Kirill Sosunov, Oleg Zamulin

THE INFLATIONARY CONSEQUENCES OF REAL EXCHANGE RATE TARGETING VIA ACCUMULATION OF RESERVES

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The paper investigates the ability of monetary authorities to keep the real exchange rate undervalued over the long run by implementing a policy of accumulating foreign exchange reserves. We consider a model of a three-sector, small, open economy, where the central bank continuously purchases foreign currency reserves and compare the results to Russian and Chinese economies in recent years. Both countries appear to pursue reserve accumulation policies. We find a clear tradeoff between the steady state levels of the real exchange rate and inflation. After calibration, the model predicts an 8.5% real undervaluation of the Russian currency and a 13.7% undervaluation of the Chinese currency. Predicted inflation is found to match observed levels.

Сосунов К., Замулин О. Инфляционные последствия таргетирования реального обменного курса посредством скупки резервов: Препринт WP13/2007/17. — М.: Издательский дом ГУ ВШЭ, 2007. —32 с. (на англ. яз.)

В статье исследуется возможность финансовых властей поддерживать заниженный реальный курс валюты в долгосрочной перспективе с помощью накопления международных резервов. Мы рассматриваем трехсекторную модель малой открытой экономики, в которой центральный банк непрерывно накапливает валютные резервы, и сравниваем результаты с развитием китайской и российской экономик в недавнее время — обе эти страны проводят политику накопления резервов. Мы находим устойчивую связь между уровнем реального курса и инфляции. Скалиброванная модель предсказывает 8,5%-ю недооценку реального курса рубля и 13,7%-ю недооценку юаня. Предсказанная моделью инфляция совпадает с фактической.

1   Introduction

The issue of foreign currency reserve accumulation by central banks
has become something of a hot topic. Developing countries — no-
tably Russia, China, and a number of countries in Southeast Asia
and Latin America — have implemented policies of reserve accumu-
lation. The wisdom of this policy has been questioned by academic
economists and policymakers and justifications from national au-
thorities vary (see [Rodrik (2006)] for discussion), so we limit our
focus here to the popular argument routinely advanced by politi-
cians and central bankers in Russia and China, whereby reserve
accumulation leads to a cheaper domestic currency and stimulates
the export sector of the economy. [Rodrik (1986)] mentions po-
tentially positive effects of a disequilibrium real exchange rate and
[Polterovich and Popov (2002)] provides empirical evidence showing
that accumulation of international reserves in developing countries
correlates with higher economic growth. These authors also demon-
strate the theoretical basis for a policy of buying international cur-
rency to show that, in the presence of an externality in the exports
production sector, such a policy leads to higher long-run growth
rates through the mechanism of real exchange rate undervaluation.

This argument is particularly relevant for resource-exporting
countries within the context of the "Dutch disease" literature
[Sachs and Warner (2000)]. Basically, the argument goes, the re-
source sector brings hard currency into the country, reducing the
incentive for domestic producers to make tradable goods because
such goods become cheaper to purchase in the world market. The
economy, in turn, reduces to extraction of natural resources and
production of non-tradable services, and overall economic growth
declines as neither sector creates demand for research and develop-
ment. The central bank can react by buying up part of the cur-
rency inflow to prevent appreciation of the real exchange rate and
stimulate production of finished goods that can compete with im-
ports. While this strategy is clearly inferior to such fiscal measures

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as corrective taxation, it seems to offer a second-best option for a developing country unable to administer a discriminatory taxation scheme.

Curiously, the same logic used to justify the policy for natural-resource-abundant countries such as Russia has also been applied by China and several countries in Southeast Asia that want to keep their currencies undervalued through aggressive accumulation of reserves [Dooley, Folkerts-Landau and Garber (2004)].

The idea that the monetary authority can influence the real exchange rate flies in the face of the classical view that the real exchange rate is merely a relative price between domestic and foreign goods, i.e. the real exchange rate is determined by the relative supply and demand for such goods, not the monetary authorities. Indeed, several authors [Calvo, Reinhart and Vegh (1995)] conclude this variable cannot be influenced in the long run. Our exercise here, however, suggests that accumulation of foreign currency reserves is analogous to an artificial increase of demand for foreign goods that shifts the equilibrium relative price. The monetary implementation of the policy involves continuous purchases of hard currency on foreign exchange markets (effectively an inflation tax). Alternatively, the fiscal implementation calls for conventional taxation of resource extraction. The government then runs fiscal surpluses and accumulates part of the revenue stream in a stabilization fund. Russia and China have used both implementations, but the monetary (inflationary) approach appears to dominate in both countries.

