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K. Sosunov, N. Ushakov

DETERMINATION OF REAL EXCHANGE RATE OF RUBLE AND ASSESSMENT OF LONG-RUN POLICY OF REAL EXCHANGE RATE TARGETING

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The equilibrium real exchange rate of Russian ruble is estimated for the period from the beginning of 1995 to the beginning of 2008. According to the methodological approach proposed by Edwards (1988) the equilibrium real exchange rate is a function of a set of fundamental variables (so-called "reduced form equation"). In order to estimate an equilibrium real exchange rate a set of fundamentals was selected: terms of trade, productivity differential, fiscal policy variable. Estimation was performed in a cointegrated VAR framework using the Johansen cointegration test. The speed of adjustment of the actual real exchange rate to the equilibrium real exchange rate as well as the influence of monetary policy and private capital flows on the short-run dynamics of real exchange rate is explored.

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JEL Classification: C32, F31, F41.

Сосунов К., Ушаков Н. Определение реального курса рубля и оценка политики долгосрочного таргетирования реального курса валюты: Препринт WP12/2009/02. — М.: Изд. дом Государственного университета – Высшей школы экономики, 2009. — 64 с. (на англ. яз.)

В работе оценивается равновесный реальный курс рубля за период с начала 1995 г. по начало 2008 г. Согласно методологическому подходу, предложенному в работе Эдвардса (1988), равновесный обменный курс связан функциональной зависимостью (т.н. уравнение «сокращенной формы») с набором фундаментальных переменных. Для получения равновесного реального обменного курса был определен набор фундаментальных переменных: условия торговли, дифференциал производительности, фискальная политика накопления бюджетных излишков. Оценка уравнения «сокращенной формы» осуществлена в рамках модели коинтеграционной векторной авторегрессии с использованием коинтеграционного теста Йохансена. Исследуется также скорость сходимости реального обменного курса к равновесному и влияние монетарной политики и потоков частного капитала на краткосрочную динамику реального курса.

Ключевые слова: равновесный реальный обменный курс, модель коинтеграционной векторoной авторегрессии, «несоответствие» фактического и равновесного курсов, период «полужизни»

Классификация JEL: C32, F31, F41.

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Introduction

The real exchange rate of national currency is one of the most important macroeconomic indicators which determines competitiveness of domestic producers relative to the foreign ones. Thus, changes in the real exchange rate may influence the growth rates of the economy. This indicator obtains special importance in those countries where most of production is export oriented. Russia belongs to this category of countries.

Therefore, this paper has two main goals. Firstly, to determine which main factors and how, in which quantitative expression, influence the real exchange rate of ruble. To answer this question an estimate of a reduced form equation for the real exchange rate is used. Secondly, to find out to what extent there is a possibility for monetary authority to influence the real exchange rate in the short-run and in the medium-run perspective. Most of the literature on this topic suggests that the possibility of long-run influence is very restricted. The question of short-run influence is open. An empirical study of these issues is interesting both from theoretical point of view as well as from the practical side, i.e. the working-out of economic policy recommendations.

1. Literature Survey

The main and well-known concept of equilibrium exchange rate is the concept of purchasing power parity (PPP). In its *absolute version* the PPP doctrine states: in the absence of substantial trade barriers international trade leads to a situation when the price levels of different trading countries corrected for nominal exchange rates coincide and, thus, the real exchange rate equals to unity. In the *relative version* of PPP doctrine price levels may not coincide but, nevertheless, change at roughly equal rates. As a result, the real exchange rate (defined as a ratio: $\frac{P}{P^{*}\cdot S}$, where P, P^{*} — domestic and foreign price levels and S — nominal exchange rate) is a constant or, in statistical language, is a stationary process.

Paper by Edwards, Savastano (1999) contains a thorough review of numerous empirical investigations which test the PPP hypothesis. The result is that the PPP hypothesis is rejected in most cases when the period of observation is 10—30 years. And in some cases for very long periods of observations of 60—70 years the real exchange rates in developed countries systematically revert to their mean levels with a half life of a deviation of 4—5 years. Very slow speed of adjustment to the equilibrium was referred to as a *PPP puzzle* in a famous paper by Rogoff (1996). Such long periods of deviations cannot be explained solely by rigid prices as compared to the nominal exchange rate in response to monetary and financial shocks which are completely absorbed within 1—2 years (and which are explained in Dornbush's sticky-price model). To explain these kinds of deviations alternative concepts of equilibrium exchange rate were proposed which assume that there are variables, called 'fundamentals', with which the real exchange rate is related in the long-run. Thus, the real exchange rate as a function of these variables is not necessarily a constant (or a stationary process) over time. One of such approaches that became very popular in applications was formulated by Edwards (1988) who defined the real exchange rate as *a relative price* at which both tradable and non-tradable goods markets are balanced.

In the book by Hinkle, Montiel (1999) the internal and external balance (for non-tradable and tradable goods, correspondingly) conditions are thoroughly derived under the following assumptions of a modified model proposed by Dornbusch (1974):

- A small open economy (prices of import and export are given)
- The production side is divided into three sectors (non-tradable goods sector, tradable goods sector represented by import and export goods)
- Flexible domestic prices and wages
- Fixed capital stock
- Mobile labor market (free movement of labor force between tradable and non-tradable goods sectors)
- A representative consumer which maximizes discounted utility
- A fulfillment of intertemporal consolidated budget constraint of the government and the central bank.

The equilibrium in the market of tradable and non-tradable goods is achieved as a result of adjustment of the real exchange rate in response to exogenous variables shocks. In this model the real exchange rate is defined as a ratio of non-tradable goods prices to tradable goods prices expressed in national currency according to the current nominal exchange rate:

$$e = P_{NT}/SP_T$$

where P_{NT} – non-tradable goods price, P_T – tradable goods price, S – value of a foreign currency in units of national currency.

As a result, the model solution provides the following equilibrium conditions for non-tradable (IB) and tradable (EB) goods markets:

$$Y_N(1/e) = (1-\alpha)(1/e)C + G_N, \quad \frac{\partial Y_N}{\partial(1/e)} < 0 \qquad \text{(IB)}$$

where Y_N – production of non-tradable goods, G_N – government purchases of non-tradable goods, α – the share of tradable goods in private consumption, C – private consumption measured in terms of tradable goods.

$$\dot{f} = Y_T(1/e, \varphi, A) - G_T - \alpha C + z - rf, \quad \frac{\partial Y_T}{\partial(1/e)} > 0, \frac{\partial Y_T}{\partial A} > 0, \frac{\partial Y_T}{\partial \phi} > 0 \qquad \text{(EB)}$$

where f – net foreign assets, Y_T – internal supply of tradable goods, G_T – government purchases of tradable goods, z – capital inflow, rf – debt service payments, ϕ – a terms of trade parameter or export prices to import prices ratio, A – productivity in the tradable goods sector.

Figure 1 illustrates the general equilibrium in a presented above and highly stylized economy model as a crossing of lines characterizing internal and external balance conditions (IB and EB). The consumption (C) is plotted on the horizontal axis, and the inverse of the real exchange rate ($1/e$) is plotted on the vertical axis.

The Crossing of EB and IB lines determines the equilibrium exchange rate that leads to simultaneous internal and external balance in the economy. The so-called "reduced form equation" for the real exchange rate is derived under the condition of simultaneous equilibriums in both sectors and represents a relation between a set of exogenous variables and the real exchange rate with the following expected signs of influence:

$$e^* = e^*\left(\underset{+}{\varphi}, \underset{+}{A}, \underset{+}{G_N}, \underset{-}{G_T}, \underset{+}{z}, \ldots\right)$$

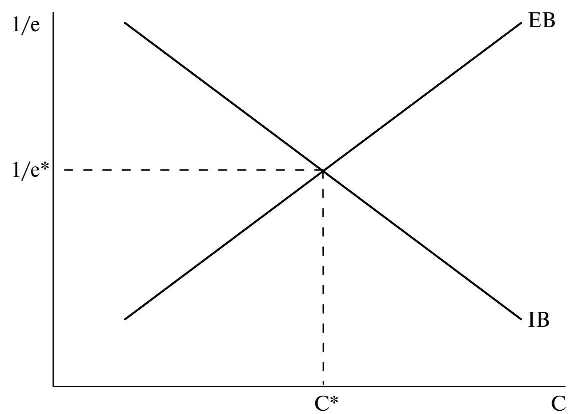


Figure 1. Internal and external balance conditions

It is easy to distinguish a relatively large set of exogenous variables by means of modifying internal and external balance conditions on the basis of the proposed model. In addition to the above mentioned 'fundamentals' different researchers also consider tariffs and trade barriers (a so-called "openness indicator"), the level and the structure of investments, the net external debt, the world interest rates, the deviation from uncovered interest parity, etc. Table A in the appendix generalizes information about variables used in empirical studies for different countries (both developing and developed). Important conclusion is that for considered period of observation of roughly 10–30 years the *productivity differentials* and the *terms of trade* variables demonstrated a substantial ability to explain the main part of variation of the real exchange rates of different countries. Additional determinants are chosen depending on the analyzed issue or as the most specifically relevant ones for a particular country for analyzed period of time.

Standard theoretical explanation of the terms of trade effect on the real exchange rate is the following. Improvements in the terms of trade lead through the *wealth effect* to an increase of internal demand and, as a result, the price of non-tradable goods increases and the real exchange rate appreciates. In practice for the countries where the main part of export consists of a small number of goods the price of the main exported goods is used as an indicator of terms of trade. In the case of Russia such an approach was conducted in Spatafora, Stavrev (2003), Sosunov, Shumilov

(2005) and Gurvich *et al* (2008) where export price of Russian oil was taken as a proxy for terms of trade.

The relation between the real exchange rate and the productivity differential is theoretically explained by the *Balassa-Samuelson effect* proposed in Balassa (1964) and Samuelson (1964). This effect states that countries with a substantial economic growth in the tradable goods sector have relatively higher internal prices than the countries without such an economic growth in the tradable goods sector. Thus, according to the Balassa – Samuelson effect, the real exchange rate is determined by the supply side of the economy.

According to the methodological approach proposed by Edwards (1988) the long-run equilibrium exchange rate responds only to the real fundamentals (as terms of trade and productivity differentials, etc.), and thus *permanent changes* in the real exchange rate are due to permanent changes in the fundamentals. The excessively expansionary monetary policy has only *a transitory effect* on the real exchange rate if a central bank desires to deviate the real exchange rate from the equilibrium level. In his article Edwards performed a panel study of the real exchange rates for twelve selected developing countries (see Table A in the appendix) and found that the short-run dynamics of the real exchange rate was well explained both by the real long-run fundamentals and the nominal short-run variables. Another finding was that for selected countries the speed of adjustment to equilibrium was very slow which supported the implication of the need of policy interventions (devaluations) in order to reduce misalignments of the real exchange rates. However, the later studies of individual countries indicated that the speeds of reaction to changes in the fundamentals are very different. Table A in the appendix contains information about the half life of deviations for different countries. Overall conclusion is that, on average, the half life of a deviation based on Edwards approach is usually less than the half life according to the PPP concept, but there are countries with relatively higher speeds (half a year) and relatively lower speeds of reaction (two years and more).

In empirical researches cointegration analysis is used in order to estimate an equilibrium real exchange rate (Engle-Granger procedure, Johansen procedure, etc.). A thorough review and critical assessment of many empirical works on the equilibrium real exchange rate is presented in Edwards, Savastano (1999).

2. Description of Data

It should be emphasized that the above used theoretical definition of the real exchange rate is a so-called *internal real exchange rate* which is defined as a relative price of non-tradable goods to tradable goods. Nevertheless, in empirical studies a so-called *external real exchange rate* is used which is a ratio of domestic prices to foreign trade partners prices expressed in domestic currency. The motivation of using external real exchange rates in empirical studies is justified by the simplicity and transparency of calculation in comparison with the internal real exchange rate. Graphs in the appendix (Figure A3 and Figure A4) illustrate that different indicators of external and internal real exchange rates have similar dynamics for the period under consideration. As the external real exchange rates the following indicators are considered: the real effective exchange rate, calculated by International monetary fund (IMF) and Bank for International Settlements (BIS), the real exchange rate of ruble w.r.t. dollar and euro, the Russian wages in dollars and euros (as a measure of cost-based real exchange rate). To calculate an internal exchange rate the prices of paid services were used as a proxy for prices of non-tradable goods, and prices of non-food goods — as a proxy for tradable goods. The behavior of all indicators of the real exchange rate is qualitatively similar: we observe a deep devaluation during the crisis of 1998 and considerable appreciation further since then.

The upper graph of Figure 2 demonstrates the real effective exchange rate (reer) for the period from quarter 1 of 1995 to quarter 1 of 2008 calculated by the IMF. This particular indicator is used in our econometric model, being very widespread in this kind of research. A more detailed discussion of measurement issues of the real exchange rate is presented in Hinkle, Montiel (1999).

A visual inspection of the real exchange rate indicates the following signs of non-stationarity: the presence of trends and shifts, and the fact that the real exchange rate crosses its mean level quite rarely[1]. The rest two graphs show nominal effective exchange rate (neer) and the price differential of Russia w.r.t. foreign trade partners. A considerable change in the behavior of variables is observed in the second half of 1998 characterized by permanent shift in all three variables. Despite positive shift in the price level differential during that period there was a real devaluation as a result of substantial nominal devaluation.

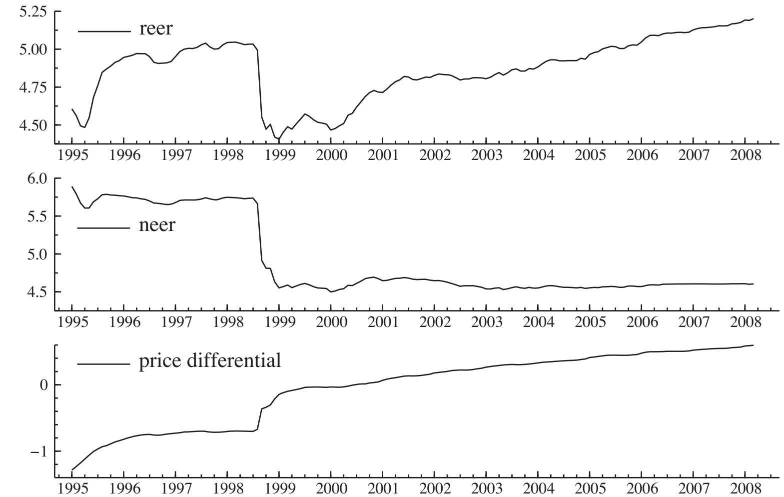


Figure 2. Decomposition of real effective exchange rate into nominal effective exchange rate and price differential

It is visually seen that because of a non-stationary behavior of the real exchange rate even a relative version of PPP is not applicable for the real equilibrium exchange rate analysis during the period under consideration. For explanation of the long-run tendencies in the real exchange rate of ruble other determinants or driving forces should be analyzed, as proposed by the above considered Edwards model.

