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Abstract

The paper investigates whether the 80% real appreciation of the Russian ruble in 1998-2005 can be explained by the increase in oil revenues in a calibrated general equilibrium model. It is shown that the oil prices alone cannot account for the appreciation with forward-looking permanent-income consumers, unless the oil price increase is assumed permanent. Accounting for the increase in the volume of oil exports, however, can help, provided that the increase is assumed to be permanent.

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Keywords: Real exchange rate; Commodity prices

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1 Introduction

In August 1998, the Russian currency, the ruble, suffered a double real devaluation following several years of a crawling peg policy. After that, as the economy recovered, the currency appreciated back significantly, by more than 80%. This appreciation has caused a great deal of concern in the Russian public debate - after all, the previous real appreciation of such magnitude was observed in 1995-1998 and culminated in a disastrous financial crisis. There is no consensus for why the currency has been appreciating back (or for that matter, why it fell in 1998). The biggest question, perhaps, is whether the observed increase in the value of the ruble is an equilibrium phenomenon and accords with the fundamentals, or whether this appreciation is unjustified.

An important factor, which could be the driving force behind both the fall of the currency in 1998 and its further recovery, is the international price of oil, Russia's primary export. Thus, aside from many intrinsic problems connected to bad macroeconomic policy (Kharas, Pinto and Ulatov 2001), Russia was hit in 1998 by a large terms of trade shock, as the price of a barrel of oil fell to a single-digit level in the spring of 1998. Consequently, in 2000s, oil price grew to unprecedented hights in nominal dollar terms.

In this paper, we concentrate our attention on the appreciation of 1998-2005, and investigate the hypothesis that this appreciation was driven by oil prices, i.e., by fundamentals. To accomplish this, we build a calibrated model of the Russian economy and subject this model economy to a series of persistent oil price shocks similar to those observed in the data. The objective is to compare the simulated appreciation to the observed one, and thus understand whether this increase in the value of the ruble is consistent with the oil price growth, or whether other factors (perhaps psychological, political, etc.) had to play a role.

Although we do not analyze in as much detail the appreciation of the ruble before the crisis, in the period 1995-1998, our model sheds some light on that episode as well. The most immediate hypothesis for the appreciation observed in that period has to do with the crawling peg policy, adopted by the Russian monetary authorities in 1995. Such policy is commonly accompanied by real appreciation, believed by many to be associated with some sort of out-of-equilibrium processes, such as inflation inertia due to adaptive expectations or lack of credibility (Calvo and Vegh 1999). If this is true, then following the devaluation of 1998, when the currency was allowed to float, the exchange rate should have returned back to its equilibrium value. Hence, we study whether further appreciation could be explained by fundamentals in absence of a rigid fixed exchange rate regime.

Good understanding of the nature of the appreciation is important for several reasons. On the basic level, it is important to know whether the Russian ruble is overvalued. Not only did the previous appreciation result in a devastating financial crisis, but international evidence suggests that rapid appreciations overall tend to end with abrupt reversions of the exchange rates back to a low level (Goldfajn and Valdes 1999). Therefore, it is not surprising that many policymakers and independent observers in Russia express concern over the current growth of the real value of the ruble.

If the appreciation can be explained by the oil price, on the other hand, then the threat of a rapid devaluation is not as big. Of course, the ruble can still fall in case oil prices fall, and the lesson to policy makers should be that trying to defend the current level of the exchange rate under such circumstances would be a mistake.[1] If oil prices stay high, however, then policy-makers face the threat of the Dutch disease, which could hamper long-run growth. Evidence of Dutch disease is scant, but can be found, for example, in Sachs and Warner (2000).

Our findings are that it is hard to explain all of the appreciation by oil prices alone, if the change of oil price is taken to be temporary and households consume out of permanent income. However, if one takes into account the large increase in the volume of oil exports that took place during the same period of time, then the observed appreciation becomes consistent with the one predicted in the model. Alternatively, one can assume rule-of-thumb behavior of consumers or a permanent nature of the oil price increase, which can generate an appreciation of the ruble of the observed magnitude with oil price alone. This finding suggests that the appreciation observed in the data is probably an equilibrium phenomenon, and is largely immune to a possible fall in the oil prices, since much of this appreciation may have been caused by increase in volume, not price, of exports.

The rest of the paper is organized as follows. Section 2 describes the most commonly cited explanations for the appreciation of the ruble. Sections 3 and 4 then build a simple two-sector model of the Russian economy. Section 5 compares the exchange rate simulated in the model subjected to a series of oil export price and volume shocks with the exchange rate reported in the official statistics. Section 6 concludes.

2 Brief overview

Here we briefly discuss all possible factors, which could lead to the observed real appreciation of the Russian ruble. In general, there could be several reasons for this appreciation. The three fundamental reasons could be the increase in the oil export revenues, which we study, the Balassa-Samuelson effect, and inflow of capital. Two more reasons are non-fundamental: state-controlled prices of non-tradables and initial under-valuation due to risk factors.