This work complements the existing literature on real exchange rate targeting by adding the specific monetary policy instrument of continuous accumulation of foreign exchange reserves. Previous studies [Dornbusch (1982), Lizondo (1991), Montiel and Ostry (1991), Calvo, Reinhart and Vegh (1995)] do not take reserve accumulation into account, perhaps because continuous removal of physical resources from the economy seems like a dead weight loss. Of these papers, only [Calvo, Reinhart and Vegh (1995)] use a dy-

namic general equilibrium model. They find that the real exchange rate cannot be influenced at the steady state.

Here, we build a dynamic general equilibrium model and add the instrument of reserve accumulation to allow for the long-run effect on the real exchange rate. We assume that the central bank continuously purchases a fraction of the export revenues on the spot market, thereby increasing demand for foreign currency that could potentially be spent on imports. This, in turn, makes imports more expensive and leads to undervaluation of the real exchange rate. As this policy acts as an inflation tax, we estimate the expected inflationary consequences. The inflationary effects turn out to be quite large, although still small enough to allow for a long-run real effect.

Our paper is inspired by the Russian experience and the model we propose mimics our understanding of the Russian economic structure. We calibrate the model using parameters relevant for Russia, then contrast this with experience of China, the country most likely to top a discussion on real exchange rate manipulation. Both countries have pursued policies of aggressive reserve accumulation during the last five years, devaluing their currencies, according to our estimation in this paper, by about 8.5% and 13.7%, respectively. Moreover, during this time both countries sterilized about a third of emitted money through fiscal or quasi-fiscal measures, while about two-thirds of foreign currency purchases were purely monetary. In Russia, the result was double-digit inflation. China, in contrast, has a highly monetized economy, which helps accumulate large amounts of reserves while avoiding significant inflation.

The rest of the paper is organized as follows. Section 2 describes the set-up and solution of the model. Section 3 discusses calibration and simulation results of the models, which show the inflationary consequences of reserves accumulation policy. Section 4 compares the results with the experience of Russia and China over recent years. Section 5 concludes.

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2 The model

We analyze the effects of the central bank's policy within the framework of a three-sector open economy without market imperfections. Households consume domestic non-tradable services and manufactured goods that are either imported or produced locally. Locally produced goods are assumed to be non-tradable and imperfectly substitutable with imports. Manufactured goods and services are complementary to each other. Production occurs in two sectors: non-tradable services and non-tradable manufacturing, while exports are assumed to be pure endowment. Foreign currency prices of exported and imported goods are exogenous. The monetary authority sets the rule on accumulation of foreign exchange reserves.

This structure was chosen with the Russian economy in mind. Russia exports predominantly raw materials, which we model here as endowment. Domestic manufactured goods, such as automobiles and processed foods, are consumed mostly within the country. Manufactured goods differ from non-tradable services in an important way: manufactured goods tend to compete with imports, while services are more likely to complement them.

The assumption of endowment export sector allows the wage level and the prices of exports to be independent of each other. As we show in our model, this de-linking of the terms of trade and wage level allows the monetary authorities to influence the real exchange rate. In reality, of course, the export sector employs a certain amount of labor. For a natural-resource based economy, however, exports are essentially resource rent, and thus better modeled as endowment.

2.1 Households

Let C be the aggregate CES index of consumption of domestic non-traded services (C_N) and manufactured goods (C_M):

$$C = \left[\mu^{\frac{1}{\eta}} C_N^{\frac{\eta-1}{\eta}} + (1-\mu)^{\frac{1}{\eta}} C_M^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{1}$$

where $\mu \in (0,1)$ and $\eta > 0$. Parameter η is the elasticity of substitution between goods and services. We restrict $\eta < 1$, which means goods and services are gross complements. Manufactured goods are a CES composite of imports C_F and import-competing domestic goods C_H:

$$C_M = \left[\theta^{\frac{1}{\varepsilon}} C_H^{\frac{\varepsilon-1}{\varepsilon}} + (1-\theta)^{\frac{1}{\varepsilon}} C_F^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2}$$

where elasticity of substitution is $\varepsilon > 1$, which means that the two types of goods are gross substitutes and a devaluation would help the domestic manufacturing sector.