As the main determinants of the real exchange rate of ruble, the following main fundamentals are considered: the terms of trade variable (**terms**) and the productivity differential of Russia w.r.t. trading partners (**pd**). In econometric model we consider productivity differential of Russia w.r.t. Germany, because Germany has the largest share in the trade turnover of Russia (in 2008 the share of trade with Germany was 10.88%). Besides that, the productivity differential of Russia w.r.t. Holland (second place in the trade turnover, in 2008 the share of trade with Holland was 9.57%) as well as Eurozone are shown in the appendix (Figure A6).

[1] Also, the traditional unit root tests of Dickey-Fuller, Phillips-Perron, Kwiatkovski-Phillips-Schmidt-Shin were performed for levels and first differences which also confirmed that the data is I(1).

In the cointegration analysis the price of Russian exported oil (Urals brand) is used as a proxy for the terms of trade. Also, the real price of Russian oil that is derived by dividing nominal price of oil by producer price index for Eurozone countries is shown in the appendix (Figure A5).

The fiscal policy variable (fiscal) was also chosen as the most relevant one for the case of Russia. In the periods of high oil prices, the fiscal policy was directed to withdraw the real income from the economy in the form of budget surpluses, referred to as the sterilization effect. It should be emphasized that such policy was conducted from the beginning of 2000, when budget surpluses appeared as a result of the energy resources price increases, and was in the most active phase since 2004 when the stabilization fund was created officially. The variable of government's deposits in the central bank (**fiscal**) is analyzed as the main indicator of the fiscal policy. The budget deficit/surplus to GDP ratio (fiscal2) and government's deposits to GDP ratio (fiscal3) are also considered as alternative indicators of fiscal policy variables. The graphs of fiscal policy indicators are presented in the appendix (Figure A7) and have visually similar dynamics. Table 1 summarizes information about the variables, which we are interested in.

*Table 1. D*escription of the data used for the cointegration analysis

Variable	Indicator	Source
reer, *real exchange rate*	Real effective exchange rate based on relative consumer prices	Data of IMF (IFS)
terms, *terms of trade*	Price of oil (Urals brand) in dollars [real price of oil (Urals brand)= price of oil (Urals brand) in dollars / producer price index for Eurozone countries]*	Data of Reuters agency, authors' calculations
PD, *productivity differential = productivity in Russia/ trading partners' productivity*	Labor productivity in Russia=industrial production index in Russia/employment index in Russia	Data of Rosstat, authors' calculations
	Labor productivity in Germany [Holland, Eurozone]=industrial production index in Germany/employment index in Germany	Data of OECD, ECB, authors' calculations
fiscal, *fiscal policy variable*	The central government's deposits in the central bank [the central government's deposits in the central bank to GDP ratio, budget deficits/surpluses to GDP ratio]	Data of IMF, Rosstat, authors' calculations

* In square brackets alternative indicators are shown.

All the variables were transformed into natural logarithms and seasonally adjusted (Census X12 procedure, additive, Eviews 5).

Figure 3 shows the real effective exchange rate of ruble and selected fundamental variables in levels and first differences. Taking first differences makes the data stationary (I(0)), at least visually, which means that the variables in levels are I(1)[2].

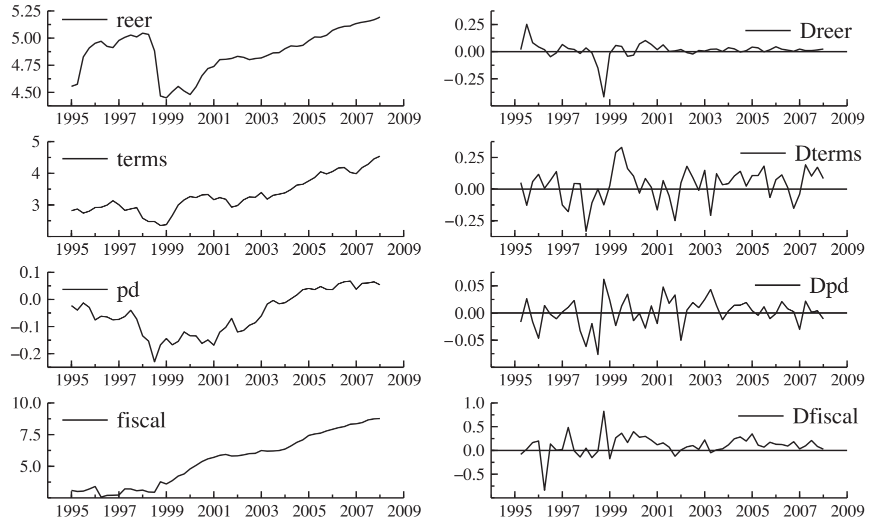


Figure 3. Variables in levels (on the left) and first differences (on the right)

Besides the terms of trade, significant outliers are seen on all graphs of first differences during the crisis of 1998 (quarters 3 and 4 of 1998). Outliers can be seen on the graph of the terms of trade at the beginning of 1999 which indicate sharp increases in the oil prices. Also, there is an outlier on the graph of the real exchange rate in the middle of 1995 when currency band was introduced.

[2] Also, the traditional unit root tests of Dickey-Fuller, Phillips-Perron, Kwiatkovski-Phillips-Schmidt-Shin were performed for levels and first differences which also confirmed that the data is I(1).

3. Methodology of Estimation

A cointegrated VAR methodology is used in order to estimate the long-run parameters of a relation between the real exchange rate and its selected determinants. The principals of this methodology were introduced in Johansen, Juselius (1988,1990,1992) and discussed in detail in Johansen (1996) and Juselius (2007).

The following model is estimated:

$$\Delta x_t = \Pi x_{t-1} + \Gamma_1 \Delta x_{t-1} + \ldots + \Gamma_{k-1} \Delta x_{t-k+1} + \Phi D_t + \varepsilon_t \quad (1)$$

The errors are assumed to be i.i.d. (Gaussian), $\varepsilon_t \sim IN_p(0,\Sigma)$. Δx_t — a vector of variables in first differences of the dimension $p \times 1$, x_t — a vector of variables in levels of the dimension $p \times 1$, D_t — a vector of deterministic variables (dummy variables and a constant) of the dimension $m \times 1$. Π, Γ_1, ..., Γ_{k-1} — matrices of coefficients in front of variables in levels and first differences of the dimension $p \times p$, Φ — a matrix of coefficients in front of deterministic variables of the dimension $p \times m$, p — number of variables, k — number of lags, m – number of deterministic variables.

The main long-run parameters of the system is characterized by the Π matrix, which in the case of cointegration may be represented as $\Pi = \alpha\beta'$. β' — is a matrix of coefficients of the dimension ($r \times p$), multiplying of which on the vector of variables gives a set of stationary linear combinations of variables in levels or so-called 'equilibrium errors' ($\beta' x_{t-1} \sim$I(0)). α — is a matrix of coefficients of the dimension $p \times r$ characterizing the reaction of variables in the system to the deviation from the equilibrium in the previous period, r — rank of Π matrix or a number of cointegration relations in the system.

The reduced form equation for the equilibrium exchange rate proposed by Edwards (1988) is estimated on the basis of cointegration relations $\beta' x_t$, where the coefficient in front of real exchange rate is normalized to unity.

The following error correction model for the real exchange rate is estimated in order to check the ability of other variables to influence the real exchange rate of ruble dynamics and to estimate an adjustment coefficient:

$$\Delta reer_t = \alpha_1 \left(\beta x_{t-1}\right) + \sum_{i=1}^{Q} c_i \Delta reer_{t-i} + \sum_{i=0}^{S} d_i \Delta F_{t-i} + \sum_{i=0}^{Z} e_i \Delta T_{t-i} + u_t \quad (2)$$

where β — a cointegration vector estimated within the model (1), α_1 — a coefficient characterizing the reaction of the real exchange rate on an equilibrium error in the previous period βx_{t-1}, F — a vector of fundamental variables, T — a vector of short-run determinants. Model (2) is formulated for the case of one cointegration relation.

4. Estimation and Analysis of Results

4.1 Statistical Model

All tests presented below are based on the unrestricted vector autoregressive model that includes a constant μ and dummy variables D_t which account for the outliers in the data and is given by the following system of equations:

$$\Delta x_t = \Pi x_{t-1} + \Gamma_1 \Delta x_{t-1} + \mu + \Phi D_t + \varepsilon_t \quad (3)$$

$$\varepsilon_t \sim IN_4(0,\Sigma)$$

where x_t is a vector of quarterly data variables

$$\left[reer, terms, pd, fiscal\right]^T \sim I(1)$$

for the period t=1995:1 – 2008:1. The variables are:

reer — the real effective exchange rate of Russian ruble,
terms — the terms of trade (the price of exported oil),
pd — the productivity differential of Russia w.r.t. Germany,
fiscal — the central government's deposits in the central bank.

The final specification of deterministic components is the following. The constant is unrestricted which means that the specification allows for the data to contain linear trends which is observed in our data. Also, there is no restrictions on the dummy variables: they could either enter the cointegration relation or be outside it in the system of equations (3). The choice of the lag length is based on Akaike and Schwarz criterion.

4.2 Estimation of Unrestricted VAR Model

It is seen from the graphs of the main variables in first differences (Figure 3) that the assumptions underlying statistical model (3) are most likely violated. Many variables demonstrate large outliers that are inconsistent with the normality assumption. It is especially typical for the period before 2000. It is important to control such large observations with dummy variable or to leave out the most volatile years from the sample in order to retain the validity of statistical inference. As far as these volatile years may be potentially informative with respect to relations we are looking for it is was decided to analyze the whole sample from 1995 to 2008 and to use dummy variables when standardized residuals are more than 3.5.

A quite general specification of the deterministic component of the model (3) is considered that assumes a linear trend in the cointegration relations (specification CIDRIFT in the software *CA*TS in *RA*TS) and test for significance of the trend (the outcomes are presented in the appendix (Outcome A1). Exclusion test from the cointegration relations indicates that the trend is not significant at the 1% level. Therefore the specification allowing for linear trends in the data but not in cointegration relations is considered below (specification DRIFT in the software *CA*TS in *RA*TS).

It was shown in studies that used simulations, and discussed in Juselius (2007), that valid statistical inference is sensitive to violations of some assumptions of the model (3) such as non-constancy of parameters, autocorrelated residuals, skewed residuals and, at the same time, robust to such as excess kurtosis and ARCH effects.

The following dummy variables were used:

$$D_t^T = [\text{dum95.3, dum96.2,dum97.2,dum98.3, dum98.4, dum99.4, dum2000.1}]_t$$

. Where dumxx,y_t takes on value “1” in *19xx.y* and “0” otherwise. VAR residuals start to demonstrate adequate behavior (see Table 2[33]) when we control for such extraordinary shocks.

[3] All dummy variables were left out of the model in order to verify the robustness of estimates. This experiment showed that the results qualitatively didn’t change concerning long-run parameters of the model.

Table 2. Misspecification tests

Multivariate tests

Tests for Autocorrelation				
LM(1):	ChiSqr(16)	=	14.610	[0.553]*
LM(2):	ChiSqr(16)	=	17.492	[0.354]
LM(3):	ChiSqr(16)	=	10.183	[0.857]
LM(4):	ChiSqr(16)	=	11.601	[0.771]
Test for Normality:	ChiSqr(8)	=	12.893	[0.116]
Test for ARCH:				
LM(1):	ChiSqr(100)	=	109.149	[0.250]
LM(2):	ChiSqr(200)	=	213.821	[0.239]
LM(3):	ChiSqr(300)	=	309.579	[0.339]
LM(4):	ChiSqr(400)	=	422.158	[0.214]

Univariate tests

	Mean	Std.Dev	Skewness	Kurtosis	Maximum	Minimum
DREER	-0.000	0.015	0.329	3.788	0.041	-0.033
DTERMS	-0.000	0.105	-0.952	4.270	0.187	-0.331
DPD	0.000	0.018	-0.583	3.352	0.036	-0.049
DFISCAL	-0.000	0.075	0.149	3.426	0.198	-0.170

	ARCH(2)	Normality	R-Squared
DREER	0.829 [0.661]	3.907 [0.142]	0.964
DTERMS	0.843 [0.656]	7.657 [0.022]	0.362
DPD	0.065 [0.968]	3.236 [0.198]	0.527
DFISCAL	7.109 [0.029]	2.209 [0.331]	0.879

Residual standard errors

DREER	DTERMS	DPD	DFISCAL
0.0130	0.106	0.018	0.075

* In square brackets p-values of tests are shown.

Multivariate autocorrelation tests for the first to the fourth order indicate the absence of autocorrelation. Multivariate normality hypothesis is not rejected but we have a borderline case. Multivariate ARCH tests indicate no ARCH effects for the first to the fourth order. It should be noted that cointegration results have been found quite robust to ARCH and excess kurtosis (Gonzalo, 1994). Thus, we regard the present model specification to be acceptable. The graphs, histograms and correlograms of residuals are presented in the appendix (Figure A1).

4.3 Cointegration Rank and Estimation of Long-run Parameters

The Johansen test or *trace test* is based on the VAR model (3) in which all the short-run dynamics (lags of first differences of variables), dummy variables and other deterministic components are "cleaned out" from the model by applying the Frisch-Waugh theorem (more detailed description is provided in Johansen (1996) and Juselius (2007)). The following *reduced rank regression* is estimated in order to make a decision about the cointegration rank of the system:

$$\begin{cases} R_{0t} = \Pi R_{1t} + \varepsilon_t \\ \Pi = \alpha\beta' \end{cases}, \ \varepsilon_t \sim N_4(0,\Sigma) \qquad (4)$$

where

R_{0t} — residuals of OLS-regression of Δx_t on $\Delta x_{t-1}, \mu, D_t$,

R_{1t} — residuals of OLS-regression of x_{t-1} on $\Delta x_{t-1}, \mu, D_t$.