In this paper we concentrate on the first fundamental reason, the oil revenues, in order to see whether that factor alone could account for the observed appreciation. The intuition is simple. The unexpected inflow of "petrodollars" into the economy gives the ability for the consumers to purchase more imported goods. The income effect raises demand for all types of goods, including domestic ones. Since import prices are exogenously given by the world markets, only domestic good prices increase and the domestic currency appreciates.

A natural alternative explanation to consider is the classic Balassa-Samuelson effect. Statistics

[1] This mistake is typical and was made by many countries in 1997-1998, not only Russia. New Zealand and Chile are famous examples, while Australia is believed to be a good counter-example, as a country that did not try to defend its currency following a terms of trade shock in 1997. See, for example, Jonas and Mishkin (2005) for discussion.

show that productivity increase in Russia has been substantial since 1998, which could in principle lead to real appreciation. Thus, simple estimation of GDP divided by employment gives an estimate of labor productivity growth by 42% between 1998 and 2004.[2] This effect needs to be studied carefully, of course, but we do not consider it very seriously here for at least two reasons. First, for the Balassa-Samuelson effect to take place, the increase in productivity needs to be in the tradable goods sector, which is substitutable with imports. However, most of the goods produced by the Russian economy seem to be complements, not substitutes of the imported goods. Besides, the productivity growth differential does not seem to be big at the first glance. According to our estimates from Rosstat data, labor productivity grew 49% between 1999 and 2005 in manufacturing, which includes the raw material exporting sectors. A much bigger productivity growth occurred in construction (73%), which is a non-tradable sector, while non-tradable services, such as transportation and communication, had labor productivity increases of about 41%. In retail and restaurants, productivity indeed grew much less, by about 23%. Although this decomposition is not strictly the same as tradable/nontradable production, and looks at gross output rather than value-added, these figures make us doubt that Balassa-Samuelson effect is a promising path for explanation of the real appreciation. The second reason for such doubts is that the evidence in favor of Balassa-Samuelson effect overall seems thin (see, for example, Edwards and Savastano (1999) for a survey), while the effect of oil prices is much less questionable.

An increase in oil prices and production can be thought of as very analogous to Balassa-Samuelson effect, however. An increase in oil prices means that relative productivity (at new relative prices) has risen in this tradable sector, which pushes up wages and prices in other sectors of the economy.

Capital flows could be another reason for the appreciation, as the government authorities frequently mention reversal of the capital flight from Russia. However, the balance of payment figures of the Central Bank continue to show huge current account surpluses, which are probably to a large extent endogenous to the high oil prices: in order to smooth consumption and insure themselves against risks, agents prefer to keep the windfall oil revenues abroad. Thus, in order to asses the effects of exogenous flows, one needs to extract that exogenous component, perhaps, by defining it as flows unexplained by consumption smoothing.

The fourth reason, often cited in the public debate, is non-fundamental: the Russian government controls prices of a large share of non-tradable intermediate goods, supplied by the "natural monopolies": electricity, railroads, and gas. It is easy to see that these tariffs are highly correlated with the real exchange rate. This high correlation is not surprising, since the prices of non-tradables and the real exchange rate are two ways of thinking about the same thing. However, this observation does not mean that the real exchange rate is controlled by government rather than market forces: what we examine in this paper is whether the appreciation, which included inflation within the state-controlled prices, accorded to the fundamentals. Thus, we believe that the growth in

[2] These and further numbers are taken from the "Russia in Figures" statistics published by the Federal State Statistics Service, also known as Rosstat, www.gks.ru.

state-controlled prices is not the *cause* of appreciation, but is appreciation *itself.*

Finally, there is a fifth potential reason, also non-fundamental. The crisis in August of 1998 was followed by a period of extreme uncertainty, which could have lead to an undervalued currency immediately after the crisis. In other words, devaluation could lead to an under-shooting of the exchange rate in the fall of 1998. As the markets calmed down, the exchange rate might have returned back to its equilibrium value.

Here, we concentrate on the first reason, connected to the oil export revenues, in an attempt to determine whether this reason alone could explain the 80% appreciation over the period in question.

3 The Baseline Model Economy

We assume that the Russian economy can be approximated by a two-sector model, in which the nontradable sector produces a composite good, which can only be consumed domestically. The tradable sector is simply an endowment of exportable natural resources (”oil”). The revenue from oil sales can be exchanged for imported goods, which are imperfectly substitutable with the domestic goods, or invested in international bonds (given the importance of capital flows, we assume the capital markets to be perfectly open).

This set-up does not include a tradable goods sector, which means that the Balassa-Samuelson effect is impossible to introduce, unless the resource extraction is itself regarded as the tradable sector, and the growth in export volume – as increase in productivity. Nevertheless, we take such a simple economy as a close approximation of the reality. Even the final goods, which seem tradable, are rarely actually traded, and about 85% of all Russian exports are raw materials. Thus, the vision of domestically produced manufactured goods and services being complements to imports rather than substitutes seems to us to be a better description of the reality.