The household's instantaneous utility function takes the form

$$u(C_N, C_M, L) = lnC - \frac{L^{1+\alpha}}{1+\alpha}, \tag{3}$$

where L is labor supply and $\alpha > 0$. The representative household maximizes the expected value of

$$U = \int_0^\infty \beta^s u(C_{N,s}, C_{M,s}, L_s)ds.$$

Since we are only interested in describing the steady state, intertemporal choice plays no crucial role in our analysis — only intratemporal conditions will matter.

Nevertheless, we still need to define a number of nominal and relative prices. Thus, P_N, P_M, P_H and P_F stand for the nominal prices of the corresponding consumption goods in the local currency. E is the nominal exchange rate. The foreign currency prices of imported goods P_F^* and exports P_X^* are exogenous and determined in the international markets. W is the nominal wage rate. It is

useful to define the following relative prices: $e \equiv \frac{P_N}{P_M}$, $q \equiv \frac{P_M}{P_F}$, and $\lambda \equiv \frac{P_H}{P_F}$. The terms of trade are $\tau \equiv \frac{P_X}{P_F}$.

In a standard model where all manufactured goods are perfectly substitutable tradables ($\varepsilon \to \infty$), e would be regarded as a measure of the real exchange rate. In our case, however, the expression for the RER is necessarily more complicated. Since our aim is to see how the policy of purchasing foreign reserves influence the official real exchange rate, we need to define the RER exactly as it is defined officially, that is, P/EP^*, or

$$
MRER \equiv \frac{P}{EP^*} = \frac{\left[\mu P_N^{1-\eta} + (1-\mu)P_M^{1-\eta}\right]^{\frac{1}{1-\eta}}}{\left[\mu (EP_N^*)^{1-\eta} + (1-\mu)P_M^{1-\eta}\right]^{\frac{1}{1-\eta}}} =
$$
$$
= \left[\frac{\mu(eq)^{1-\eta} + (1-\mu)q^{1-\eta}}{\mu(e^*q^*)^{1-\eta} + (1-\mu)(q^*)^{1-\eta}}\right]^{\frac{1}{1-\eta}} , \quad (4)
$$

where P is the CES price index, and $e^* \equiv P_N^*/P_M^*$ is the relative price of non-tradables to that of the international tradable good in the rest of the world, while $q^* \equiv P_M^*/P_F^*$, and the law of one price holds: $EP_F^* = P_F$. In the above formula, we implicitly assume that the rest of the world has the same preferences over their own non-tradables and manufactured goods as the home country. In principle, this restriction needs not be particularly strict — all we need is that the foreign price index can be divided through by P_F, hence any foreign price index homogeneous of degree one with respect to P_N^*, P_F^* and P_H^* is sufficient. The denominator becomes simply a constant and is therefore irrelevant to the analysis of percent change in the RER.

Utility maximization with standard budget constraints gives the following first order conditions for consumption and labor allocation:

$$\frac{C_N}{C_M} = \frac{\mu}{1-\mu}e^{-\eta}, \tag{5}$$

$$\frac{C_H}{C_F} = \frac{\theta}{1-\theta}\lambda^{-\varepsilon}, \tag{6}$$

$$\frac{W}{P_N} = L^\alpha \left[1 + \left(\frac{1-\mu}{\mu}\right)^{\frac{1}{\eta}} \left(\frac{C_M}{C_N}\right)^{\frac{\eta-1}{\eta}} \right] C_N = \tag{7}$$

$$= L^\alpha \left[1 + \left(\frac{1-\mu}{\mu}\right) e^{\eta-1} \right] C_N.$$

Equations (5) and (6) simply show how consumption of different goods relate to the relative prices. Equation (7) is the labor supply schedule of households. Note that $\alpha = \infty$ corresponds to the vertical labor supply — in that case utility is just a function of consumption. In the following discussion, we denote $w \equiv \frac{W}{P_N}$ — the real wage (deflated by the price level of non-traded goods).

2.2 Production

Production technologies for the firms in the two non-traded sectors are given by simple formulae:

$$Y_N = L_N, \tag{8}$$

$$Y_H = AL_H, \tag{9}$$

$$X = const, \tag{10}$$

where A is the relative productivity factor. The assumption of constant returns to scale simplifies the analysis of the labor market as the real wage expressed in terms of non-tradables is equal to unity at all times:

$$w = 1. \tag{11}$$

Firms are ready to hire any amount of labor at this wage, so the amount of labor input is determined by the labor supply (7).