LR test for a system with *p* variables includes the following competing hypotheses:

$H(p): rank\Pi = p$, i.e. there are no common stochastic trends in the system, x_t — is a vector of stationary variables (*I(0)*),

$H(r): rank\Pi = r < p$, i.e. there are $p - r$ common stochastic trends in the system and r cointegration relations, x_t — is a vector containing non-stationary variables (*I(1)*).

Hypothesis $H(p)$ is considered as a null hypothesis (which corresponds to no imposed restrictions on the long-run parameters Π), against which an alternative hypothesis $H(r)$ is tested. The Johansen test verifies whether it is possible or not to impose restrictions on the model (3) by lowering the rank of Π without loss of important information in the data. In other words, I(1) model forms a sequence of nested models:

$$H(0) \subset \ldots \subset H(r) \subset \ldots \subset H(p),$$

where hypothesis $H(p)$ corresponds to I(0) model of unrestricted VAR and hypothesis $H(0)$ corresponds to imposing restriction $\Pi = 0$, that is equivalent to an ordinary VAR model in differences. The models in between guarantee the presence of cointegration, which is the most interesting to test for us.

Trace statistic that allows to make a decision about the quantity of cointegration relations is defined in the following way:

$$\tau_{p-r} = -2Q\left(H(r)/H(p)\right) = -T\sum_{i=r+1}^{p} \log\left(1-\hat{\lambda}_i\right)$$

where $Q\left(H(r)/H(p)\right)$ — a likelihood ratio test statistic for H(r) in H(p), $\hat{\lambda}_i$ — i-th estimated eigenvalue in the eigenvalue problem incurred in the maximization of the likelihood function over β, and which are ranged from large to small (the second column in Table 4). 95% critical values (C_{p-r}) for this statistic are presented in Johansen (1996).

The Johansen procedure in case of our model consists of five tests:

$$H(0): \{p - r = 4, r = 0\}, \text{ if } \{\tau_4 \le C_4\}$$

$$H(1): \{p - r = 3, r = 1\}, \text{ if } \{\tau_4 > C_4, \tau_3 \le C_3\}$$

$$H(2): \{p - r = 2, r = 2\}, \text{ if } \{\tau_4 > C_4, \tau_3 > C_3, \tau_2 \le C_2\}$$

$$H(3): \{p - r = 1, r = 3\}, \text{ if } \{\tau_4 > C_4, \tau_3 > C_3, \tau_2 > C_2, \tau_1 \le C_1\}$$

$$H(4): \{p - r = 0, r = 4\}, \text{ if } \{\tau_4 > C_4, \tau_3 > C_3, \tau_2 > C_2, \tau_1 > C_1\}$$

The first four hypotheses are tested and results are presented in Table 3. The first raw of Table 3 corresponds to testing a hypothesis $H(0): r = 0$, i.e. $p - r = 4$ against the null hypothesis $H(4): r = 4$, i.e. $p - r = 0$, which means that there are 4 non-stationary I(1) variables and not related in the long-run. In other words, there are no cointegration relations and there are 4 stochastic trends in the system. Table 3 shows that this possibility is credibly rejected when using standard and also small sample corrected (Bartlett correction) critical values. Testing a hypothesis $H(1): r = 1$, i.e. $p - r = 3$ against the null hypothesis $H(4): r = 4$, i.e. $p - r = 0$ allows to answer whether it is possible to impose a restriction of only one cointegration relation, and accordingly 3 common stochastic trends. This hypothesis is not rejected for analyzed data with which we proceed in the following analysis.

Table 3. The Johansen test

I(1)-ANALYSIS

p-r	r	Eig. Value	Trace	Trace*	Frac95	P-Value	P-Value*
4	0	0.660	81.175	70.389	47.707	0.000	0.000
3	1	0.258	26.137	20.292	29.804	0.128	0.414
2	2	0.183	10.938	8.940	15.408	0.219	0.378
1	3	0.012	0.624	0.380	3.841	0.430	0.537

* – The Bartlett small sample corrected critical values.

Hence, estimated number of cointegration relations is consistent with the number of hypothetical *pushing forces* of the system or common stochastic trends for the real exchange rate of ruble and selected determinants. That means that $rank\Pi = 1$ is both economically and statistically significant.

Estimated parameters of the long-run relation of variables β' and a speed of adjustment to equilibrium parameter α are shown in Table 4. Also, in the appendix (Outcome A3) the same estimates for two alternative fiscal policy variables are shown and they are very close to the ones presented in Table 4.

*Table 4. Re*sults of the model long-run parameters estimation

BETA(transposed)

	REER	TERMS	PD	FISCAL	CONSTANT
Beta(1)	1.000	-0.229	-1.340	0.044	-4.43287
	(.NA)	(-4.304)	(-6.582)	(3.790)*	

ALPHA

	Alpha(1)
DREER	-0.211 (-8.005)
DTERMS	-0.275 (-1.355)
DPD	0.031 (0.894)
DFISCA	-0.754 (-5.631)

* – in square brackets t-statistics of tests are shown

As a result of cointegration analysis an estimated reduced form equation for the equilibrium real exchange rate of ruble is the following:

$$reer_t = 0.229 \cdot terms_t + 1.34 \cdot PD_t - 0.044 \cdot fiscal_t + 4.433 + \varepsilon_t^{EQ} \quad (5)$$

where $\varepsilon_t^{EQ} \sim I(0)$

A few important questions arise in respect to estimated model at this stage of analysis. First, is it possible to exclude any variable from the cointegration relation, i.e. is it necessary to include all chosen variables in order to reveal a stationary relation. Second, what is the sensitivity of results to the choice of the estimation period, i.e. is the constancy of parameters assumption of the model (3) satisfied for the chosen period of analysis. Finally, is it possible to argue that some variables are exogenous based on statistical test (weak exogeneity test), that may help to identify which variables determine the dynamics in the system bringing in the main contribution to the forming of stochastic trends and which variables mainly adjust the system to equilibrium. To this and other questions we would try to answer in the next section.

4.4 Sensitivity Analysis

Parameter Constancy Verification

An important assumption behind the cointegration analysis of model (3) is the *parameter constancy*. The results of different recursive tests are considered below that may indicate the violation of the parameter constancy assumption. The model was re-estimated and the tests of the constancy of the corresponding parameters were conducted with respect to the two chosen base sub-samples. The first part of the sample 1995-1:2003:4 was considered as a base sub-sample, and *forwards recursive tests* were conducted. Similarly, the last part of the sample 2000:1-2008:1 was considered as another base sub-sample, and *backwards recursive tests* were conducted. It should be emphasized that the base sub-sample should have enough observations for the recursive tests to be statistically valid.

*Table 5. Re*cursive tests of model parameters constancy

Type of a test	What is tested	Conclusion of a test*
Forwards recursive tests, base sample 1995:1-2003:4		
Test of constancy of likelihood	parameters of a whole model	H0 is not rejected
Trace test statistics	long-run parameters of a model (cointegration rank)	H0 is not rejected
Fluctuation test	long-run parameters of a model	H0 is not rejected
Nyblom test of beta constancy	cointegration relation beta constancy coefficients (β′)	H0 is not rejected
Backwards recursive tests, base sample 2000:1-2008:1		
Test of constancy of likelihood	parameters of a whole model	instability in 1998 is observed
Trace test statistics	long-run parameters of a model (cointegration rank)	H0 is not rejected
Fluctuation test	long-run parameters of a model	H0 is not rejected
Nyblom test of beta constancy	cointegration relation coefficients (β′)	H0 is not rejected

* — all tests were conducted for cleaned of short-run effects model (R-model (4)) and for the whole model (X-model (3)). The conclusions are presented for both types of tests if they coincide and only for R-model otherwise.

Table 5 summarizes conclusions of four different types of recursive tests which verify constancy of different parameters of the model (3). Overall conclusion for the forwards recursive tests is that most of performed tests confirm the constancy of parameters as compared to the base sub-sample 1995:1-2003:4. On the other hand, the conclusions are not so straightforward for the backwards recursive tests: a part of tests indicate existence of instability in the short-run parameters of the model in 1998 when comparing with a base sample. Nevertheless the constancy of long-run parameters is maintained. All graphs of recursive tests are presented in the appendix (Figure A2). A thorough description of conducted recursive tests are presented in Juselius (2007).

Long-run Exclusion Test

Table 6 shows the results of a test that verifies a possibility to exclude selected determinants out of the cointegration relation.

*Table 6. Te*sts of variables exclusion from the cointegration relation

TEST OF EXCLUSION

LR-test, Chi-Square(r), P-values in brackets.

r	DGF	5% C.V.	REER	TERMS	PD	FISCAL
1	1	3.841	39.344	9.720	13.905	8.271
			[0.000]	[0.002]	[0.000]	[0.004]*
2	2	5.991	44.226	13.122	18.668	8.976
			[0.000]	[0.001]	[0.000]	[0.011]
3	3	7.815	52.675	21.272	26.775	18.260
			[0.000]	[0.000]	[0.000]	[0.000]

* — in square brackets p-values of tests are shown

From the Table 6 it is seen that all selected variables are significant regardless of the cointegration rank choice, i.e. their exclusion from the cointegration relation would lead to the loss of important information in the data.

4.5 Weak Exogeneity Test of Real Exchange Rate Determinants

Found cointegration relation (5) indicates the presence of a long-run relation between the real exchnge rate of ruble and its determinants. Potentially each variable in the cointegration relation may be *a cause of a deviation* from the long-run equilibrium and, at the same time, play a role of *adjusting to disequilibrium*. There are cases when variables mostly create deviations from the equilibrium and not adjusting which means that they are *weakly exogenous*[4]. The weak exogeneity analysis helps to identify which variables create the common stochastic trends in the system that is important for the determination of the equilibrium real exchange rate. Table 7 presents a test of weak exogeneity for the analyzed system.

*Table 7. Te*st of weak exogeneity

TEST OF WEAK EXOGENEITY

LR-Test, Chi-Square(r), P-values in brackets.

r	DGF	5% C.V.	REER	TERMS	PD	FISCAL
1	1	3.841	34.842	1.534	0.693	22.356
		[0.000]	[0.216]	[0.405]	[0.000]*	
2	2	5.991	36.317	4.470	2.065	22.800
		[0.000]	[0.107]	[0.356]	[0.000]	
3	3	7.815	43.328	13.252	10.620	27.732
		[0.000]	[0.004]	[0.014]	[0.000]	

* — in square brackets p-values of tests are shown

The conclusion of the test of weak exogeneity is that the terms of trade and the productivity differential are both weakly exogenous even at a 10% level of significance for the chosen rank. There is no such a conclusion for the rest two variables, the real exchange rate and the fiscal policy variable. That may be interpreted as that the third stochastic trend in the system is created by both the real exchange rate of ruble and the fiscal policy variable and at the same time that both of these two variables play the role of adjusting or pulling the whole process to the long-run equilibrium. These possibilities will be analyzed in detail in the next section where an exercise similar to the impulse responses will be conducted.

[4] For weakly exogenous variables adjustment coefficient ( ) in front of equilibrium error ( ) is zero. In our case for terms of trade and productivity differential equations, as shown in Table 4, this coefficient is not significant.

The results of the cointegration vector estimation for the system with a restriction of weakly exogenous terms of trade and productivity differential are presented in the appendix (Outcome A2). This restriction qualitatively does not change the results concerning the long-run parameters of the model (β'). Also, estimation results for models with two alternative fiscal policy variables are presented in the appendix (Outcome A3) as a robustness analysis of the chosen fiscal variable indicator. In case when the fiscal policy variable is presented by the budget deficits/surpluses to GDP ratio all selected determinants become weakly exogenous. Possible explanation is that the budget deficits/surpluses to GDP ratio behaves much more volatile than the central government's deposits that may blur the adjustment process of that variable to the long-run equilibrium or the *pulling feature* of that variable and pick out its *pushing feature*[5].

Thus, while we are sure about the structure of long-run influence of terms of trade and productivity differential in the sense of weak exogeneity property, it is not a clear cut case for the fiscal policy variable. A more detailed analysis of these issues is presented in the next section.

4.6 Moving Average Representation

In order to study the structure of cointegration relation which is interpreted as a long-run equilibrium to which the process is adjusting in case of an equilibrium error the VAR representation (3) is convenient. Forces or shocks that create non-stationarity in the system and are the *common stochastic trends* for the analyzed variables. There is a complete equivalence between the vector autoregressive (VAR) representation used for the analysis of the structure of cointegration relations and moving average (MA) representation used in the analysis of the common stochastic trends structure[6]. The MA representation for the model (3) is the following:

$$x_t = C \cdot \sum_{i=1}^{t} \left(\varepsilon_i + \Psi D_i\right) + C^*\left(L\right)\left(\varepsilon_t + \Phi D_t\right) + A ,$$

[5] It is seen from the outputs in the appendix that the standard error in the equation of DFISCAL2 variable (budget deficits/surpluses to GDP ratio) equal to 1.575 versus 0.075 for the equation of DFISCAL variable (the central government's deposits) in the main specification (see Table 2).

[6] This representation is called a "Granger representation theorem" (see Johansen (1996)).

where $C = \tilde{\beta}_{\perp}\alpha'_{\perp}$ (the long-run impact matrix) and $C^{*}(L)$ — infinite order polynomial, given by the VAR model parameters, A depends on the initial values and satisfies $\beta' A = 0$. A matrix $\alpha'_{\perp}$ is responsible for the forming of common stochastic trends out of the shocks of the variables and a matrix $\tilde{\beta}_{\perp}$ contains the coefficients with which the common stochastic trends enter the process x_t.

