta}}{P_t^*}$$

$$e_{t-1} = k^2 \frac{P_{t-1} Q_{t-1}^{-2/3\delta}}{P_{t-1}^*}.$$

Extending the model to multi-period case, we get the following dynamic multifactor dependence of exchange rate of ruble from the real aggregate output and price levels in the country and abroad:

$$e(t, Q(t), P(t), P^*(t)) = e_t(CA) = k^2 \frac{P_t}{P_t^*} Q_t^{-2/3\delta}. \quad (4)$$

Thus, under perfect regulation of the movement of capital by Central Bank of Russia, the main determinants of the movement of exchange rate of ruble are the consumer price index and the price index of exports.

Basic formula (1) in an expanded form was studied by Strizhkova, Yermolayeva and others (2001) based on quarterly data from Q1 1995 to Q1 2001:

$$e_t = \alpha + \sigma I_t / E_t,$$

where α, σ — the settings for the econometric model. The calculations showed satisfactory suitability of the model.

THE INCLUSION OF CAPITAL FLOWS IN THE MODEL

The inflow and outflow of capital into the country are one of the most important factors in the behavior of the exchange rate of the ruble and, along with other components should have an impact on the result of the formula (1).

In advanced econometric models (Strizhkova, Yermolayeva and others, 2001) have also been investigated flows on accounts of the balance of payments and their impact on the dynamics of the ruble nominal exchange rate in the form:

$$e_t = \alpha + \sigma(I_t + \sum_{t=1}^{5} C_{it}) \Big/ (E_t - Z_t),$$

where Z_t is the change in the outstanding import advances and in lost export revenue, C_{1t} — net errors and omissions, C_{2t} — the government debt service, C_{3t} — change in foreign assets of the banking system, C_{4t} — net increment of cash foreign currency, C_{5t} — change of the official foreign reserves of the Central Bank of Russia. Calculations based on this econometric model have helped to clarify previously obtained results of the authors, albeit marginally.

Generally speaking, the study of capital flows faced with a serious problem of the separation of medium- and short-term speculative components, specifically outlined by the IMF in 1984 and which is typical not only for Russia. In addition, the examination of the actual inflows and outflows of capital from Russia is complicated by significant mystery of the escape and return of capital across borders, and the imperfect statistics. However, this problem can get a permit in the framework of this model on the formal logical level through the adoption of several hypotheses about the dynamics of capital movements.

For the dependence of capital outflow we will accept here the hypothesis that it is part of a comprehensive income of microeconomic agents domestically displayed abroad for the purpose of savings:

$$K_t^- = k_{K^-} P_t (Q_{t-1}^{1/3} Q_t^{2/3}), \tag{5}$$

where $k_{K^-} = const$.

The inflow is a function, increasing on total real product (international investors and speculators want to buy a part in their prices for the above reasons) and the terms of trade. The last explanation lies in the fact that the fall of the national currency (respectively increase of the exchange rate) improves investment conditions for non-residents. This was also confirmed by studies on Japan and the United States and several other countries.

Based on this we will take the following hypothesis:

$$K_t^+ = k_{K^+} P_t^* (Q_{t-1}^{1/3} Q_t^{2/3})^{1+\theta} \sqrt{e_{t-1}^R}. \tag{6}$$

where $k_{K^-} = const$, $\theta > 0$.

The increased inflow of capital to GDP growth is more than proportional (the indicator θ in a member $(Q_{t-1}^{1/3} Q_t^{2/3})^{1+\theta}$), in this case due to the following reasons:

- Due to the growth of the economy improves the investment climate,
- Realized and expected positive effect of import substitution;
- Investor's expectations of higher interest rates to keep the economy from overheating increase,
- Psychological mood of market participants improves.

Take also without restricting the generality that (5) and (6) consider the operations of the Central Bank of the Russian Federation.