The production technology dictates $P_N/P_H = A$. We rewrite this expression as

$$\frac{P_N}{P_H} = \frac{eq}{\lambda} = A, \tag{12}$$

where, once again, $e \equiv P_N/P_M$, $q \equiv P_M/P_F$, and $\lambda \equiv P_H/P_F$. Note that if we steered away from the assumption of the endowment export sector and introduced a constant-returns-to-scale technology as in the other two sectors, then the RER would become fixed and thereby immune to any policy influence. This is because the relative price of all three domestically produced goods would be determined by relative technology, while the terms of trade $\tau = P_X/P_F$ are determined by world markets. Thus, both e and q in the formula (4) would be constant. Ways of avoiding an unchangeable RER include making an assumption of an endowment export sector (as we do here), as well as blockage of free labor mobility between sectors to allow wage differentials or introduction of decreasing returns to scale in production. In the model with decreasing returns to scale developed earlier in [Obrezkov (2004)], the inflationary effects of RER targeting turned out to be highly sensitive to the degree of returns to scale.

2.3 Market clearing

In equilibrium, market clearing in both non-traded good sectors and the labor market implies

$$Y_N = C_N \tag{13}$$
$$Y_H = C_H \tag{14}$$
$$L = L_N + L_H. \tag{15}$$

In addition, the steady state current account balance implies that

$$P_X^* X = P_F^* C_F + R, \tag{16}$$

where R is the *flow* of the international currency reserves accumulated by the central bank. Equation (16) can also be viewed as a condition of market clearing in the foreign currency market.

Note that equation (16) holds only in the steady state. In the short run, private capital flows would need to be added into the equation, as the private sector can accumulate its own stock of international assets. Moreover, if the policy of reserve accumulation is expected to end sometime soon, the economy will react to current reserve purchases by borrowing from abroad, thus reducing the effect of the policy, perhaps to zero. In the long-run, however, private economy cannot continuously accumulate assets or debt, as such behavior will violate the transversality or no-Ponzi game condition. Hence, net private flows in the steady state must be zero. The government, on the other hand, is not bound by the transversality condition and can choose to accumulate reserves forever. Then, the steady state current account is exactly equal to reserve accumulation.

The assumption that government accumulates reserves forever may seem strange — this is pure removal of resources from the economy, analogous to burning of a fraction of export revenues, or throwing them into the ocean. However, such behavior may be rational if there is a sufficient technological externality in the import-substitution sector (see [Polterovich and Popov (2002)]), which gets stimulated by such a policy. Furthermore, if the export sector were not endowment as in our model, such policy would stimulate that sector as well — hence, this policy is not identical to imposition of export barriers (see [Obrezkov (2004)]). These are precisely the arguments used by the central banks in Russia and China, and these central banks have attempted to communicate to the public that the reserve accumulation will continue indefinitely.

If one does not believe that such purchases of reserves can go on forever and constitute a steady state, our model can be viewed as an approximation to a model with finite planning horizons. If consumers believe that policy of reserves accumulation will continue

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for several years to come, and are sufficiently short-sighted, they will behave as if this policy describes the steady state. An overlapping generations model will yield the same result. Thus, it seems legitimate to assume that Chinese and Russian central banks are expected to continue their accumulation of reserves for some years, and the possibility that they will stop at some point in the future does not affect the behavior of economic agents today, because this change of policy is sufficiently distant in the future and its timing is uncertain.

2.4 Foreign exchange reserves accumulation rule

To close the system of equations, one needs to specify the rule of reserves accumulation.

We assume here that the monetary authority announces that the constant fraction ω of exporters' forex revenues will be purchased by the central bank such that

$$R = \omega P_X^* X. \tag{17}$$

While equations (16) and (17) imply that an increase in ω leads to a decrease in imports, a fall in the demand for foreign goods can only occur if there is an increase in the (relative) price of manufactured goods (5) that is equivalent to a fall in e and the real exchange rate. Thus, active purchasing of foreign currency by the central bank leads to RER depreciation.