Table 8. Common stochastic trends analysis

THE MA-REPRESENTATION AND DECOMPOSITION OF THE TREND

The Long-Run Impact Matrix, C:

	$\Sigma\varepsilon_{REER}$	$\Sigma\varepsilon_{TERMS}$	$\Sigma\varepsilon_{PD}$	$\Sigma\varepsilon_{FISCAL}$
REER	-0.163	**0.349**	**1.684**	**-0.013**
	(-0.342)	(2.029)	(2.058)	(-0.290)*
TERMS	-1.489	1.578	2.068	-0.074
	(-0.894)	(2.617)	(0.722)	(-0.485)
PD	-0.004	0.045	1.104	0.030
	(-0.022)	(0.623)	(3.202)	(1.638)
FISCAL	**-4.159**	**1.653**	6.096	0.812
	(-1.693)	(1.859)	(1.442)	(3.595)

* — in round brackets t-statistics of tests are shown

Table 8 presents the results of estimation of the long-run impact matrix C. Each column is denoted by the past cumulated residuals of a particular variable. A column contains the coefficients with which the past cumulated shocks of a particular variable enter the marginal processes of x_t, i.e. variables REER, TERMS, PD and FISCAL. Thus, the coefficients of the C matrix are interpreted as showing the long-run responses of analyzed variable to different past shocks. The t-statistics are based on asymptotic standard errors suggested in Paruolo (1997).

Firstly, weak exogeneity tests suggested that terms of trade and productivity differential (TERMS, PD) are not reacting to the equilibrium error and pushing the system by means of creating two independent stochastic trends to which the other variables (REER and FISCAL) adjust. The estimate of the impact matrix confirms it: in these marginal processes (TERMS, PD) only their own cumulated shocks are significant and not the cumulated shocks of other variables. For the rest of marginal processes, i.e. for REER

and FISCAL, past cumulated shocks of other variables matter. For example, for the REER marginal process the past cumulated shocks of TERMS and PD have the most significant and positive effects. Thus, in regard to the asked question of real exchange rate determination the two stochastic trends that are contained in the REER are generated by TERMS and PD with very high degree of confidence.

Secondly, weak exogeneity tests suggested that both (REER and FISCAL) are not weakly exogenous, meaning that the third stochastic trend in the system is generated by both (REER and FISCAL), i.e. that there could be *bilateral feedback effects* of shocks to both of the variables. The impact matrix C for the main specification where the fiscal policy variable (FISCAL) is proxied by the central government's deposits indicates more significant influence from REER to FISCAL[7]. Although the opposite influence from FISCAL to REER is not significant for the main specification, it is very significant for the alternative specification (see appendix (Outcome A3)) where the fiscal policy variable (FISCAL2) is proxied by the budget deficits/surpluses to GDP ratio. This suggests that it is hard to argue with high degree of confidence about the existence of a *direct long-run unilateral influence* of fiscal policy on the real exchange of ruble. However, it is easier to argue about an *indirect influence* of the fiscal policy variable through the influence on the equilibrium error term which is in fact *a sterilization policy* that was conducted from 2000 and became very active in 2004. By more active correction of the fiscal variable to the equilibrium errors generated by the terms of trade and productivity differential shocks the fiscal authority may reduce the extent to which the real exchange rate would react to the disequilibrium. In other words, the fiscal policy variable may be used to change the equilibrium real exchange rate according to the reduced form equation of the real exchange rate (5) to which the actual real exchange rate would adjust over some time.

At this stage we have estimated a cointegration relation between the real exchange of ruble and its main theoretically relevant determinants. The analysis performed indicated one cointegration relation and respectively three common stochastic trends in the analyzed system of four variables (REER, TERMS, PD and FISCAL). Additional econometric procedures indicated that two independent stochastic trends contained in the margin-

[7] This relation is expected because fiscal revenues in Russia are to large extend depend on taxes from export and thus the appreciation of ruble leads to lower revenues.

al process of the real exchange rate (REER) are generated by the shocks to terms of trade and productivity differential meaning that they are direct determinants of the real exchange rate. The nature of the third stochastic trend is not so obvious and depends on the indicator of fiscal policy variable used. On average it is likely that both variables generate this stochastic trend influencing bilaterally on each other. However, fiscal policy variable may be considered as indirect determinant of the real exchange rate in the sense that it could change the equilibrium error, by conducting sterilization policy in the periods of improved terms of trade and productivity differential increases and flooding the economy with money policy in case of terms of trade deterioration and productivity differential decreases.

5. Short-run Dynamics of the Real Exchange Rate of Ruble

Following Edwards (1988) we estimate a single equation error correction model for the real exchange rate of ruble which includes information about long-run fundamentals as well as additional possible determinants of the real exchange rate.

As additional factors that may affect the real exchange rate of ruble an excessively expansionary monetary policy variable (**MP**) and a variable of net private capital flows (**CAP**) are considered. The description of these variables is presented in Table 9.

Table 9. Description of the data used for the real exchange rate error correction model

Variable	Indicator	Source
MP, *excessively expansionary monetary policy variable*	Increase in the ratio of M2 (in national definition) to GDP in the preceding quarter **[**the same for monetary base**]***	Data of Russian CB, Rosstat, authors' calculations
CAP, *private capital flows variable*	Increase in the ratio of net private capital flows to GDP	Data of Russian CB, Rosstat, authors' calculations

* In square brackets alternative indicators are shown.

All variables were transformed into natural logarithms and seasonally adjusted (Census X12 procedure, additive, Eviews 5).

Figure 4 shows the real effective exchange rate of ruble and additional possible determinants of the real exchange rate in levels and first differences. Taking first differences makes the data at least visually stationary (I(0)) which means that the variables in levels are I(1)[8].

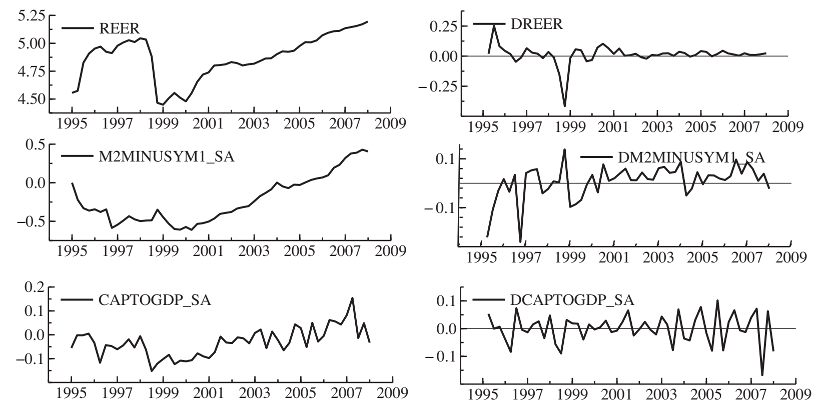


Figure 4. Variables in levels (on the left) and first differences (on the right), MP=DM2MINUSYM1_SA, CAP=DCAPTOGDP_SA

The equation of the model (2) that shows a more detailed short-run dynamics of the real exchange rate of ruble is estimated by OLS. The results of the estimation are presented in Table 10.

The following error correction model for the real exchange rate of ruble was found (t-statistics of tests are shown in round brackets):

$$\Delta reer_t = \underset{(1.22)}{0.009} + \underset{(3.9)}{0.39} \cdot \Delta reer_{t-1} -$$

$$-\underset{(-4.8)}{0.28} \cdot \left(reer_{t-1} - 0.229 \cdot terms_{t-1} - 1.34 \cdot PD_{t-1} + 0.044 \cdot fiscal_{t-1} - 4.443 \right)$$

$$-\underset{(-1.85)}{0.25} \cdot \Delta mp_t + \underset{(1.89)}{0.360} \Delta cap_{t-1} + \tilde{\varepsilon}_t$$

[8] Also traditional unit root tests of Dickey-Fuller, Phillips-Perron, Kwiatkovski-Phillips-Schmidt-Shin were performed for levels and first differences which also confirmed that the data is I(1).

Table 10. Error correction model for the real exchange rate of ruble

Dependent Variable: D(REER)				
Method: Least Squares				
Sample (adjusted): 1995Q3 2008Q1				
Included observations: 51 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(REER(-1))	0.387734	0.098974	3.917551	0.0003
EC(-1)	-0.283794	0.059149	-4.797944	0.0000
D(MP)	-0.251427	0.135770	-1.851855	0.0705
D(CAP(-1))	0.293951	0.155483	1.890570	0.0650
C	0.009690	0.007919	1.223617	0.2273
R-squared	0.562911	Mean dependent var		0.012161
Adjusted R-squared	0.524903	S.D. dependent var		0.079470
S.E. of regression	0.054776	Akaike info criterion.		-2.878226
Sum squared resid	0.138020	Schwarz criterion		-2.688831
Log likelihood	78.39476	F-statistic		14.81044
Durbin-Watson stat	1.925958	Prob(F-statistic)		0.000000

The speed of adjustment of the real exchange rate is measured in the literature via a «half life» indicator, which states how much time it is needed for the real exchange rate to decrease an initial deviation from the equilibrium by 50%, other things equal. A half life is calculated using alpha coefficient in front of equilibrium error ($\beta' x_{t-1}$). The coefficient in front of equilibrium error ($\beta' x_{t-1}$) is highly significant and negative which indicates a gradual adjustment to equilibrium real exchange rate. The error correction model for the real exchange rate indicates that a "half life" for the real exchange rate of ruble is roughly 2 quarters (which is close to the estimate obtained in the cointegration analysis).

Negative coefficient in front of monetary policy variable (Δmp_t) indicates that in response to excessively expansionary monetary policy the effect of nominal depreciation dominates the effect of prices increases and that the central bank's policy of foreign exchange interventions in order to appreciate ruble before 1998 crisis and in order to lower the appreciation of ruble after the 1998 crisis actually have an effect on the real exchange rate. But the coefficient is significant only at the 10% level.

Coefficient in front of capital inflow variable (Δcap_{t-1}) has an expected sign and significant at the 10% level – an increase in the capital inflow leads to a real appreciation with a lag of 1 quarter.

6. Summary of Econometric Analysis and Comparisons

Performed cointegration analysis and estimated error correction model for the real exchange rate indicate the following.

- An increase of oil price (terms of trade) by 1% is associated with *an increase* of the real equilibrium exchange rate by 0.22%.
- An increase in productivity differential of Russia w.r.t Germany by 1% is associated with *an increase* of real equilibrium exchange rate by 1.34 %.
- An increase of the central government's deposits in the central bank (fiscal policy variable) by 1% is associated with *a decrease* of the equilibrium real exchange rate by 0.044%.
- *Average adjustment time* of the real exchange rate of ruble to the equilibrium for more than 50% (what is in literature called a "*half life*") is roughly 0,5/0,28=2 quarters.
- Excessively expansionary monetary policy is associated with a *depreciation* of the real exchange rate of ruble in the short-run (but only using a 10% significance level).
- Private capital inflow with one lag is *positively* associated with real exchange rate of ruble. (but only using a 10% significance level).

In order to compare the estimated results a few examples of estimates in similar empirical researches for Russia and other countries are presented below in the Table 11 (see also a more detailed Table A in the appendix).

The estimate of the coefficient in front of terms of trade variable (price of oil) is very close to the one of Spatafora, Stavrev (2003) estimated for Russia for the period 1995-2002, where the coefficient is 0.31%. In Gurvich et al (2007) for Russia for the period 1999-2007 this coefficient is 0.16% and 0.24% (for two different specifications of an econometric model). As shown in Table 11 roughly similar results were obtained for the USA relative to euro area, Finland and developing countries such as Ghana, South Africa, Morocco, Malawi, Zambia, Algeria, Syria, Tanzania and Brazil.

*Table 11. E*quilibrium real exchange rates estimation results for different countries

Country	Terms of trade, coefficient	Productivity differential, coefficient	Half lifetime (in years)
Finland	[**0.37**]	[**0.85**]	**1.5**
Turkey	[**-0.91**] inverse quotation	[-]	**0.4**
Spatafora, Stavrev, ***Russia***	[**0.31**]	[**1.3**]	**0.3**
Sosunov, Shumilov, ***Russia***.	[**0.64**]	[**-2.99**]	**0.5 (0.6)**
Gurvich, Sokolov, Ulukaev, ***Russia***	[**-0.16** and **-0.24**] inverse quotation	[**-1.7** and **-0.93**]	-
New Zealand	[**1.85 and 1.4**]	[-]	**0.9**
Ghana	[**0.35**]	[**4.68**]	**1.1**
South Africa	[**0.46**]	[**0.14**]	**2.1**
USA w.r.t. euro area	[**-0.31** and **-0.26**]	[**1.87**], [**1.46**]	**0.5** (**0.2**)
Bulgaria	[**3.99**]	[**1.3**]	**0.6**
Malawi	[**0.18**]	[**4.32**]	**0.6** (**0.8**)
China	[**-3.38**] inverse quotation	[**0.37**]	**4.3**
Morocco	[**0.24**]	[**1.46**]	**3.3**
Costa Rica	[**0.75**]	via a trend	**1.3**
Zambia	[**0.32**;**0.70**;**0.47**]	[-]	**1.4; 0.4; 0.4**
USA, ***Germany***, ***Japan***	[US dollar **0.084**] [German mark **0.062**, but insignificant] [Japanese jen **0.22**]	[USA **2.70**] [German mark **5.22**] [Japanese jen **1.88**]	for US dollar **1.5**
Algeria	[**0.24**]	[**1.88**]	**0.8**
Syria	[**0.38** and **0.3**]	[**0.38** and **1.14**, **1.44**]	**3.5**
Tanzania	[**0.19**]	[**1.05**]	-
Brazil	[**0.21** and **0.27**]	[**0.2** and **0.32**]	**0.4** (**0.2**)
Egypt	[**1.26**]	[**1.81**]	-

(Highlighted figures indicate similar estimation results to our estimates)

The estimate of the coefficient in front of productivity differential (indicating a Balassa-Samuelson effect) is also very close to the one of Spata-

fora, Stavrev (2003) estimated for the period 1995–2002, where the coefficient is 1.31%. In Gurvich et al (2007) for the period 1999–2007 this coefficient is 1.7% and 0.93% (for two different specifications of an econometric model). As shown in Table 11 roughly similar results were obtained for the USA relative to euro area, Japan and developing countries as Bulgaria, Morocco, Algeria, Syria, Tanzania and Egypt.

Negative and statistically significant coefficient in front of a fiscal policy variable was expected and explained by the sterilization effect in periods of high oil prices and productivity growth and fiscal injections in periods of deteriorated terms of trade and low productivity. But the influence of this factor is quantitatively significantly lower than the influence of terms of trade and productivity differential.

Estimated average time of adjustment, or a half life, of 2 quarters is consistent with empirical researches on emerging and developed countries, where this indicator ranges on average from 1 quarter to 3 years. As shown in Table 11 for Russia very similar results were obtained in Sosunov, Shumiliv for the period 1995–2003, and Spatafora, Stavrev for the period 1995–2002. Roughly similar results were obtained for the USA relative to euro area, Japan and developing countries such as Bulgaria, Morocco, Algeria, Syria, Tanzania and Egypt.