3.1 The set-up

The consumer problem is to maximize the present value of utility with respect to the two types of goods and labor supplied to the nontradable sector:

$$\max_{C_t^D, C_t^M, L_t} \sum_{t=0}^{\infty} (1+\theta)^{-t} \left[\log C_t - \frac{L_t^{1+s}}{1+s} \right],$$

where $C_t \equiv \left[a(C_t^D)^\beta + (1-a)(C_t^M)^\beta \right]^{1/\beta}$ is a CES aggregate of consumption of the domestic good C_t^D and of the imported good C_t^M, and L is labor supply. The discount rate θ is restricted to equal the world interest rate r.

Producers operate in competitive environment. Domestic goods are produced with a single factor (labor) subject to a production function of the form $Y_t^D = L_t^\gamma$. Exported goods are not consumed but can be exchanged for imported good in the world market at the exogenous price P_t (terms of trade). We assume that each period an endowment X_t of the exportable good is available.

The log of the terms of trade follows a first order autoregressive stochastic process:

$$p_t = \rho_0 + \rho p_{t-1} + \varepsilon_t.$$

The material balance condition for the economy is given by

$$C_t^M = P_t X_t - R_t - (B_{t+1} - (1+r)B_t), \tag{1}$$

where R_t is the reserves accumulation by the monetary authority and B_t is the stock of foreign assets owned by the economy's individuals.

3.2 Analysis

The first order conditions are the following:

$$-\frac{\partial U/\partial L_t}{\partial U/\partial C_t^M} = W_t, \tag{2}$$

$$Q_t \frac{\partial Y_t^D}{\partial L_t} = W_t, \tag{3}$$

$$\frac{\partial U/\partial C_t^D}{\partial U/\partial C_t^M} = Q_t, \tag{4}$$

$$\partial U/\partial C_t^M = E_t \partial U/\partial C_{t+1}^M, \tag{5}$$

where W_t is the real wage measured in terms of import goods, $Q_t \equiv \frac{P_t^D}{P_t^M}$ is the price of domestic goods in terms of imports (the inverse real exchange rate), and U denotes instantaneous felicity. The first equation (2) is labor supply, (3) is labor demand by producers. Then, (4) represents intratemporal choice by consumers with respect to the two types of goods, while (5) is the Euler equation showing intertemporal choice for imported good.

To solve the system, observe that (2) and (3) together with domestic market clearing give

$$(C_t^D)^{\frac{1+s}{\gamma}-1} = \gamma \frac{Q_t}{C_t}, \tag{6}$$

while the intratemporal consumption choice reduces to

$$\left[\frac{aC_t^D}{(1-a)C_t^M}\right]^{\beta-1} = Q_t. \tag{7}$$

These two equations show that there is a unique function translating consumption of one type of goods into another. Using this observation, we re-write the Euler equation as a function of only import consumption.

$$f(C_t^M) = E_t f(C_{t+1}^M), \tag{8}$$

where $f(.)$ is some function.

Hence, there exists a steady state (with perfect foresight for terms of trade process and reserve purchases) solution, in which consumption of both types of goods and the real exchange rate are constant. Consumption of imports is equal to the present value of export revenues minus the present value of reserves accumulation. Consumption of domestic good and its price can be found using the first order conditions written above.

3.3 Consumption with autoregressive process for oil price

Even though oil prices are assumed to follow a stationary process, consumption will not be stationary, thus, the steady state is not unique (much like in the model of Obstfeld and Rogoff (1995)). The logic here is that of a standard permanent income hypothesis with imported consumption equal to expected present value of export less reserves purchases by the central bank.

For the time being, we will abstract from reserves accumulation and return to this issue in an extension in Section 4.1. Thus, we set here $R_t = 0$. Log-linearizing the Euler equation around an initial steady state (see Appendix for technical details) we get

$$\Delta c_t^M = \frac{\theta}{1+\theta-\rho}\varepsilon_t,$$

where ε_t is a period t percentage innovation to the terms of trade process and all lower case variables are percentage deviations of corresponding upper case variables. Here, we temporarily set the volume of exports X_t to be a constant, that is, $\Delta x_t = 0$. As could be expected, a positive shock to terms of trade leads to an increase in imports. The magnitude of this increase crucially depends on persistence of terms of trade process. In the extreme case when oil prices follow a random walk and $\rho = 1$, consumption increases one for one with the increase in oil price.

Log-linearizing the other first order conditions one gets

$$c_t^D = \frac{A-\beta}{(1+s)/\gamma - \beta(1-A)} c_t^M,$$

where A is the steady state share of domestic good consumption in total expenditure (calculated at market prices). The direction of change of domestic consumption depends on substitutability between domestic and imported goods in the CES consumption aggregate. If these two goods are gross complements as we assume ($\beta < 0$) then domestic production and consumption of home goods will rise also following an oil price increase. If they are substitutes instead ($\beta > 0$), then consumption of home good may fall, since more of the very similar goods can be acquired abroad and this will free time for leisure.