As our main objective here is to determine steady state inflation, we introduce two more equations. The first simply states that the central bank expands the money supply M by buying the foreign exchange at the equilibrium nominal exchange rate E:

$$\dot{M} = mER = m\omega E P_X^* X, \tag{18}$$

where m is the money multiplier. The second equation is money demand, which is represented here as a simple consumption-based quantity equation:

$$MV = P_N C_N + P_M C_M, \tag{19}$$

where V is velocity of money (treated as an exogenous parameter). In order to derive the steady-state inflation rate, we take the derivative of (19) with respect to time and combine the resultant expression with (18) and the fact that in the steady state, $\dot{C}_N = \dot{C}_M = 0$. From this, we obtain

$$\pi \equiv \frac{\dot{P_N}}{P_N} = \frac{\omega \tau X m V}{q(e C_N + C_M)}. \tag{20}$$

2.5   Solution of the model

Equation (20) says that in order to solve for the steady-state value of inflation as a function of the policy variable ω, we need to solve for variables q, e, C_N, and C_M. We start by noting that the relation between q and λ can be obtained by dividing the CES price index P_M through by P_F:

$$q = \left[\theta \lambda^{1-\varepsilon} + (1-\theta) \right]^{\frac{1}{1-\varepsilon}}. \tag{21}$$

We also eliminate L from the labor supply equation (7) to get

$$\left(C_N + \frac{C_H}{A} \right)^{\alpha} \left[1 + \frac{1-\mu}{\mu} e^{\eta-1} \right] C_N = 1, \tag{22}$$

where we used the production functions (8), (9), aggregation (15), and the result that $w = 1$.

Then, equations (2), (5), (6), (12), (21), and (22) are six equations with six unknowns $(e, q, \lambda, C_N, C_H, C_M)$. Note that C_F is pinned down by (16). These six equations give us the values of all of the necessary variables to solve for the level of steady-state inflation.

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<div align="center">**Table 1.** Baseline parameter values for the model</div>

Parameter	Description of the parameter	Value
η	elasticity of substitution between non-traded services and manufactured goods	0.4
ε	elasticity of substitution between foreign and domestic manufactured goods	2
$\frac{P_N C_N}{PC}$	expenditure share on services	0.5
$\frac{P_H C_H}{P_M C_M}$	expenditure share on home manufactured goods	0.5
τX	export revenues	1
A	technological coefficient in exports sector	1
α	elasticity of labor supply	1
Vm	money velocity times money multiplier	8

3 Calibration and simulations of the model

We now calibrate the model using the parameter values relevant for the Russian economy. First, we normalize the terms of trade and the amount of exports to unity. Let elasticity of labor supply α equal 1.[1] Money velocity is set to 4, which corresponds to 25% monetization of the Russian economy; the money multiplier m is set to 2, which is the ratio of M2 to the monetary base. Normalization of velocity implies that calculated inflation is per annum. Our benchmark parameter choices are described in Table 1.

Important parameters are shares of the three types of goods in the consumption baskets and the elasticities of substitution between them. To assess the share of non-tradable services in total expenditure, we consider the average sum of all services and construction divided by the GDP in 1999-2004. According to the national accounts data from the Federal State Statistics Service (Rosstat), this

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[1]This choice is arbitrary, but we shall see later that labor elasticity does not affect long-run inflation.

number is 0.6. It has been widely recognized, that the official fig-
ure grossly overstates the size of the service sector, mainly because
oil-exporting companies use transfer pricing schemes to shift a large
part of their official value added to trading companies, which shows
up as services. An estimate that may be regarded as reasonable is
on the order of 0.4 [Gurvich (2004), World Bank (2004)]. One final
correction needs to be made, since 0.4 is the share of non-tradables
in GDP, while we would like to have their share in total absorp-
tion, which is only about 85% of GDP. Hence, we take the share of
non-tradable services as 0.5 of absorption.

To estimate the relative share of domestic goods in the manu-
factured sector, we take imports to Russia for 1999-2005 and divide
them by total absorption (sum of private and public consumption
and investment). This figure seems to be around 0.25. Thus, im-
ports are a quarter of total absorption or half of tradable goods.
Hence, we assume that expenditure on manufactured goods is equally
split between domestic and imported products.

Finally, we need the elasticities of substitution η and ε. The
Armington elasticity ε is the subject of numerous papers. It is es-
timated for a wide variety of goods in many countries, both on the
aggregated and disaggregated level. To our knowledge, the most
elaborate study using the Russian data is that by [Ivanova (2005)].
Ivanova estimates the Armington elasticity using microeconomic
data and obtains that for different goods the parameter ranges be-
tween 1.29 and 6.29. The most representative number seems to
be around 2. We take this value for our purposes. This number
looks reasonable: it shows that import-competing goods are present
in the Russian industry, while, at the same time, the elasticity of
substitution is not that great.