In order to answer a question about the possibility of Russian monetary authority to influence the real exchange rate of ruble an error correction model was estimated encompassing information on selected long-run fundamentals and also short-run determinants. The results of estimation confirm a highly significant influence of selected long-run determinants. The effect of monetary policy and capital inflows is confirmed with expected signs but only at the 10% level of significance.

7. Real Exchange Rate Misalignment and Analysis of Current Situation

A real exchange rate misalignment index based on current values of fundamentals is calculated using an estimate of the reduced form equation for the real exchange rate. Below the graphs of real effective exchange rate of ruble and its determinants are shown for the period since quarter 1 of 1995 to the beginning of 2009 (the grey color indicates authors' estimates for quarter 1 of 2009, taking into account the data for the beginning of March 2009). In the beginning of 2009 the graphs show a substantial oil price decrease and lowering of productivity differential, slowing down of fiscal deposits accumulation in the central bank and responding downwards correction of the real exchange of ruble.

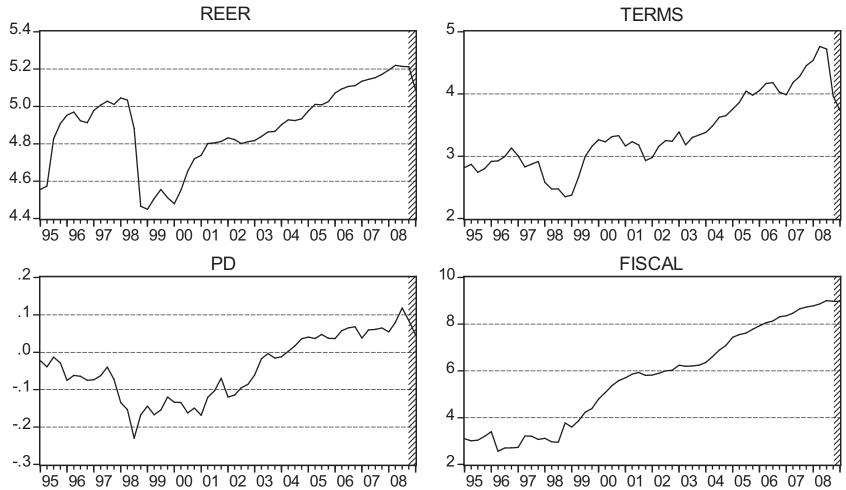


Figure 5. The Real effective exchange rate of ruble (reer) and its determinants for the period quarter 1 of 1995 –quarter 4 of 2008.
A grey region on graphs indicates authors' estimates for quarter 1 of 2009, taking into account the data for the beginning of March 2009

To understand how actual and equilibrium real exchange rate are related Figure 6 presents percentage deviation of actual real exchange rate of ruble (reer) from predicted (reer*) based of estimated cointegration relation (where reer* = $0.229 \cdot terms_t + 1.34 \cdot PD_t - 0.044 \cdot fiscal_t + 4.433$).

The period before the end of 2000 is characterized by substantial deviations of actual exchange rate from predicted equilibrium real exchange rate. From the end of 2000 the amplitude of fluctuations decreases significantly. Despite short-run and medium-run deviations of the actual real exchange rate from the equilibrium real exchange rate a gradual return to the horizontal line is observed characterizing the long-run equilibrium of the system. The correction to the long-run equilibrium may be a result of change in actual exchange rate and also as a result of changes in the equilibrium exchange rate (which is determined by the price of oil (terms of trade), productivity differential and a fiscal policy variable). Concluding, for the current situation (the beginning of March 2009) under the assumption of constant parameters conducted misalignment analysis suggests the following:

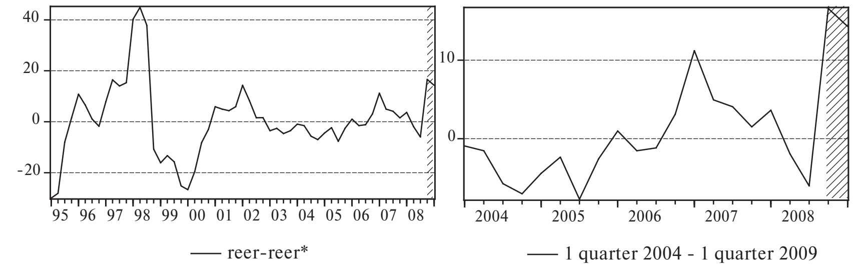


Figure 6. Current percentage deviation of actual real exchange rate from estimated equilibrium real exchange rate for the whole period and more in detail for the last 5 years. Grey region on graphs indicates authors' estimates for quarter 1 of 2009, taking into account the data for the beginning of March 2009

- For the first quarter of 2009 an excess of actual real exchange rate of ruble over estimated equilibrium real exchange rate is observed approximately by 15%.
- In case if the price of oil and productivity differential stay at current levels most probably the correction of this overvaluation will take place as a result of further real devaluation and minor increase of equilibrium real exchange rate by fiscal measures.

Summary and Conclusions

Determination of the main factors influencing the real exchange rate of ruble is an important issue because Russia belongs to the export oriented group of countries. The purpose of this empirical study was to determine the main factors and estimate their influence on the real exchange rate of ruble.

Edwards approach to determination of the real exchange rate provides good explanation of the real exchange rate behavior for not very long periods of time (10-30 years) and especially for developing countries like Russia which are subject to substantial terms of trade and productivity shocks. According to the small open economy model proposed by Edwards the long-run determinants of the real exchange rate enter the reduced form equation for the real exchange rate, and nominal variables may influence the real exchange rate only in the short-run.

The analyzed quarterly data from quarter 1 of 1995 to quarter 2 of 2008 is characterized by high degree of variation (including the period of the crisis of 1998 and rocketing prices of oil in the second part of the sample). The influence of oil prices and labor productivity differential with respect to Germany are considered as the main long-run factors for the real exchange of ruble which are theoretically explained by means of wealth and Balassa-Samuelson effects. The fiscal policy variable capturing the sterilization effect in the periods of high oil prices and productivity is considered as a third important determinant of the real exchange rate of ruble.

Cointegrated analysis in a cointegrated VAR framework was conducted in order to estimate a reduced form equation for the real exchange rate of ruble. An error correction model for the real exchange rate of ruble was estimated according to the Edwards approach.

Cointegarted VAR model was estimated with a maximum effort to satisfy its statistical assumptions and with an accurate choice of the deterministic components. As sensitivity analysis parameter constancy tests were conducted. *Overall conclusion for forwards recursive tests is that most of performed tests confirm constancy of parameters when comparing with the base sample 1995:1-2003:4. On the other hand, the conclusions are not so straightforward for the backwards recursive tests: a part of tests indicate existence of instability in the short-run parameters of the model in 1998 when compared with a base sample. Nevertheless, the constancy of long-run parameters is maintained.*

The Johansen procedure has determined one cointegration relation and, respectively, three common stochastic trends in the data. Exclusion tests indicate the significance of all three determinants in the cointegration relation.

The conclusion of the weak exogeneity tests is that the price of oil and productivity differential are weakly exogenous with a high level of significance and thus identify two stochastic trends. There is no such a conclusion for the real exchange rate of ruble and the main specification of the fiscal policy variable (i.e. central government deposits) which may be interpreted as that the third stochastic trend in the system is created by both the real exchange rate of ruble and the fiscal policy variable and that both of these two variables play the role of adjusting or pulling the whole process towards the long-run equilibrium. These possibilities were analyzed in detail by means of an exercise similar to the impulse responses. In case when the fiscal policy variable was presented by the budget deficits/surpluses to GDP ratio all selected determinants became weakly exogenous. Possible explanation is that the budget deficits/surpluses to GDP ratio behaves much more volatile than the central government's deposits that may blur the adjustment process of that variable to the long-run equilibrium or the *pulling feature* of that variable and pick out its *pushing feature*.

Thus, while we are sure about the structure of long-run influence of terms of trade and productivity differential in the sense of weak exogeneity property it is not a clear cut case for the fiscal policy variable.

Additional econometric procedures (moving average representation) indicate that two independent stochastic trends that are contained in the marginal process of the real exchange rate of ruble are generated by price of oil and labor productivity differential meaning that they are direct determinants of the real exchange rate. The nature of the third stochastic trend is not so obvious and depends on the indicator of fiscal policy variable used. *On average it is likely that both variables generate the third stochastic trend influencing each other bilaterally. However, the fiscal policy may be considered as an indirect determinant of the real exchange rate in the sense that it could change the equilibrium error by way of conducting sterilization policy in the periods of improved terms of trade and productivity and flooding the economy with money in the case of terms of trade deterioration and productivity decreases.*

In order to conduct a more detailed analysis of the real exchange rate dynamics a single equation error correction model was estimated, as proposed by Edwards, which accounted for information on changes in the selected long-run determinants and possible effects of excessively expansionary monetary policy, as well as the flows of private capital. The reaction on equilibrium error determined by the long-run determinants is very significant. Excessively expansionary monetary policy leads to the depreciation of the real exchange rate, while the private capital inflow in the previous quarter leads to the real appreciation of ruble. However, these variables are significant only at the 10% level. Finally, the results of estimation allowed us to determine the time of adjustment to equilibrium by more than 50% of an initial deviation (which is called a "half life" in the literature) for the real exchange rate of ruble by 2 quarters when for different countries, on average, this indicator ranges from 1 quarter to 3 years which indicates relatively quick reaction of the real exchange rate of ruble to the changes in fundamentals.

On the basis of the estimated reduced form equation for the real exchange rate of ruble a current misalignment indicator was calculated which measures the difference of an actual and equilibrium real exchange rate based on the selected fundamentals. The period before the end of 2000 is characterized by considerable positive and negative misalignments (i.e. before and immediately after the crisis of 1998, correspondingly), while for the period after the end of 2000 the real exchange of ruble was much closer aligned with the chosen fundamentals. The recent period of time is analyzed from quarter 1 of 2008 to quarter 1 of 2009 under the assumption of constant parameters. At the end of 2008 the deterioration of terms of trade and the fall in productivity differential has lead to a sharp overvaluation of the real exchange rate of ruble which was partly compensated by the central bank's decision to devalue the nominal exchange rate of ruble. According to the estimates, approximately a 15% positive misalignment is observed by the end of March 2009. Assuming that the price of oil and productivity stay at current levels, the correction of this misalignment will take place via a fiscal policy of injecting money in the economy and further tendency of real devaluation of ruble.

References

Balassa B. (1964) The Purchasing Power Parity Doctrine: A Reappraisal // Journal of Political Economy. Vol. 72. P. 584–596.

Dornbush R. (1974) Real and Monetary Aspects of the Effects of Exchange Rate Changes // National Monetary Policies and the International Financial System. University of Chicago Press, 1974.

Dornbusch R. (1976) Expectations and Exchange Rate Dynamics // Journal of Political Economy. Vol. 84. P. 1161–1176.

Edwards S. (1988) Real and Monetary Determinants of Real Exchange Rate Behavior // Journal of Development Economics. Vol. 29. P. 311–341.

Edwards S., Savastano M.A. (1999) Exchange Rates in Emerging Economies: What Do We Know? What Do We Need to Know? // NBER Working Paper. No. w7228.

Feyzioglu, Tarhan (1998) Estimating the Equilibrium Real Exchange Rate: An Application to Finland: WP/97/109, International Monetary Fund.

Hinkle L.E., Montiel P. (1999) Exchange Rate Misalignment: Concepts and Measurement for Developing Countries. Oxford University Press, 1999.

Johansen, Soren (1988) Statistical Analysis of Cointegration Vectors // Journal of Economic Dynamics and Control. No. 12. P. 231–254.

Johansen, Soren (1991) Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models // Econometrica. Vol. 52. P. 389–402.

Johansen, Soren and Katarina Juselius (1990) Maximum Likelihood Estimation and Inference on Cointegration – with Applications to the Demand for Money // Oxford Bulletin of Economics and Statistics. Vol. 52. P. 169–210.

Johansen, Soren (1996) Likelihood-Based Inference in Cointegrated Vector Autoregressive Models. Oxford University Press.

Juselius, Katarina (2007) The Cointegrated VAR Model, Methodology and Applications. Oxford University Press.

Paruolo P. (1997) Asymptotic inference on the moving average imapact matrix in cointegrated I(1) VAR systems // Econometric Theory No. 13. P. 79–118.

Rogoff K. (1996) The Purchasing Power Parity Puzzle // Journal of Economic Literature. Vol. 34. No. 2. P. 647–668.

Samuelson P. (1964) Theoretical Notes and Trade Problems // Review of Economic Statistics. Vol. 46. P. 145–154.

Sosunov K., Shumilov A., (2005) Estimation of equilibrium exchange rate of ruble," Jekonomicheskij Zhurnal VShJe. No. 2. P. 216–229.

Spatafora, Nikola, Stavrev, Emil (2003) The Equilibrium Real Exchange Rate in a Commodity Exporting Country: the Case of Russia: WP/03/93, International Monetary Fund.

Gurvich E., Sokolov, V., Ulukaev A. (2008) Estimation of the contribution of Balassa-Samuelson effect to the real exchange rate of ruble dynamics // Voprosy Jekonomiki. No. 7.

Additional References (Empirical Papers)

Alper C., Saglam I. (1999) The Equilibrium Real Exchange Rate: Evidence from Turkey // MPRA Paper No. 1924.

Buchs T. (2004) Equilibrium Real Exchange Rate in Brazil, Estimation and Policy Implications. Paper presented at the 9th meeting of the Latin American and Caribbean Economic Association (LACEA) in San José (Costa Rica) on November 4th, 2004.

Chobanov D., Sorsa, P. (2004) Competitiveness in Bulgaria: An Assessment of the Real Effective Exchange Rate: IMF Working Paper No. 04/37.

Chudik A., Mongardini J. (2007) In Search of Equilibrium: Estimating Equilibrium Real Exchange Rates in Sub-Saharan African Countries: IMF Working Paper No. 07/90.

Clark P., MacDonald R. (1998) Exchange Rates and Economic Fundamentals – A Methodological Comparison of BEERs and FEERs: IMF Working Paper No. 98/67.