Finally, we look at the effect of the oil price shock on the exchange rate. Using the log-linearized first-order condition for the intratemporal consumption choice (4), we get an expression for the real exchange rate

$$\Delta q_t = \frac{(1-\beta)(1+s)/\gamma}{(1+s)/\gamma - \beta(1-A)} c_t^M = \frac{(1-\beta)(1+s)/\gamma}{(1+s)/\gamma - \beta(1-A)} \frac{\theta}{1+\theta-\rho}\varepsilon_t, \tag{9}$$

where we again restrict $\Delta x_t = 0$. Unambiguously, the real exchange rate appreciates following terms of trade improvement.

3.4 Calibration of parameters

The result that a terms of trade improvement leads to a real appreciation is not new: any standard model would say the same (Obstfeld and Rogoff 1996). Here, we concentrate on the case of the

Table 1: Baseline parameter values.

Parameter	Description	Value
β	Relates to elasticity of substitution between domestic and imported good	-0.5
s	Inverse of elasticity of labor supply w.r.t. real wage	0
θ	Discount rate	0.04 p.a.
γ	Labor share in production of domestic goods	0.5
ρ	First order autocorrelation of oil price process	0.975 p.m.
A	Share of domestic goods in total consumption	0.7
$d\tau_t/dlnP_t$	Semi-elasticity of reserve purchases w.r.t. oil price	0.25

Russian economy to obtain the exact magnitude of the effect given the process for the oil prices and the observed reserves accumulation.

The baseline parameter values are given in the Table 1. Parameter β is set to be equal to -0.5 in order to match the elasticity of import with respect to the real exchange rate found to be -2/3 by Belomestnova (2002), and then later confirmed by New Economic School (2005). For this elasticity estimate, a regression of the general form

$$C_t^M = \alpha_o + \alpha_1 RER_t + \alpha_2 C_t$$

was estimated using several different cointegration-based techniques and with several different measurements of the real exchange rate RER_t and absorption or output C_t. The estimate of the parameter α_1, which in our model corresponds to $\frac{1}{1-\beta}$, varied between about -0.45 and -0.9. Turns out, the result of our experiment in this paper does not depend strongly on variation of this parameter within this range. The choice of infinite elasticity of labor supply (obtained, for example, in Hansen (1985) indivisible labor model) seems to be standard in the literature. Discount rate of 4% per year is also standard. In accordance with national accounts statistics we set γ to one half since total wage bill is roughly equal to half of the GDP. Likewise, we set A to 0.7, which matches proportion of value added in services and construction in total GDP. The persistence of the oil price is chosen to be 0.975 per month, as this is an estimate of an AR(1) specification for the Brent oil price for 1987-2005 deflated by the US CPI. Thus, the process is highly persistent, but not a random walk.

4 Extensions to the baseline model

Before we proceed with the simulations, several extensions need to be made to the baseline model in order to bring the model closer to the reality. We discuss three such extensions: accumulation of international reserves and the stabilization fund, the change of the volume of oil exports, and proper measurement of the real exchange rate.

4.1 Accumulation of foreign reserves

During the years 1998-2005, the Central Bank of Russia (CBR) has played an active role on the foreign exchange market, buying off a portion of the dollar inflow in order to fight excessive appreciation of the ruble. Simultaneously, the Ministry of Finance started to run large budget surpluses, which eventually developed into a stabilization fund, which draws away a large portion of the export revenues. On average, during these years, the Bank of Russia and the stabilization fund accumulated about 16% of the export revenues. This policy could indeed have lead to real depreciation, although the magnitude of this effect and inflationary consequences are a subject of controversy. Sosunov and Zamulin (2006) have shown that this policy might have lead to a real long-term depreciation of about 8-9%.

In our model, reserves accumulation can be introduced in several ways, and the effect on RER will depend greatly on stochastic properties of the term R_t. If this term is pure random noise, then the effect on the RER will be negligible, as the shock is transitory in every period. The only way to obtain a meaningful effect on RER is to commit to a policy of continual reserve accumulation in every period. Such assumption is probably much closer to reality. However, if we set R_t to be a constant, then there will be an effect on the *level* of the RER but not on the rate of its appreciation - the ruble is cheaper but appreciates at the same speed, which corresponds to a vertical shift of the predicted RER path. The same will happen if we were to assume that R_t is a constant share τ of export receipts - this policy is mathematically equivalent to reduction of endowment X_t.

The only way to make the reserve policy influence the RER appreciation rate is to make the share τ depend on the total export revenue. Suppose that the CBR buys back a bigger share of petrodollars at times of high oil prices, and smaller share at times of low prices. This assumption is not out of touch with reality. The regression

$$\tau_t = a_0 + a_1 \log(P_t) + e_t$$

estimated on quarterly data using real Brent price (deflated by US CPI) for 1999-2005 gives an estimate $\hat{a}_1 = 0.25$ with significance at the 1% level. Here, $\tau_t \equiv \frac{R_t}{P_t X_t}$ is the share of revenues that go into reserves, and $P_t X_t$ is the total export revenue.