We take the coefficient η from the literature on other countries
and set it equal to 0.4. This is a value taken for similar pur-
poses, among others, by [Burstein, Eichenbaum and Rebelo (2005)]
and previously by [Stockman and Tesar (2000)]. For Russia, studies
have   been   made   by   [Belomestnova (2002)]   and   later

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[New Economic School (2005)], in which the authors estimated the elasticity of imports with respect to the real exchange rate to be about 0.5-0.6 in absolute value. Unfortunately, this is not the ideal parameter for our purposes; we need an elasticity of substitution between non-tradable goods and all complementary manufactured goods, not just imports. This elasticity is probably lower, and hence, the number 0.4 seems both reasonable and consistent with the literature.

To solve the model, we first back out the coefficients μ and η from known expenditure shares on non-tradable services and domestic manufactured goods. We do this by solving the system of six non-linear equations described in Section 2.5, but treating μ and η as unknown variables and treating $\frac{P_N C_N}{P_M C_M}$ and $\frac{P_H C_H}{P_F C_F}$ as known parameters in (5) and (6). We also take $\omega = 0.155$ for this calculation, because this is the average share of export revenues that went into the foreign reserves of the Bank of Russia during 1999-2005 (see Section 4). It is important to use this value of ω, because it must have been a factor in determining the expenditure shares used to back out μ and η.

We use the obtained parameters to solve for the values of inflation and other variables for different values of ω or, equivalently, for different values of target long-term devaluation.

Figure 1 shows how the policy instrument ω influences the real exchange rate, i.e. what share of export revenues needs to be purchased by the central bank (or withdrawn from the economy through fiscal measures) to achieve the desired degree of devaluation. The dotted line on the picture demonstrates the predicted level of devaluation for the Russian case, where about 15.5% of the export revenues are withdrawn from the economy. This indicate that this policy would lead to an approximately 8.5% undervaluation of the ruble.

Figure 2 depicts the long-run trade-off between the real exchange rate devaluation up to 33% and inflation, while Table 2 shows inflation and implied policy variable ω for different degrees of target

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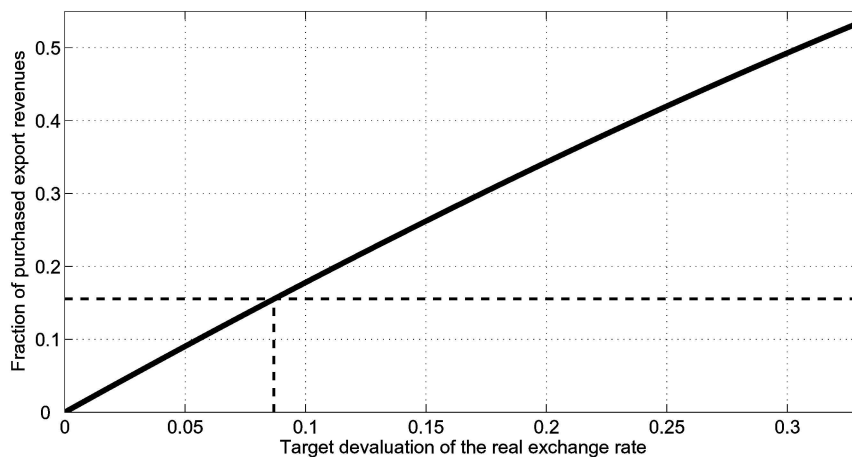
Figure 1. The fraction of purchased export revenues vs. target devaluation

Table 2. Inflation and policy variable for different degrees of devaluation

Real devaluation	Policy variable ω	Annual long-run inflation
1%	1.9%	4.00%
5%	9.0%	20.60%
10%	18.0%	44.00%
20%	34.5%	100.00%
33%	53.00%	197.00%

devaluation. A devaluation of 10%, for instance, causes 40% annual inflation.

The real-side effects of a 10% real devaluation RER depreciation are reported in Table 3. The results are quite predictable: both the production in the service sector and consumption of imports decrease. Due to the fall in imports domestic production of import-substitution goods expands. Overall production continues to in-