Hasan M., Dridi J. The Impact of Oil-Related Income on the Equilibrium Real Exchange Rate in Syria: IMF Working Paper No. 08/196.

Iossifov, P., Loukoianova E. (2007) Estimation of a Behavioral Equilibrium Exchange Rate Model for Ghana: IMF Working Paper No. 07/155.

Koranchelian T. (2005) The Equilibrium Real Exchange Rate in a Commodity Exporting" Country: Algeria's Experience: IMF Working Paper No. 05/135.

MacDonald R., Ricci L. (2004) Estimation of the equilibrium real exchange rate for South Africa // *South African Journal of Economics*. Vol. 72. Issue 2. P. 282–304.

MacDonald, Ronald, (2001) Modelling the long-run real effective exchange rate of the New Zealand Dollar: DP2002/02, Reserve bank of New Zealand.

Mathisen J. (2003) Estimation of the Equilibrium Real Exchange Rate for Malawi: IMF Working Paper No. 03/104.

Mkenda, Beatrice Kalinda (2001) Long-run and Short-run Determinants of the Real Exchange Rate in Zambia: Working Papers in Economics no 40, Department of Economics, Göteborg University.

Mongardini J. (1998) Estimating Egypt's Equilibrium Real Exchange Rate: IMF Working Paper No. 98/5.

Paiva C. (2001) Competitiveness and the Equilibrium Exchange Rate in Costa Rica: IMF Working Paper No. 01/23.

Schnatz B., Vijsellaar F., Osbat C. (2004) Productivity and the Euro-Dollar exchange rate // *Review of World Economics*. Vol. 140. No. 1.

Sekkat K., Varoudakis A. (1998) Exchange-Rate Management and Manufactured Exports in Sub-Saharan Africa // Development Centre Technical Papers No. 134. Paris: OECD.

Zhang, Zhichao, (2001) Real Exchange Rate Misalignment in China: An Empirical Investigation // *Journal of Comparative Economics*. Vol. 29. P. 80–94.

Zouhar, Younes (2004) Competitiveness and the Equilibrium Real Exchange Rate in Morocco", Draft.

Sources of Statistical Data:

International Financial Statistics Database of International Monetary Fund, CD-ROM, March 2008, web address: http://www.imfstatistics.org/imf/

OECD MEI database, web address: http://stats.oecd.org/WBOS/index.aspx

Statistical data provided by the central bank of Russia, web address: http://www.cbr.ru

Statistical data provided by the Russia's Federal State Statistics Service, web address: http://www.gks.ru

Statistical data on oil prices "Urals" provided by Energy Information Administration (Official Energy Statistics from the U.S. Government), web address: http://tonto.eia.doe.gov/dnav/pet/pet_pri_wco_k_w.htm

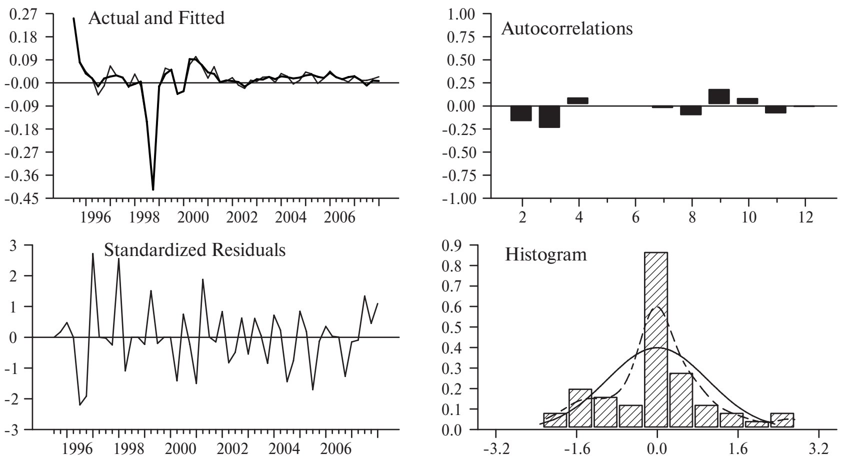
Statistical data provided by Reuters.

Econometric Software:

CATS in RA*TS* Version 2 by Estima.

Econometric Views Version 5.1

Appendix



Terms

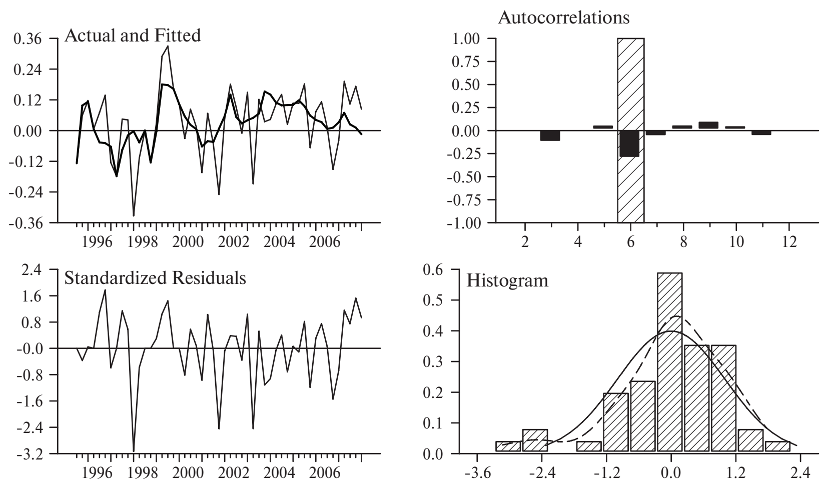
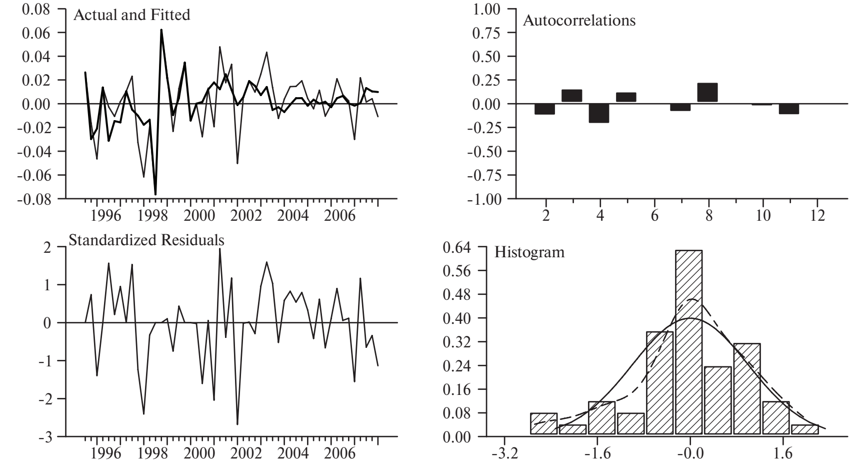
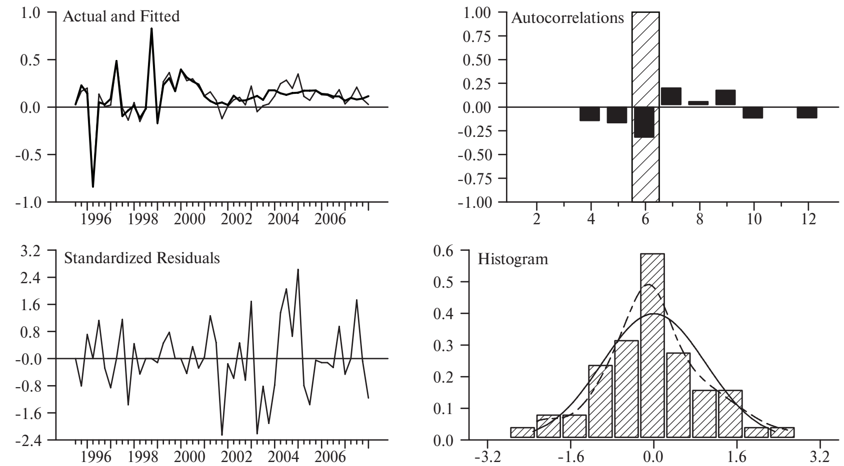


Figure A1. Graphs , histograms and correlograms of residuals for estimated model (3)

PD



Fiscal



Forwards recursive tests, base sub-sample 1995:1-2003:4

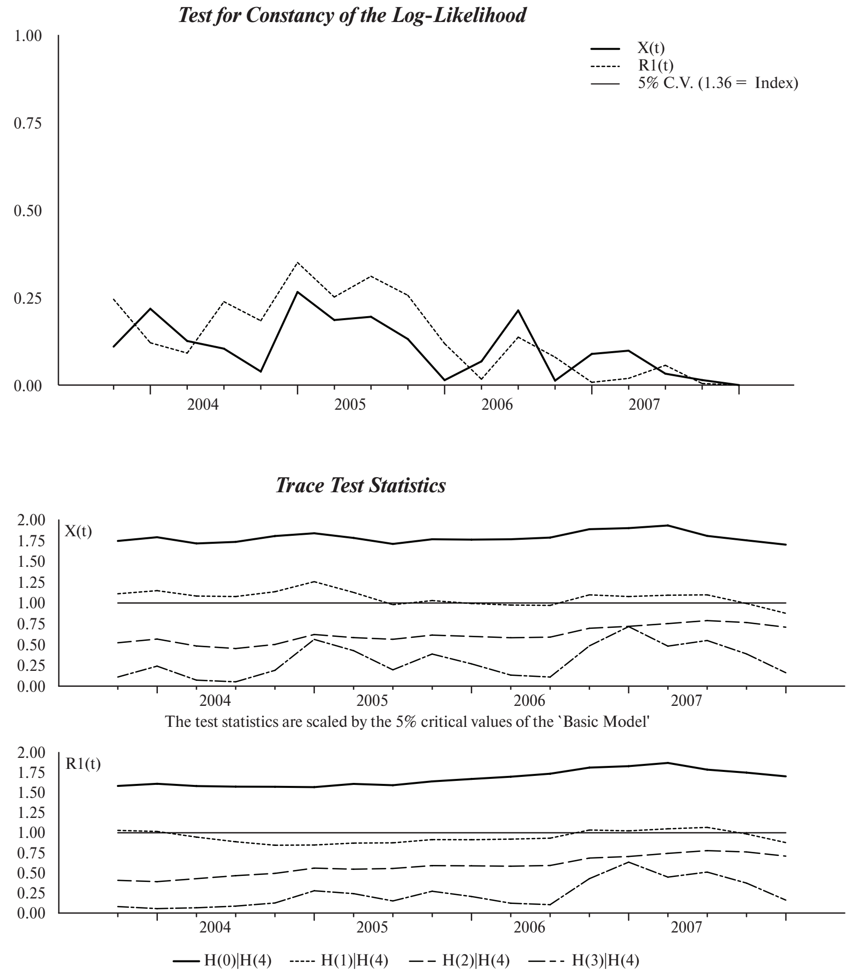
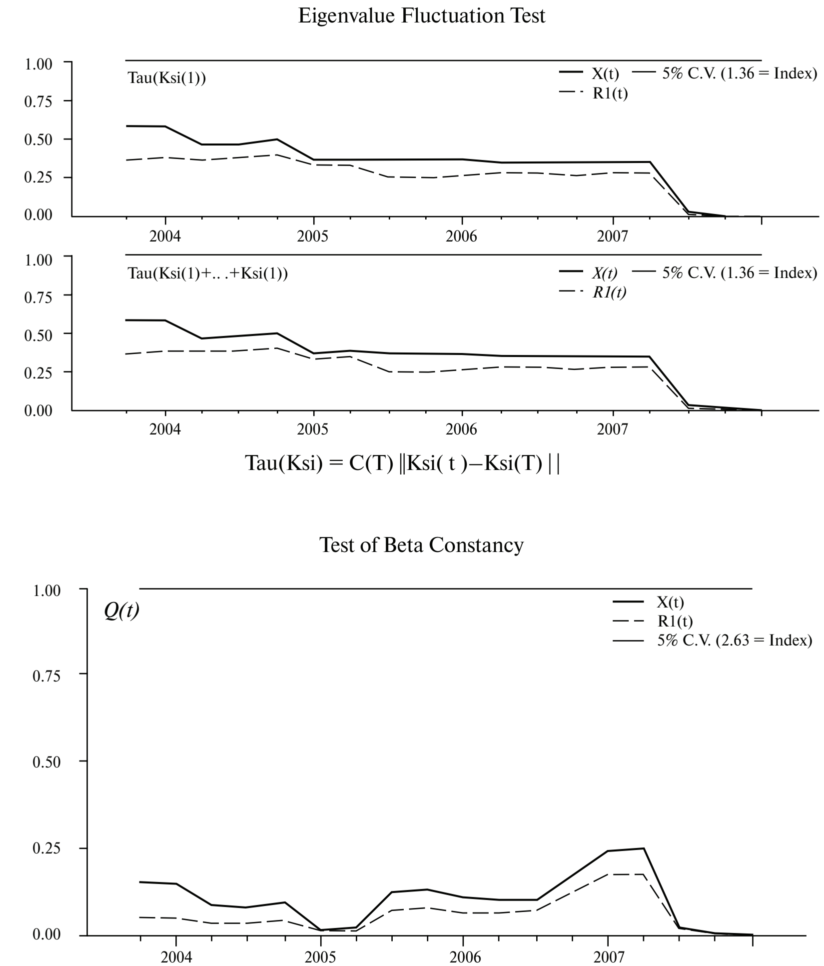


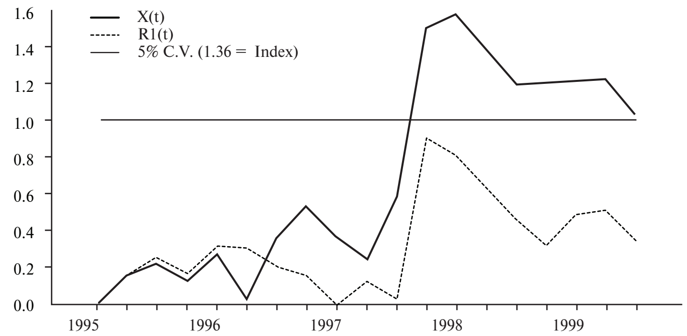
Figure A2. Graphs of recursive tests on parameter constancy of model (3)

In all presented below tests rejection of hypothesis of constancy means a crossing of horizontal line on the level of 1 (corresponds 95% quintile of distribution). All test statistics are presented for “cleaned” short-run effects (R-model) and a “full” model encompassing short-run effects (X-model).