Substituting in (1) formulas (2) — (6), we obtain

$$e_t = \frac{k_I P_t (Q_{t-1}^{1/3} Q_t^{2/3}) + k_{K^-} P_t (Q_{t-1}^{1/3} Q_t^{2/3})}{P_t^* k_E (Q_{t-1}^{1/3} Q_t^{2/3})^{1+\delta} \sqrt{e_{t-1} P^*_{t-1} / P_{t-1}} + P_t^* k_{K^+} (Q_{t-1}^{1/3} Q_t^{2/3})^{1+\theta} \sqrt{e_{t-1} P^*_{t-1} / P_{t-1}}} =$$

$$= \frac{P_t (Q_{t-1}^{1/3} Q_t^{2/3})(k_I + k_{K^-})}{P_t^* (Q_{t-1}^{1/3} Q_t^{2/3})^{1+\theta} \sqrt{e_{t-1} P^*_{t-1} / P_{t-1}} (k_E (Q_{t-1}^{1/3} Q_t^{2/3})^{\delta-\theta} + k_{K^+})}. \tag{7}$$

Because by logic $(\delta - \theta) \approx 0$ and reasonable stability of the member $(Q_{t-1}^{1/3} Q_t^{2/3})$ compared to the rest settings of the model we will assume the following member in formula (7) as a constant:

$$\frac{(k_I + k_{K^-})}{(k_E (Q_{t-1}^{1/3} Q_t^{2/3})^{\delta-\theta} + k_{K^+})} = (k')^3 \approx const.$$

And *k'* is the more stable the smaller is the ratio (k_E / k_{K^+}) is, i.e. more capital flows compared with transactions on current balance.

Then (7) can be rewritten

$$e_t \sqrt{e_{t-1}} = \frac{k'^2 P_t Q_t^{-2/3\theta}}{P_t^*} = \sqrt{\frac{k'^2 P_{t-1} Q_{t-1}^{-2/3\theta}}{P_{t-1}^*}},$$

and by analogy with (4):

$$e(t, Q(t), P(t), P^*(t)) = e_t = k'^2 \frac{P_t}{P_t^*} Q_t^{-2/3\theta} = k \frac{P_t}{P_t^*} Q_t^{-2/3\theta}. \quad (8)$$

Comparative dynamics of functional dependencies (2), (3), (4), (8) was studied by the author in different works (Kuzmin, 2014c, 2011, 2010a, 2010b, 1999) in the periods 1997–99 and 2008–2009. As a result, the theoretically calculated indices show a good agreement with empirical observations of the dynamics. Possible deviations may be explained by the inaccuracy of the calculations (primarily index of export prices), within a month fluctuations in the rate, as well as a random component.

SETTING UP THE INTERNAL MODEL COEFFICIENT

The choice of the starting point of the research period. As the starting point of the period to study the medium-term dynamics of the nominal exchange rate ruble we choose date, which meets the following criteria:

1. Stable finding the real exchange rate of ruble against the US dollar in the previous period.
2. Stable or moderately increasing reserves of the Central Bank of Russia in the previous period, indicating that the balance of payments is in the medium term equilibrium.
3. World prices for Russian exports correspond to the medium-term values.

Thus, for the purposes of this study as the starting point of the period to study the medium-term dynamics of the ruble was chosen December 2013.

Main economic indicators — fundamental determinants of the model. In the context of this paper, it is indicative that the subject matter of essential raw material component of Russian exports, which occupies about two thirds of total exports, underscores one of the basic macroeconomic indicators — the index of average actual export price P^*_t.

In the presented system the determinants of the exchange rate, as can be seen from (8), it directly determines (as the most volatile from economic position) short-term dynamics of exchange rate of ruble due to sufficient stability compared to other factors of the index of real aggregate output Q_t and the consumer price index P_t. The interested reader can also be recommended a slightly different view in the paper by V. Putko, A. Didenko, M. Dubovikov (2014) on the volatility of the exchange rate RUR/USD, when volatility unfolded into components characterizing the fractal structure of financial time series.

However, none of the famous Russian economic agencies (incl. Federal service of state statistics of Russia) does not calculate this index (export prices). Therefore, the first and one of the most time consuming tasks were the collection and processing of data on the subject. Due to sparseness and lack of information on quantitative indicators (indices of prices and the share in total exports of various commodity groups in retrospect) construction of a complete index of export prices was practically impossible. However, the analysis and selection of the most important groups of foreign trade shows that oil, petroleum products, natural gas covers about 70% of Russian exports. And due to the high correlation of crude oil, petroleum, gas indices it became possible to use the price index of oil as a substitute for our entire index of export prices.