In order to bring this change into the model, we need to re-define the export revenues to equal $P_t(1-\tau_t)X_t$ in (1). Thus, effectively, we change the oil price to equal $\tilde{P}_t \equiv P_t(1-\tau_t)$, and log-linearizing about the steady state, we get

$$\tilde{p_t} = p_t(1 - d\tau_t/dlnP_t).$$

The term $d\tau_t/dlnP_t$ is the semi-elasticity estimated above to be 0.25.

This result is quite striking. Effectively, we obtain that due to the aggressive interventions on the part of the CBR, the ruble appreciated 25% less than it could have appreciated. This comes solely from the fact that the share of the export revenues extracted by the government depended strongly on the total revenues. If the CBR bought a much bigger share of the revenues (say, half of them), but the rate were flat, than there would be a one time decline in the exchange rate at the time the policy is announced, but no effect on the *rate* of real appreciation thereafter. In other words, by increasing the share of export revenues that went into reserves in response to increase in this export revenue, the Central Bank has made a signal that this share will be high in the future as well, as long as exports remain large. Thanks to these expectations, the effect of this policy on the RER turn out to be so great.

4.2 Accounting for volume change

So far, we held the volume of the endowment X fixed and looked only at the effect of the change in the price of oil. However, beginning 2000, the volume of oil sales has increased considerably. Thus, after a rather stagnant period before 2000 (in 1995, Russia exported 100 million of tons of oil to non-CIS countries, then 114 in 1997, 118 in 1998, and 116 in 1999) the oil exports increased to 128 million tons in 2000, 138 in 2001, 156 in 2002, 186 in 2003, 217 in 2004, and then leveled off at 214.5 in 2005. Thus, the sheer volume of exported oil almost doubled, growing by over 85% between 1999 and 2005. To a large extent, this increase was caused by opening of new oil fields and general investment in more capital. Therefore, it is reasonable to expect that this increase in export volume has a permanent character.

The figures for export volume are available from the customs statistics only on annual basis. In order to asses the impact of this volume change, we split the annual figures into equal monthly increments, and add them as permanent changes of X_t. The exact formula for this addition is shown in (21) at the end of the Appendix. This method of adding the volume change rests on the assumption that the increase of the volume of oil export is permanent.

4.3 Proper measurement of the real exchange rate

Up to now, we defined the real exchange rate as the price of domestic goods in terms of imports. Theoretically, this seems to be the correct way of defining the real exchange rate, but this is not how the RER is measured in international statistics. Rather, the statistics give us the ratio of domestic CPI to the foreign one. The closest we can get to that measure within our model is the ratio of domestic CPI to price of imports, which in log-linear form equals

$$(Ap_t^D + (1 - A)p_t^M) - p_t^M = A(p_t^D - p_t^M) = Aq_t.$$

This is the measured RER, which we will compare to the actual RER computed by the IMF and the Bank of Russia. It should be noted that the officially measured RER has smaller fluctuations than Aq_t, simply because the officially measured RER includes prices of imports in the numerator (the CPI), which cancel out with import prices in the denominator. To account for this in our simulations, we multiply the coefficient in front of ε_t in the formula (9) by A.

However, even this "measured RER" is still not the same as the one reported by the monetary authorities. The official reported RER is the ratio of domestic CPI to the foreign CPI, which includes prices of foreign non-tradables. Therefore, we estimate an alternative RER, using the national accounts data from the Federal State Statistics Service (Rosstat). This measure is the implicit GDP deflator divided by the implicit import deflator, and is available at quarterly frequency.

As will be seen below, the RER measured in this way has grown in Russia significantly more than the officially reported RER over the time period in question. There are at least two hypothesis for why this discrepancy can be the case. The first hypothesis is that relative prices of non-tradable goods have grown in trade partner countries as well, thus putting downward pressure on the officially measured RER. The second hypothesis is that the officially reported RER puts too little weight on the U.S. dollar, since most of the Russian exported raw materials are sold to Europe.

5 Simulations

In order to simulate the predicted real exchange rate, we use the formula (9) and feed into it the residuals from the AR(1) process for Brent oil price deflated by the US CPI with imposed coefficient of 0.975. We also pre-multiply the formula by $(1 - d\tau_t/dlnP_t)$ in order to capture the effect of reserves accumulation as discussed in Section 4.1. Finally, we pre-multiply the formula by A to account for proper measurement of the RER, as discussed in Section 4.3. We then normalize the predicted exchange rate to be equal to the actual in December 1998, the trough of the RER series. The resultant series is demonstrated in figure 1.