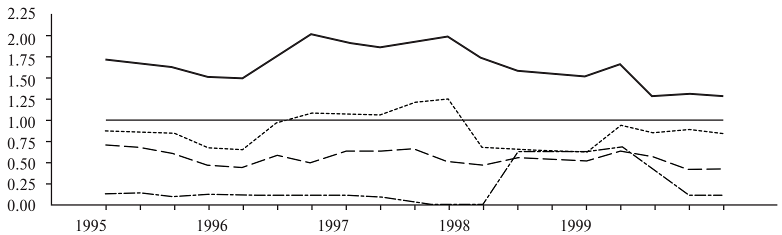


Backwards recursive tests, base sub-sample 2000:1-2008:1

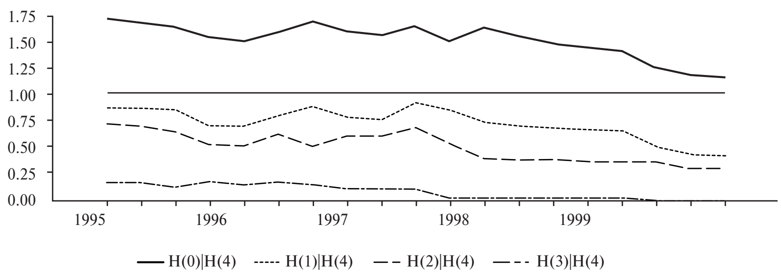
Test for Constancy of the Log-Likelihood



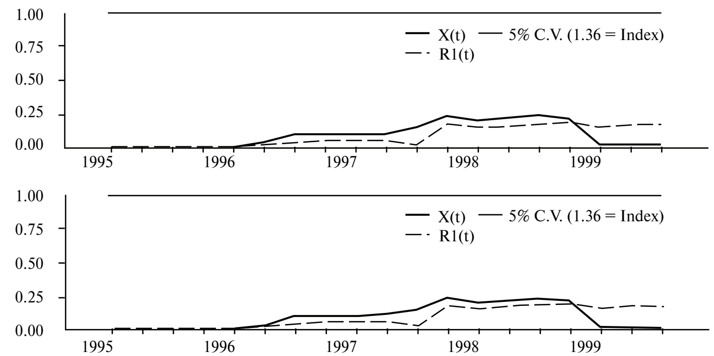
Trace Test Statistics



The test statistics are scaled by the 5% critical values of the `Basic Model'



Eigenvalue Fluctuation Test



Tau(Ksi) = C(T) ‖Ksi(t)−Ksi(T) | |

Test of Beta Constancy

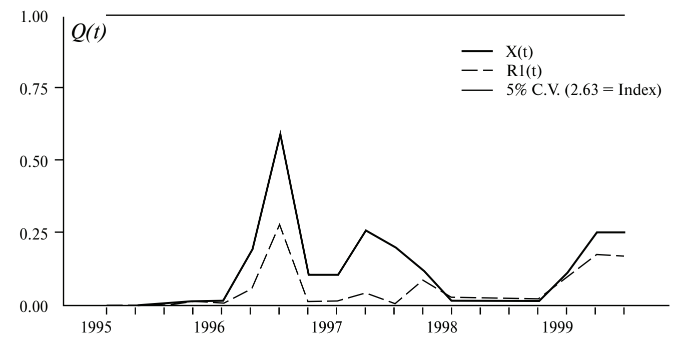


*Table A. Em*pirical papers on estimation of equilibrium real exchange rates for different countries

Authors, country, period	Real exchange rate	Terms of trade, coefficient	Productivity differential, coefficient	Other determinants	Adjustment coefficient	A half life (in years)
Feyzioglu, 1997(IMF), ***Finland***, 1975q1-1995q2, 82 obs.	CPI based REER (IFS)	Price of exports relative to price of imports [**0.37**]	Productivity in manufacturing sector (Finland w.r.t. trading partners) [**0.85**]	long-term Germany real interest rate (CPI deflated), shift dummy (drop of trade with the USSR), devaluations blip dummies, price differential (Finland w.r.t trade partners), deviations from uncovered interest parity	**-0.11**	**1.5 years**
Alper, Saglam, 1999, ***Turkey***, 1987q1-1999q1, 49 obs.	WPI(US)*S/ CPI(Turkey) and alternatives	Price of exports relative to price of imports [**-0.91**]	The growth of real GDP [-]	Openness indictor, long-term US real interest rate (CPI deflated), capital inflow variable, shift dummy (trade liberalization), blip dummies (domestic financial crisis)	**-0.39**	**0.4 years**
Spatafora, Stavrev, 2003 (IMF), ***Russia***, 1995q1-2002q3, 31 obs.	CPI based REER (IFS)	World price of Russian Urals oil [**0.31**]	Industrial labor productivity in Russia w.r.t trading partners [**1.3**]	Shift dummy (crisis 1998), growth of reserves over monthly imports, growth of broad money over GDP, growth of fiscal deficits over lagged high powered money	**-0.49**	**0.3 years**
Sosunov, Shumilov, 2005, ***Russia***, 1995q1-2003q4, 36 obs.	CPI based REER (IFS)	World price of Russian Urals oil [**0.64**]	The difference between real GDP and real export (1995=100) [**-2.99**]	Net outflow of private capital to GDP, the growth of reserves over quarterly import, growth of M2 over GDP in a previous quarter, growth of budget deficit over reserve money (high powered money) in a previous quarter	**-0.3** and **-0.25** (for alternative specifications)	**0.5 years (0.6 years)**
Gurvich, Sokolov, Ulukaev, 2008, ***Russia***, 1999m1-2007m1, 96 obs.	Nominal exchange of euro*CPI (Germany)/ CPI (Russia)	World price of Russian Urals oil divided by PPI of OECD [**-0.16** and **-0.24** for alternative specifications]	Industrial labor productivity in Russia w.r.t Germany [**-1.7** and **-0.93** for alternative specifications]	-	-	-
MacDonald, 2001, ***New Zealand***, 1985q4-2000q1, 58 obs.	REER	Price of exports relative to price of imports [**1.85 and 1.4 DOLS**]	Labor productivity index for New Zealand w.r.t. trading partners [-]	Net foreign assets to GDP, difference of output gap in NZ w.r.t trading partners, NZ long-term real interest rate w.r.t. the trade-weighted real foreign long term interest rate	**-0.18**	**0.9 years**
Iossifov,Loukoianova, 2007 (IMF), ***Ghana***, 1984q1-2006q1, 89 obs.	CPI based REER (IFS)	Index of main export commodities (cocao beans, gold, timber) to G7 countries exports deflator [**0.35**]	Per capita GDP in PPP U.S. dollars relative to trading partners [**4.68**]	Difference of real interest rate w.r.t to trading partners, openness indicator, fiscal balance to GDP, NFA to GDP	**-0.14**	**1.1 years**
MacDonald, Ricci, 2004 (IMF), ***South Africa***, 1970q1-2000q1, 121 obs.	REER	Real commodity prices—choosing the more general one, based on 5 commodities (gold, coal, iron, copper, platinum) and deflated by the industrial countries export deflator [**0.46**]	Real GDP per capita w.r.t. trading partners [**0.14**]	Real interest rate w.r.t. trading partners, openness indicator, fiscal balance to GDP, NFA to GDP	**-0.08**	**2.1 years**

Table A

Authors, country, period	**Real exchange rate**	**Terms of trade, coefficient**	**Productivity differential, coefficient**	**Other determinants**	**Adjustment coefficient**	**A half life (in years)**
Schnatz, Vijselaar, Osbat, 2004 (ECB), ***USA w.r.t. euro area***, 1985q1 — 2001q4, 68 obs.	Inverse of the nominal exchange rate of euro weighted currency (per US dollar), multiplied by the ratio of euro area to US consumer prices.	Real price of oil: IFS spot price index (line 00176AADZF) divided by the US wholesale price index (IFS line 63) [**-0.31** and **-0.26** for relative price ratio as productivity differential]	GDP per person employed for the euro area w.r.t. non-farm business sector output per hour worked for the United States and additional 2 alternatives of productivity differentials [**1.87**], Relative euro are effective price ratio (Consumer prices divided by wholesale or producer prices) w.r.t. Relative US price ratio (Consumer prices divided by wholesale or producer prices. For consumer prices, IFS (line 64). For producer prices, IFS (line 63).) [**1.46**]	Shift dummy (introduction of the euro), US Government spending to GDP at current prices w.r.t., real euro effective long-term interest rate w.r.t. real US long-term interest rate (computed as nominal interest rate [IFS (line 61)] minus the annual rate of consumer price inflation of the previous year).	**-0.31** and **-0.55** for relative price ratio as productivity differential	**0.5 years (0.2 years)**
Chobanov , Sorsa, 2004 (IMF), ***Bulgaria***, 1997q3 — 2003q1, 23 obs	CPI based REER	Bulgarian export prices devided by import prices of trading partners (Germany, Italy, Greece, and Russia representing about 50 percent of Bulgarian foreign trade in the post-CBA period. For the first three very open economies these are PPI indexes, which should closely approximate export prices. For Russia it is the Ural oil price index) [**3.99**]	Real GDP in 1995 prices divided by the number of employees [**1.3**]	Gross savings (gross savings are obtained from nominal GDP. Gross Savings = National Disposable Income – Consumption Expenditures), an index of quarterly average three-month LIBOR rates for the U.S. dollars deflated by the index of quarterly inflation in the United States, index of foreign direct investment denominated in U.S. dollars with 1997 as a base year.	**-0.245**	**0.6 years**
Mathisen, 2003 (IMF), ***Malawi***, 1980q2 — 2002q2, 89 obs.	CPI based REER (IFS)	Price of exports relative to price of imports [**0.18**]	Real GDP per capita [**4.32**]	Government consumption excl. salaries/wages to GDP, government salaries/wages to GDP (cons. of tradables), investment to GDP, changes in NFA minus changes in the trade balance to GDP, domestic credit to nominal GDP, 10000 minus nominal government balance as a share of high powered money	**-0.27** and **-0.20** for alternative specifications	**0.6 years (0.8 years)**
Zhang, 2001, ***China***, 1952y — 1997y, 46 obs.	WPI(US)*S/retail price index(China)	Growth of export [**-3.38**]	Index of real gross fixed capital formation (1952=100) [**0.37**]	Openness indicator, index of real government consumption (1950=100)	**-0.15**	**4.3 years**

Table A

Authors, country, period	Real exchange rate	Terms of trade, coefficient	Productivity differential, coefficient	Other determinants	Adjustment coefficient	A half life (in years)
Zouhar, 2004, ***Morocco***, 1969y — 2003y, 35 obs.	CPI based REER	Price of exports relative to price of imports [**0.24**]	Non-agricultural real GDP per capita w.r.t. trading partners [**1.46**]	Net private capital flows to GDP, net foreign liabilities to GDP, openness indicator, investment to GDP, gov. consumption to GDP, value added of the agricultural sector, difference between domestic credit growth and real GDP growth, fiscal balance as to GDP, fiscal financing requirements to GDP, NEER	**-0.19**	**3.3 years**
Paiva, 2001 (IMF), ***Costa Rica***, 1970y-1999y, 30 obs.	CPI based REER (IFS)	An index of international terms of trade [**0.75**]	via a trend	Central government current expenditures to GDP, openness indicator, net foreign direct investment to GDP, time trend, shift dummy (1991 national account revisions)	**-0.41**	**1.3 years**
Mkenda, 2001, ***Zambia***, 1965y — 1996y, 32 obs.	Export real exchange rate, import real exchange rate, internal real exchange rate (see definitions in the article)	Real dollar price of copper/real price of imports [**0.32**;**0.70**;**0.47**]	The growth rate of real GDP [-]	Real government consumption to real GDP, real gross fixed capital formation to real GDP, real central bank reserves to real GDP, openness indicator, trade taxes to GDP, real money supply, period average official nominal exchange rate, aid flows to GDP, shift dummy (1988)	**-0.38**;**-0 .79**;**-0.80**	**1.4 years; 0.4 years; 0.4 years**
Clark, MacDonald. 1998 (IMF), ***USA***, ***Germany***, ***Japan***, 1960y-1996y, 37 obs.	CPI based REER w.r.t. G7 trading partners	Domestic export unit value to the import unit value w.r.t. to equivalent effective foreign ratio using G7 trading partners [US dollar **0.084**] [German mark **0.062**, but insignificant] [Japanese jen **0.22**]	Domestic CPI to domestic PPI (or wholesale index) w.r.t. equivalent foreign effective ratio [USA **2.70**] [German mark **5.22**] [Japanese jen **1.88**]	Net foreign assets to GNP, domestic government net financial liabilities to nominal GDP w.r.t. equivalent effective ratio of G7 trading partners, differential of average annual domestic long-term (10 year) government bond yield minus change in CPI from the previous year w.r.t. equivalent G7 trading partners effective real interest rate.	US dollar **-0.37**, German mark insignificant, Japanese jen insignificant	for US dollar **1.5 years**
Koranchelian, 2005 (IMF), ***Algeria***, 1970y — 2003y, 34 obs.	REER using INS data (2001=100)	Real price of oil calculated, as in Cashin et al. (2002), by deflating the U.K. Brent spot price index by the manufactured exports unit price index for developed countries (2001=100) [**0.24**]	Real GDP per capita relative to trading partners [**1.88**]	-	**-0.6**	**0.8 years**