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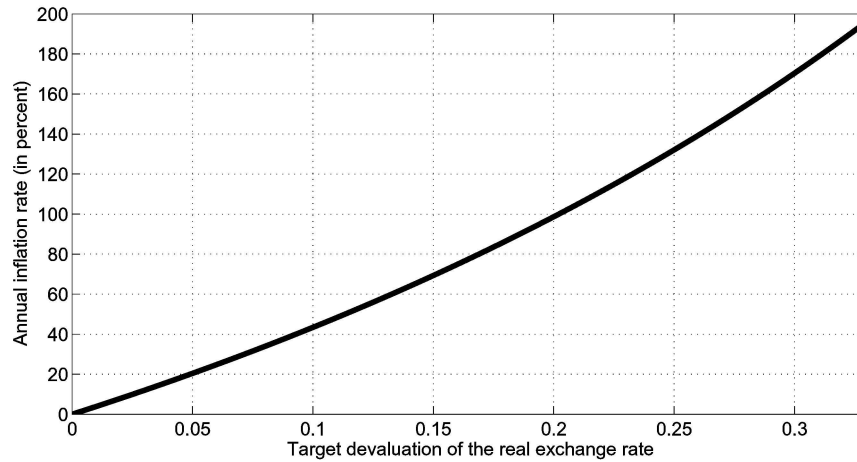
Figure 2. The annual long-run inflation vs. the real exchange rate devaluation

Table 3. The real effects of the RER devaluation by 10%

Description of the variable	Percentage change
Production of non-tradeable services	-3.0%
Production of import-substituting goods	+9.5%
Production index	+0.8%
Consumption of imports	-18%

crease, but only marginally with the chosen parameter values. Note that the changes in the Laspeyres and Paasche production indices are identical since the relative price between the two domestically produced goods does not change by formula (12).

4 Comparing the Russian and Chinese experiences

While many countries have intensified their accumulation of reserves in the years following the financial crises of the late 1990s, the goals they hope to achieve by pursuing this policy is not exactly clear. [Rodrik (2006)] claims that most countries adopted this strategy as a way to guarantee stability of their nominal exchange rate and signal low risks to foreign investors. Rodrik questions this explanation for China, where real exchange rate manipulation, as in our model, appears to be the main consideration. Likewise, the Bank of Russia ostensibly claims it has been accumulating foreign exchange reserves to fight real appreciation of the ruble as export earnings from oil and other commodities have skyrocketed.

Our paper has been inspired primarily by the Russian experience, and therefore we proceed first with the analysis of the Russian policy toward reserves. We then make some inferences about China, re-calibrating our parameters. The structure of the Chinese economy differs considerably from Russia's, so we modify the model accordingly.

4.1 Russia

The Bank of Russia started active accumulation of the foreign exchange reserves in 2000. According to the statistics published on the Bank of Russia's website, they have annually been purchasing about 15.5% of all export revenues on average. Almost 40% of these purchases have been sterilized through fiscal surpluses, which eventually became known as the stabilization fund in early 2004. In 2005, over two-thirds of extracted revenues went to the stabilization fund. In other words, not all purchases were inflationary.

Table 4. Statistics for Russia, 1999-2005

	1999	2000	2001	2002
Total Exports[a]	84618	114598	113326	120912
Reserves Purchases	1778	16010	8212	11375
Fiscal Surplus[b]	1381.3	5852	1865.8	2008.5
Reserves/Exports	2.1%	13.97%	7.25%	9.41%
Surplus/Exports	1.63%	5.11%	1.65%	1.66%
(Res-Surpl)/Exp	10.47%	8.86%	5.60%	7.75%
CPI Inflation	36.5%	20.2%	18.6%	15.1%
	2003	2004	2005	Average 2000-05
Total Exports	152158	203497	268136	
Reserves Purchases	26365	45235	61461	
Fiscal Surplus	2872.3	20892.1	43903.9[c]	
Reserves/Exports	17.33%	22.23%	22.92%	15.5%
Surplus/Exports	1.89%	10.27%	16.37%	6.16%
(Res-Surpl)/Exp	15.44%	11.96%	6.5%	9.36%
CPI Inflation	12.0%	11.7%	11.2%	14.8%

[a] Exports and purchased reserves in millions of US Dollars, source: Bank of Russia.

[b] Increase in cash holdings by government at the central bank, in millions of US Dollars, source: Bank of Russia.

[c] The figure for 2005 figure includes re-payment of Central Bank's 1999 loan to the Ministry of Finance, maid for foreign dept re-payment purposes, in the amount of USD5,092 million.