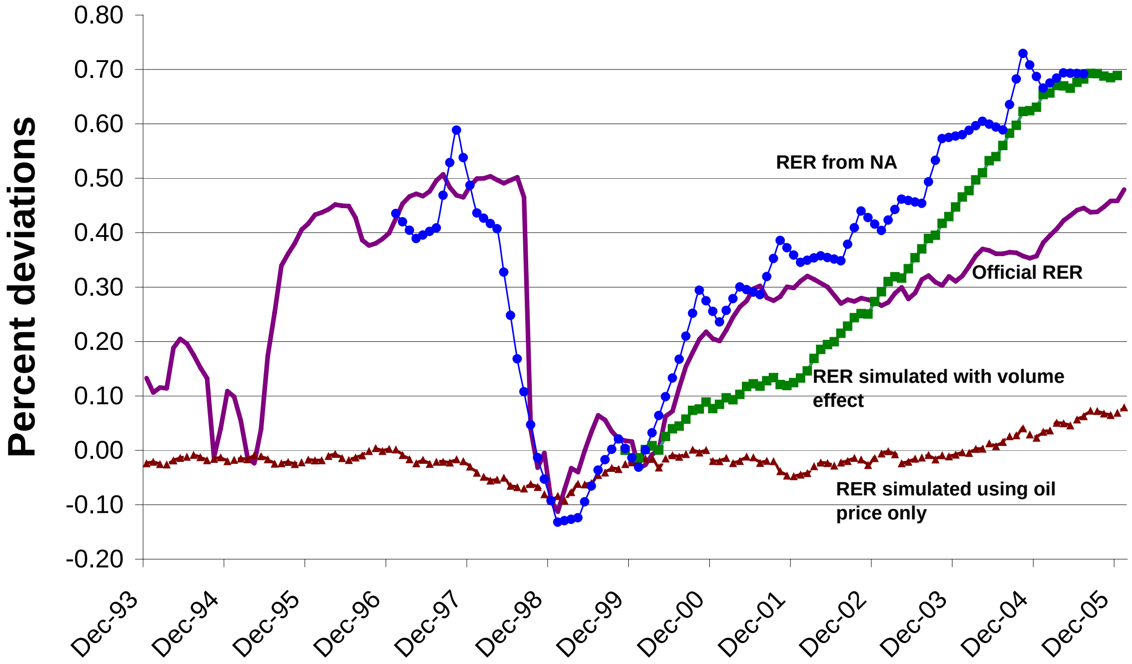
The figure shows four series: the logarithm of the official real effective exchange rate, the rate calculated by us using the national accounts statistics from Rosstat, the rate simulated from the oil price series alone, and the rate simulated using both price changes and changes in the volume of export.

The graph produces several important results. First of all, the two measurements of the RER give very different pictures. Thus, the officially measured RER has not reached the pre-crisis level of 1998 in our sample. At the same time, the RER measured using the national accounts data has surpassed the 1998 level in the spring of 2004. As we discussed above, this can be explained by the fact that the official RER includes the prices of non-tradable goods in foreign countries, which also could have grown relative to tradables during the period in question.

Second, we can see that the RER appreciation cannot be explained by oil price increase alone. This result is very sensitive to some of the parameters, most notably the persistence of oil price shocks. Obviously, if the shocks are more persistent, then consumption of imports increases by more, so the RER has to increase more to allow for a greater amount of imported goods in equilibrium. If the oil price process approaches random walk, that is, if ρ approaches unity, then the simulated RER will go well above the measured RER, even the RER measured using the national accounts data. In that way, oil price increase would become sufficient to explain the observed appreciation.

In principle, increasing the magnitude of ρ can be justified in at least two ways. First, the value 0.975 we use is only a point estimate, while the null hypothesis of unit root cannot be rejected

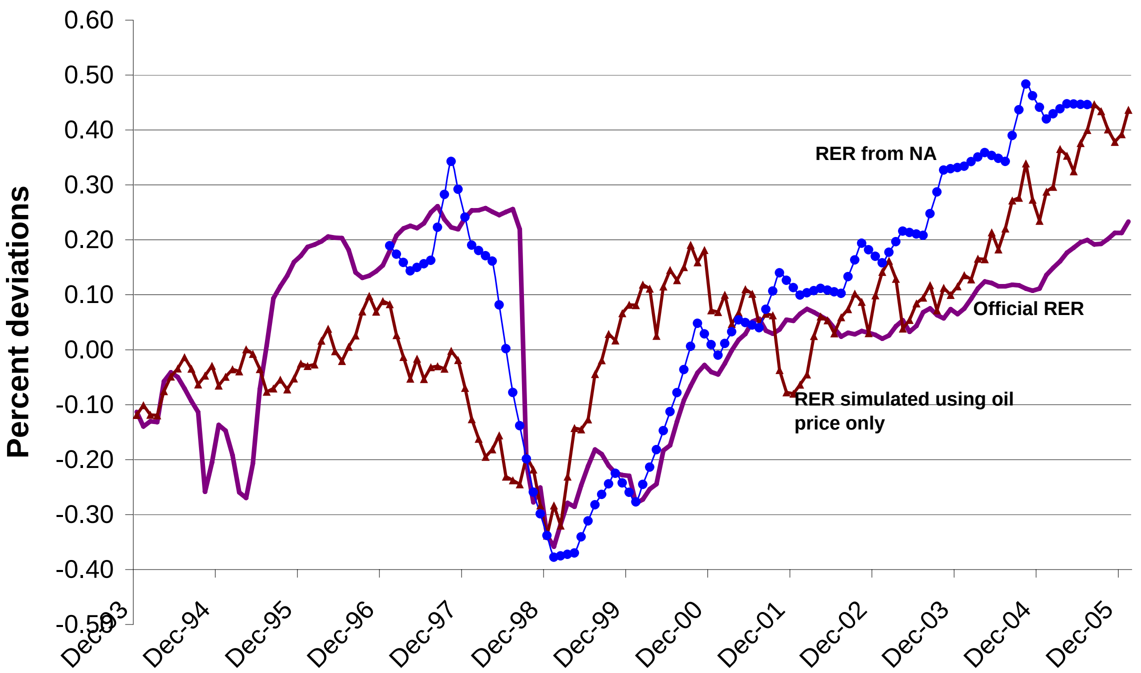
Figure 1: Exchange rate actual and simulated