Table A

Authors, country, period	Real exchange rate	Terms of trade, coefficient	Productivity differential, coefficient	Other determinants	Adjustment coefficient	A half life (in years)
Hasan, Dridi, 2008 (IMF), ***Syria***, 1963y — 2005y, 43 obs.	CPI based REER	Net oil exports to GDP (using oil prices would not be appropriate in the case of Syria due to the substantial change in the level of production between 1960 and 2005, and the move from importer to exporter) [**0.38** and **0.3** for alternative specification]	Syria's per capita real GDP by the weighted trade partners' per capita real GDP [**0.38** and **1.14**, **1.44** for alternative specifications]	Government expenditures to GDP, openness indicator, NFA to GDP	**-0.18**	**3.5 years**
Chudik and Joannes Mongardini, 2007 (IMF), ***Tanzania***, 1970y — 2005y, panel study	Real Effective Exchange Rate	Ratio of Export and Import deflators. Source: WEO [**0.19**]	Real gross domestic product relative to weighted average of trading partners. Source: WEO [**1.05**]	Government consumption as a share of GDP, Investments to GDP, NFA to GDP, total debt service to exports	-	-
Buchs, 2004, ***Brazil***, 1994m7-2003m11, 113 obs.	CPI based REER (IFS)	Weighted average of Brazil's top five commodity export nominal prices (i.e. Sugar, Soy, Iron, Coffee and Tobacco) deflated either by a trade-weighted price index for the exports from a group of industrialized countries (Germany, Korea, Japan, the UK and the US), or by the US CPI index [**0.21** and **0.27** for alternative specifications]	CPI/PPI of Brasil w.r.t.CPI/PPI of trading partners [**0.2** and **0.32** for alternative specifications]	Government investment spending to GDP (proxy for tradables), total government spending minus investment and debt service spending to GDP (proxy for non-tradables) , openness indicator, difference of real overnight interest rate in Brasil and real 90 day US T-bill rate, shift dummy (1999 devaluation)	**-0.14** and **-0.23** (for alternative specifications)	**0.4 years (0.2 years)**
Mongardini, 1998 IFS, ***Egypt***, 1987m2 — 1996m12, 118 obs.	CPI based REER (IFS)	Price of exports (mainly oil and cotton)) relative to price of imports (mainly wheat) [**1.26**]	Total factor productivity from Bisat et al (1997) [**1.81**]	Government consumption to GDP, capital account balance to GDP, shift dummy (Gulf War), debt service ratio	-	-
Edwards, 1988, ***Colombia, El Salvador, Brazil, Greece, Israel, Malaysia, India, Philippines, Sri Lanka, Thailand, South Africa, Yugoslavia***, 1960y — 1985y, panel study	WPI(US)*S/ CPI(selected developing country)	Price of exports relative to price of imports [**negative**]	Growth rate of real GDP [**positive**]	Government consumption on non-tradables to GDP, investment to GDP, capital flows, openness indicator, rate of growth of domestic credit minus the lagged rate of growth of real GDP, rate of growth of domestic credit, fiscal deficit to lagged high powered money, nominal devaluations, parallel black market premium	-	**very slow**
Rogoff, 1996, consensus estimates of ppp half lives	-	-	-	-	-	**very slow: from 3 to 5 years**

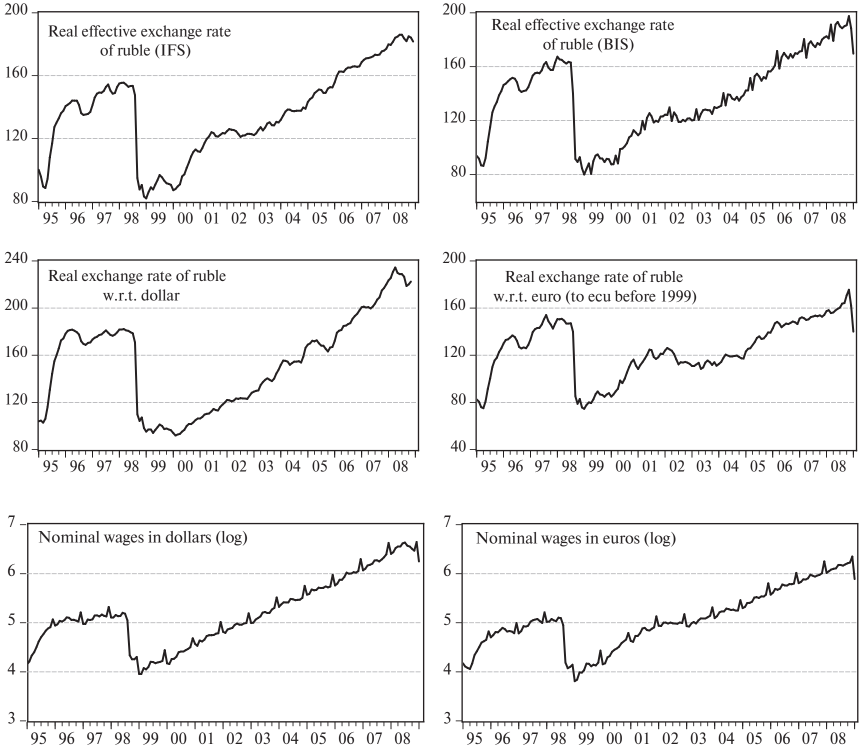


Figure A3. External real exchange rate indicators (External RER)

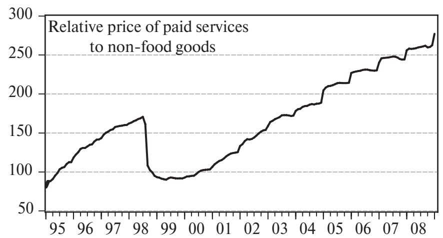


Figure A4. Internal real exchange rate indicator (Internal RER)

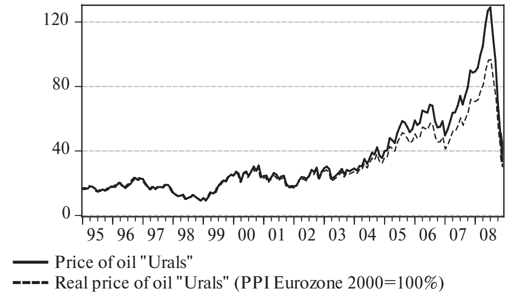


Figure A5. Terms of trade indicators

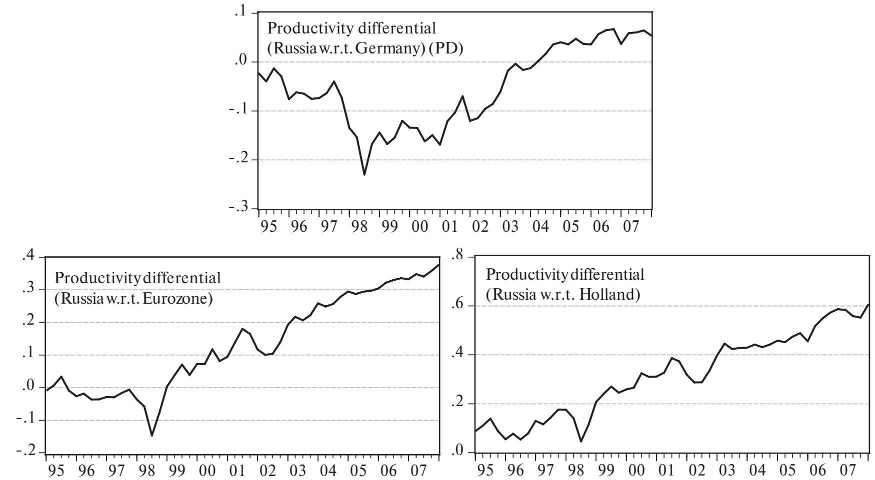


Figure A6. Productivity differential indicators

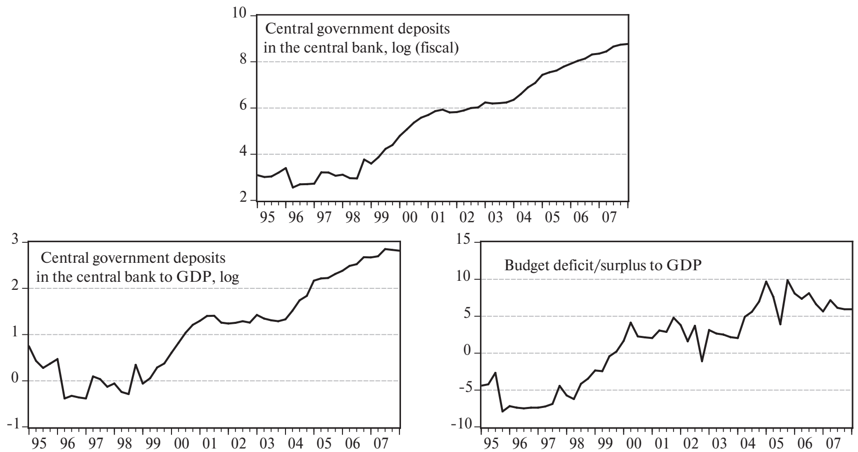


Figure A7. Fiscal policy indicators

Output A1. Analysis of the model with a linear trend in the cointegration relation (CIDRIFT).

Johansen's test

p-r	r	Eig. Value	Trace	Trace*	Frac95	P-Value	P-Value*
4	0	0.665	83.071	72.033	63.659	0.000	0.008
3	1	0.260	27.238	21.536	42.770	0.670	0.921
2	2	0.198	11.898	9.721	25.731	0.817	0.929
1	3	0.012	0.629	0.558	12.448	0.999	0.999

BETA(transposed)

	REER	TERMS	PD	FISCAL	TREND
Beta(1)	1.000	-0.247	-1.242	0.080	-0.005
	(.NA)	(-4.354)	(-5.559)	(1.920)	(-0.913)

ALPHA

	Alpha(1)
DREER	-0.209
	(-7.984)
DTERMS	-0.281
	(-1.393)
DPD	0.027
	(0.787)
DFISCA	-0.758
	(-5.761)

TEST OF EXCLUSION

LR-test, Chi-Square(r), P-values in brackets.

r	DGF	5%C.V.	REER	TERMS	PD	FISCAL	TREND
1	1	3.841	39.827	10.515	11.199	3.469	0.796
			[0.000]	[0.001]	[0.001]	[0.063]	[0.372]
2	2	5.991	43.851	13.401	15.116	4.047	0.937
			[0.000]	[0.001]	[0.001]	[0.132]	[0.626]
3	3	7.815	53.059	21.123	23.500	4.048	1.891
			[0.000]	[0.000]	[0.000]	[0.256]	[0.595]

Output A2. Imposing a weak exogeneity restriction on the base model (3)

TEST OF RESTRICTED MODEL: CHISQR(2) = 2.419 [p-value=0.298]

BETA(transposed)

		TERMS	PD	FISCAL
Beta(1)	1.000	-0.268	-1.169	0.049
	(.NA)	(-4.867)	(-5.557)	(4.025)

ALPHA

	Alpha(1)
DREER	-0.210
	(-7.993)
DTERMS	0.000
	(0.000)
DPD	0.000
	(0.000)
DFISCA	-0.673
	(-4.801)

Output A3. Long-run parameters (alpha and beta) and long-run impact matrices for the model with alternative indicators of fiscal policy variable

Model with deficit/surplus to GDP ratio as a fiscal variable indicator

BETA(transposed)

	REER	TERMS	PD	FISCAL2
Beta(1)	1.000	-0.216	-1.200	0.015
	(.NA)	(-5.070)	(-6.072)	(4.936)

ALPHA

	Alpha(1)
DREER	-0.248
	(-9.040)
DTERMS	-0.339
	(-1.631)
DPD	0.001
	(0.023)
DFISCA	-3.446
	(-1.185)

Residual	**standard**	**errors**	
DREER	DTERMS	DPD	DFISCAL2
0.015	0.104	0.019	1.575

TEST OF WEAK EXOGENEITY

LR-Test,Chi-Square(r),P-values in brackets.

r	DGF	5%C.V.	REER	TERMS	PD	FISCAL2
1	1	3.841	37.362	2.257	0.000	1.347
			[0.000]	[0.133]	[0.983]	[0.246]
2	2	5.991	45.450	6.469	4.267	1.918
			[0.000]	[0.039]	[0.118]	[0.383]
3	3	7.815	49.391	12.255	10.069	3.308
			[0.000]	[0.007]	[0.018]	[0.346]

The Long-Run Impact Matrix, C

	$\Sigma\varepsilon_{REER}$	$\Sigma\varepsilon_{TERMS}$	$\Sigma\varepsilon_{PD}$	$\Sigma\varepsilon_{FISCAL2}$
REER	-0.180	**0.306**	**1.653**	**-0.017**
	(-0.363)	(1.891)	(1.909)	(-2.038)
TERMS	-1.628	1.567	2.733	-0.037
	(-0.902)	(2.661)	(0.868)	(-1.224)
PD	-0.026	0.027	1.099	-0.000
	(-0.133)	(0.415)	(3.161)	(-0.145)
FISCAL2- **13.311**	**4.262**	16.788	0.541	
	(-1.389)	(1.362)	(1.004)	(3.403)

Model with the central government's deposits to GDP ratio as a fiscal variable indicator

BETA(transposed)

	REER	TERMS	PD	FISCAL3
Beta(1)	1.000	-0.253	-1.307	0.094
	(.NA)	(-4.244)	(-6.001)	(3.520)

ALPHA

	Alpha(1)
DREER	-0.208
	(-8.261)
DTERMS	-0.260
	(-1.381)
DPD	0.013
	(0.411)
DFISCA	-0.600
	(-4.916)

Residual standard errors

DREER	DTERMS	DPD	DFISCAL3
0.016	0.104	0.018	0.074

TEST OF WEAK EXOGENEITY

LR-Test, Chi-Square(r), P-values in brackets.

r	DGF	5% C.V.	REER	TERMS	PD	FISCAL3
1	1	3.841	37.921	1.592	0.151	18.870
			[0.000]	[0.207]	[0.697]	[0.000]
2	2	5.991	39.225	6.364	2.114	18.973
			[0.000]	[0.042]	[0.348]	[0.000]
3	3	7.815	42.449	11.355	6.501	19.832
			[0.000]	[0.010]	[0.090]	[0.000]

The Long-Run Impact Matrix, C

	$\Sigma\varepsilon_{REER}$	$\Sigma\varepsilon_{TERMS}$	$\Sigma\varepsilon_{PD}$	$\Sigma\varepsilon_{FISCAL3}$
REER	-0.113	**0.329**	**1.544**	**-0.069**
	(-0.266)	(2.121)	(2.072)	(-1.582)
TERMS	-1.290	1.483	1.621	-0.158
	(-0.863)	(2.730)	(0.621)	(-1.036)
PD	-0.074	0.066	1.205	0.024
	(-0.339)	(0.829)	(3.169)	(1.071)
FISCAL3	**-3.290**	**1.402**	4.677	0.639
	(-1.751)	(2.053)	(1.426)	(3.329)

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Типография Государственного университета – Высшей школы экономики
125319, Москва, Кочновский проезд, 3
Тел.: (495) 772-95-71; 772-95-73

Notes