The media names as one of the causes of the 2014–2015 currency crisis the falling prices of oil on international markets (for example, the statements by chairman of the Central Bank E. Nabiullina, minister of economic development A. Ulyukaev, minister of Finance A. Siluanov, etc.) It is important to note that many analysts use the price index of oil as a determinant of exchange rate dynamics. As you know in the foreign exchange market, expectations are most often true. It is interesting to note that, for example, in the author's paper (Kuzmin, 2010b) also shows that in certain periods of time, when used as the determinants of price index, brent-mix of oil as a substitute for actual average export prices P^*_t than the currency rate *e (P*(oil))* approximates the official ruble exchange better than any other settlement rate.

Table 1 presents the price of brent-mix blend crude oil on ICE (Intercontinental Exchange, the data from Bloomberg, U. S. dollars per barrel). As determinants of P was used the consumer price index (CPI). As determinants of Q was used the index of the real GDP.

Setting up the internal model coefficient. In the process of verification and elaboration of methodological recommendations on the use of the model it was carried out to configure the internal coefficients (the coefficient θ of the basic formula research (8)).

For a given coefficient *k*, equal to the rate of the ruble at the start point of the period minimized the sum of squared normalized differences of the calculated rate (8) and the nominal exchange rate e (nominal) provided that the indexes at the start point of period were *P(start)* = 1, *P*(start)* = 1, *Q(start)* = 1:

$$\min_{\theta} \sum_{t} \left(\frac{e_t(\theta) - e(\text{nominal})_t}{e(\text{nominal})_t} \right)^2 .$$

As simulation results of modeling it is necessary to set the parameter θ value in terms of $\theta \geq 0$.

In this period of time as the nominal exchange rate is considered the nominal rate of the US dollar against the ruble at the end of the period (month), calculated by the Central Bank of Russia and presented in table 2.

As a result of numerical simulation for a given coefficient *k* = 32,73 was set the parameter value θ, amounting to θ = 0,45.

In Table 3 and Figure 1 (author's calculations, monthly data) presents:

1. Dynamic calculation of the ruble on the basic formula of research (8) if θ = 0,45 (*e (Theor)*, line 1).
2. Normalized deviation values of the nominal and calculated exchange rate of ruble (line 2)

Table 1. Dynamics of key economic indicators – fundamental determinants of the model in 2013–2015. (December 2013 taken as a unit).

	December 2013	January 2014	February	March	April	May	June	July
ICE BRENT (U. S. dollars per barrel)	103,680	100,450	103,400	102,990	102,630	104,270	108,500	106,240
The cumulative index	1,000	0,969	0,997	0,993	0,990	1,006	1,046	1,025
CPI (2000 =100)	405,9	408,3	411,2	415,3	419,1	422,8	425,5	427,5
The cumulative index	1,000	1,006	1,013	1,023	1,033	1,042	1,048	1,053
Real GDP — p rices with reference to 2008, quarterly data	11956,0	9745,8	9745,8	9745,8	10464,6	10464,6	10464,6	11504,7
The cumulative index	1,000	0,815	0,815	0,815	0,875	0,875	0,875	0,962

Continuation of table 1

	August	September	October	November	December	January 2015	February
ICE BRENT (U. S. dollars per barrel)	104,520	97,150	88,280	72,240	60,220	55,000	63,150
The cumulative index	1,008	0,937	0,851	0,697	0,581	0,530	0,609
CPI (2000 = 100)	428,6	431,4	434,9	440,5	452	469,4	479,8
The cumulative index	1,056	1,063	1,071	1,085	1,114	1,156	1,182
Real GDP — prices with reference to 2008, quarterly data	11504,7	11504,7	12007,5	12007,5	12007,5	12007,5*	12007,5*
The cumulative index	0,962	0,962	1,004	1,004	1,004	1,004	1,004

* Extrapolated data

Source: Bloomberg (reference date: 22.04.2015)), data of Federal service of state statistics (www.gks.ru (accessed: 24.05.2015)).

Table 2. Dynamics of the nominal exchange rate US dollar to ruble in 2013–2015.

	December 2013	January 2014	February	March	April	May	June	July
Nominal exchange rate of the US dollar against the ruble at the end of the period	32,73	35,24	36,05	35,69	35,70	34,74	33,63	35,73

Continuation of table 2

	August	September	October	November	December	January 2015	February
Nominal exchange rate of the US dollar against the ruble at the end of the period	36,93	39,39	43,39	49,32	56,26	68,93	61,27

Source: data of the Central Bank of Russia (reference date: 17.05.2015).

$$ND(\text{å})_t = \frac{e_t(\theta) - e(\text{nominal})_t}{e(\text{nominal})_t}.$$

Table 3. Dynamics of the nominal exchange rate US dollar to ruble in 2013–2015.