for the deflated Brent series on the sample 1987-2006, and regressions of this type suffer from a well-known downward small-sample bias. What is interesting is that the unit root is rejected on the 1987-2003 sample. Thus, the failure to reject the unit root is a product of the last several years of intensive growth in the oil prices, which produced discussion about their permanent shift to a new long-run level. If the increase in the oil price is indeed permanent, then taking $\rho = 1$ at least for this period seems appropriate. Second, $\rho = 1$ can be an approximation for rule-of-thumb behavior of consumers. So far, we have assumed perfect permanent income consumers in our economy, while this assumption is clearly stretching. Many consumers react to current income, especially in developing countries, due to precautionary savings, borrowing constraints, and habit formation.

What is interesting is that the trough of the simulated price-based RER occurs exactly at the time of the trough in the officially measured RER, in December 1998. This coincidence speaks in favor of the oil-based explanation of the RER behavior, suggesting that the RER fell in 1998 following the decline of its fundamental oil price based value. However, the fall in the "fundamental"

Figure 2: Exchange rate simulated with $\rho = 0.998$



value in 1996-1998 is half as big as the further rise in 1998-2005. Hence, an increase in ρ to 0.998 (justified, for example, by rule-of-thumb consumers) would help replicate the after-crisis behavior of the RER, but not the pre-crisis level of the RER, which would still seem unjustifiably high. This situation is shown in Figure 2. This picture shows that after 1998, the RER followed a similar path to the oil price based fundamental. That is, a rapid appreciation of 1999-2000 (which seems to have occurred with a year lag after the growth in the fundamental) was followed by about two years of stagnation, and then growth resumed. Ultimately, the overall predicted appreciation with this value of ρ seems in line with that in the national accounts based measure of the RER. At the same time, it is clearly seen that before the crisis, especially in 1997-1998, the measured RER was well above the oil price based fundamental.

Although we think that a higher ρ may be plausible due to deviations from the permanent income hypothesis, we view the trick of setting $\rho = 0.998$ as too artificial to be convincing. Therefore, we return to the Figure 1 with $\rho = 0.975$ and study the effect of the increased volume of exports, which, as we already mentioned, we assume to be permanent. We feed in these changes as shown in formula (21) of the Appendix, starting to add the volume changes in 2000. The resultant simulated RER seems to have increased exactly as much as the RER measured with the national accounts data. Hence, it seems like the observed appreciation of the Russian ruble is consistent with the growth of export volume and the oil price.

One big concern about the graph is that the actual RER seems to have appreciated most rapidly in 2000, as is seen from the graph in Figure 1. At the same time, simulated RERs do not show any such rapid appreciation in that year. Hence, this rapid appreciation of 2000 may point towards the "undershooting" story, according to which the value of the Russian currency fell too low in 1998 due to political uncertainty, and then recovered in 2000 when the uncertainty resolved with the election of Vladimir Putin as president. Alternatively, one can write off this rapid appreciation of the 2000 to short-term rigidities. Thus, until January 2000, the ruble was allowed to fall rapidly against the dollar in nominal terms. Throughout 2000, however, the nominal exchange rate was effectively fixed, while domestic prices continued to grow. Thus, inflation inertia together with fixed nominal exchange rate could have produced excessive real appreciation in 2000.

Finally, we again come back to the comparison of the real appreciation of 1995-1998 with that of 1998-2005. The volume-based story makes an even stronger case towards the disequilibrium level of the 1995-1998 RER, since the volume of annual oil exports was even lower then than in 1999. Therefore, our analysis deems groundless the frequently voiced concerns that the ruble reaching the pre-crisis level may cause the same balance of payments problems as in 1998. The appreciation of 1999-2006 has been in full accordance with the fundamentals. At the same time, as our Figures 1 and 2 show, there were no such fundamental reasons for appreciation in 1995. Instead, most likely, the appreciation in 1995 was disequilibrium — the fixed exchange rate policy often produces such a side effect (Calvo and Vegh 1999). In this way, these two appreciation episodes should not be regarded to be similar.