	December 2013	January 2014	February	March	April	May	June	July
Calculated exchange rate of the ruble, e (Theor)	32,73	36,16	35,38	35,87	35,55	35,30	34,14	34,04
Normalized deviation, ND		0,0260	–0,0187	0,0051	–0,0042	0,0161	0,0152	–0,0474

Continuation of table 3

	August	September	October	November	December	January 2015	February
Calculated exchange rate of the ruble, e (Theor)	34,69	37,56	41,13	50,91	62,67	71,26	63,44
Normalized deviation, ND	–0,0608	–0,0464	–0,0520	0,0323	0,1139	0,0338	0,0354

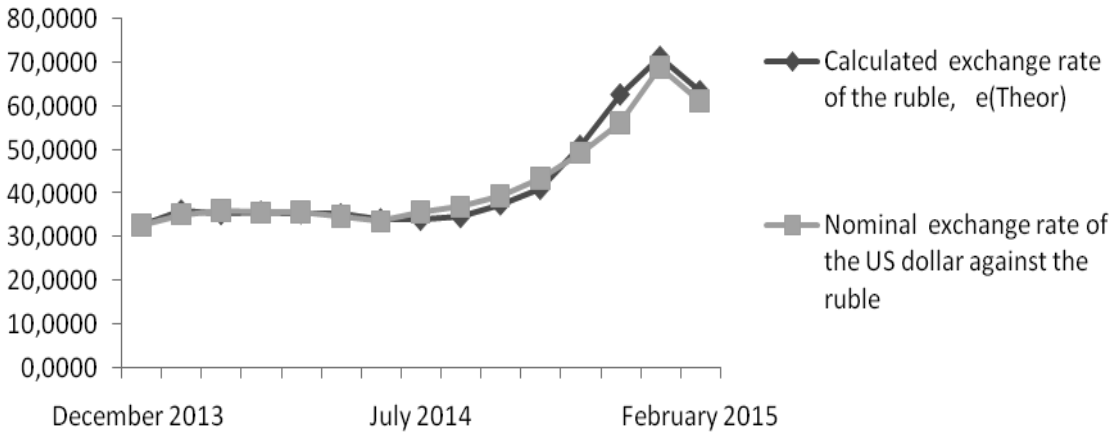

Fig. 1. The calculated and nominal rates of US dollar to Russian ruble (December 2013 — February 2015, author's calculations).

The average absolute normalized deviations and average normalized deviations of the nominal and calculated exchange rate of ruble were, respectively, 0.28% and 2,98%, which indicates the high quality of the model.

CONCLUSION

Looking at some results of the conducted analysis it is possible to allocate the main causes of the fall of the nominal exchange rate of US dollar against the ruble in the period of December 2013 — February 2015: the substantial (actually twofold) fall in export prices of oil and other energy resources on international markets as a result of worsening global conditions. This is due to the overwhelming predominance of mineral commodities in the index of average actual export prices. However, it should be noted that in this period a significant effect on the result was an increase in consumer prices (18,2%) with incomparably low impact of the short-term fall in GDP.

The development of a new approach to modeling the dynamics of exchange rates has led to the construction-based model of equilibrium dynamics of exchange rate of ruble. As the basic determinants in the model are used: export-import operations, factors of capital flows, terms of trade, indexes of domestic and export prices and real GDP, the elasticities of foreign trade, intermediate-run solution of microagents.

In the process of creating the model was based on a number of key internal dynamic functional dependencies: export-import operations, and the movement of capital. That allowed us to put on formal logical level the capital flows in the model, and, thus, to extend the model to the case of capital mobility. The result was multifactor formula of the dynamics of the exchange rate of ruble

$$e(t,Q(t),P(t),P^*(t),\theta) = e_t = k\frac{P_t}{P_t^*}Q_t^{-\frac{2}{3}\theta},$$

The results of the model can be seen not only in the context of the determination of dependence, but also as a balance equation. In practice, its use will give the Central Bank a tool to regulate the dynamics of the exchange rate in accordance with the dynamics of internal and external fundamental key economic indicators.

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