6 Conclusion

The calibration experiment in the paper has demonstrated that the observed real appreciation of the Russian ruble in 1999-2005 is fully consistent with the growth of the oil export revenues that took place during this period. This growth was due to both the increase in the international price of oil, and the sheer volume of the exported crude oil. The increase of the oil price alone, however, cannot explain the appreciation, unless one is willing to accept the increase as permanent, or the Russian households — as current income consumers. However, a combination of a series of temporary but persistent oil price shocks with permanent increases in the volume of exports produces appreciation in a model economy of similar magnitude observed in reality.

This result suggests that, unlike the appreciation of the mid-1990s, which culminated in a financial crisis, the current appreciation has an equilibrium nature, and does not pose threats to the balance of payments.

Appendix

With the felicity function given by

$$U_t = \log C_t - \frac{L_t^{1+s}}{1+s},$$

where $C_t \equiv \left[a(C_t^D)^\beta + (1-a)(C_t^M)^\beta\right]^{1/\beta}$, the first order conditions (2)-(5) take the form:

$$L_t^s = W_t \cdot \frac{(1-a)(C_t^M)^{\beta-1}}{a(C_t^d)^\beta + (1-a)(C_t^M)^\beta}, \tag{10}$$

$$Q_t \cdot \gamma L_t^{\gamma-1} = W_t, \tag{11}$$

$$\frac{a(C_t^d)^{\beta-1}}{(1-a)(C_t^M)^{\beta-1}} = Q_t, \tag{12}$$

$$\frac{(C_t^M)^{\beta-1}}{a(C_t^D)^\beta + (1-a)(C_t^M)^\beta} = E_t\left[\frac{(C_{t+1}^M)^{\beta-1}}{a(C_{t+1}^D)^\beta + (1-a)(C_{t+1}^M)^\beta}\right]. \tag{13}$$

Substituting equations (11) and (12) for W_t and Q_t into the labor supply equation (10), and using the balance condition $C_t^D = Y_t^D = L_t^\gamma$, we get an equation, which relates the consumption of the domestic and imported goods at the optimum:

$$(C_t^D)^{\frac{1+s}{\gamma}} \cdot \frac{a(C_t^D)^\beta + (1-a)(C_t^M)^\beta}{a(C_t^D)^\beta} = \gamma. \tag{14}$$

Using this relation between the consumption of the domestic and foreign goods, we can rewrite the Euler equation (13) as a function of only import consumption:

$$f(C_t^M) = E_t f(C_{t+1}^M), \tag{15}$$

where $f(\cdot)$ is some function.

From equations (12), (14), and (15) we observe that there exists a steady state solution in which consumption of both types of goods and the real exchange rate are constant. Log-linearizing these equations around this steady state we get:

$$(\beta-1)(c_t^D - c_t^M) = q_t, \tag{16}$$

$$\frac{1+s}{\gamma}c_t^D + \beta(1-A)(c_t^M - c_t^D) = 0, \tag{17}$$

$$c_t^M = E_t c_{t+1}^M, \tag{18}$$

where q_t is the inverse real exchange rate, and $A = \frac{QC^D}{QC^D + C^M}$ is the share of domestic goods consumption in total consumption expenditure in the steady state.

The intertemporal material balance condition for the economy with the zero reserves accumulation gives:

$$\sum_{k=0}^{\infty}(1+\theta)^{-k} E_t C_{t+k}^M = X_t \sum_{k=0}^{\infty}(1+\theta)^{-k} E_t P_{t+k}.$$

Log-linearizing this condition around the steady state we obtain:

$$\frac{\theta}{1+\theta}\sum_{k=0}^{\infty}(1+\theta)^{-k}E_t c_{t+k}^M = x_t + \frac{\theta}{1+\theta}\sum_{k=0}^{\infty}(1+\theta)^{-k}E_t p_{t+k}. \tag{19}$$

From (18) we observe that the left-hand side of the latter equation is equal just to c_t^M. The stochastic process assumed for p_t gives: $E_t p_{t+k} = \rho^k p_t$. Hence, we rewrite (19) as:

$$c_t^M = x_t + \frac{\theta}{1+\theta}\sum_{k=0}^{\infty}(1+\theta)^{-k}\rho^k p_t = \frac{\theta}{1+\theta-\rho}\,p_t. \tag{20}$$

Therefore, taking into account that $E_{t-1}c_t^M = c_{t-1}^M$ and $p_t - E_{t-1}p_t = \varepsilon_t$, assuming that x_t follows a random walk so that $E_{t-1}x_t = x_{t-1}$ and subtracting from equation (20) its expectation of period $t-1$, we obtain:

$$\Delta c_t^M = \Delta x_t + \frac{\theta}{1+\theta-\rho}\,\varepsilon_t.$$

Then, from equations (16) and (17) we get:

$$c_t^D = \frac{\beta(1-A)}{\beta(1-A)-(1+s)/\gamma}\,c_t^M,$$

and, finally,

$$\Delta q_t = \frac{(1-\beta)(1+s)}{(1+s)-\beta\gamma(1-A)}\Delta x_t + \frac{(1-\beta)(1+s)}{(1+s)-\beta\gamma(1-A)}\frac{\theta}{1+\theta-\rho}\,\varepsilon_t. \tag{21}$$

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