Table 4 presents statistics for Russia in 1999-2005. Exports and the change in reserves are taken from official Bank of Russia figures.[2] The fiscal surpluses are also taken from the Bank of Russia data and

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[2] In principle, this figure should be corrected, because this growth of reserves is partly caused by exchange rate fluctuations. Part of the central bank's reserves is held in euros, so an appreciation of the euro causes an increase in reserve dollar figures without the actual purchase of export revenues. The official figure on the composition of reserves are unavailable, however. Our estimates, based on unofficial data, suggest that the results do not change much.

are not the same as the consolidated budget surpluses of the Ministry of Finance. Instead, we take the change in currency holdings of the Russian government at the Bank of Russia. This number is quite different from the official surplus, mainly because the change in cash holdings does not include the tax revenues, which went into payment of the foreign debt. Instead, they just show the part of surplus, which went into stabilization fund.[3] We also consider the averages for 2000-2005, since it seems that the Bank of Russia embarked on intensive accumulation of reserves beginning year 2000.

Our model allows us to estimate the effect of the policy implemented by the Bank of Russia and the Ministry of Finance on inflation and the real exchange rate. Specifically, $\omega = 0.155$ implies an undervaluation of about 8.5%. In other words, the policies of the Bank of Russia and the Ministry of Finance (the administrator of the stabilization fund) throughout the period 2000-2005 kept the ruble's value 8.5% cheaper than its equilibrium value. Of course, this undervaluation is dwarfed by the more than 80% real appreciation that occurred during the same period. Thus, if the policy of buying up international reserves had not been introduced in late 1990s, the Russian ruble would have appreciated by 88.5% instead of 80%. The observed appreciation, on the other hand, was probably due to the huge change of terms of trade (the increase in oil prices) as well as in the volume of oil exports. These two effects more than tripled the nominal dollar value of exports between 1999 and 2005 (see top line of Table 4).

To estimate predicted inflation, we note again that only about 9.4% of the export revenues were purchased without being sterilized by the stabilization fund. Hence, predicted inflation is that estimated using $\omega = 0.094$. This turns out to be 21.5% per year, which

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[3]Arguably, foreign debt repayment should affect the real exchange rate as this money withdrawal is analogous to reserve accumulation and the stabilization fund. We do not include Russia's repayments here, however, because they affect the RER independently of the policy decision, i.e. they are an exogenous constraint faced by the government.

is somewhat higher than the observed 14.8% average for 1998-2005. However, if we add balanced economic growth in C_N, C_H, and X to the model, this growth rate should have been subtracted from predicted inflation in equation (20). Since the average growth rate of the Russian economy was about 6.8% in the period discussed, the predicted inflation rate becomes 14.7%, which is astonishingly close to the observed inflation. This exact match of the average could, of course, merely be a coincidence; inflation fell to around 11-12% in 2004-2005. This is probably due to the fact that in later years a greater share of the purchased reserves was sterilized by fiscal surpluses, and due to growing demand for the local currency holdings due to de-dollarization, which allowed the economy to digest much of the increase in the ruble money supply.[4] It is also noteworthy that the predicted impact of monetary devaluation alone (with $\omega = 0.094$) is only 5.2%.

4.2   China

China is often cited as a country that tries to influence its real exchange rate via accumulation of reserves, so it is interesting to see what kind of predictions our model delivers for the Chinese economy, especially given that China has enjoyed low inflation and a fixed nominal exchange rate for several years now.

Over the last decade, China has been putting aside roughly 18% of its export revenues. During the last five years, 2001-2005, this average was as high as 26%, peaking at 35% in 2004 (see Table 5). These figures are higher than in Russia's case, and therefore, may have a stronger influence on the real exchange rate. China's rapid accumulation of reserves started in 2001, so we use averages

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[4]In addition to the evidence of growing demand for rubles, there is also evidence that the broader money demand for the sum of rubles and dollars has remained rather stable (see [Oomes and Ohnsorge (2005)]). Thus, the trend to de-dollarization might have helped the Bank of Russia to accumulate reserves without spurring excessive inflation.

<div align="center">**Table 5.** Statistics for China, 1999-2005</div>

	1999	2000	2001	2002
Total Exports[a]	194.93	249.20	266.10	325.59
Reserves Purchases	8.54	10.55	47.33	75.52
Bond sales	0.00	-1.44	0.00	17.97
Reserves/Exports	4.38%	4.23%	17.79%	23.20%
Bonds/Exports	0.00%	-0.58%	0.00%	5.52%
(Res-Surpl)/Exp	4.38%	4.81%	17.79%	17.68%
CPI Inflation	-1.4%	0.3%	0.5%	-0.8%
	2003	2004	2005	Average 2001-05
Total Exports	437.90	593.44	762.07	
Reserves Purchases	117.02	206.35	207.01	
Bond sales	18.66	97.23	114.21	
Reserves/Exports	26.72%	34.77%	27.16%	25.9%
Bonds/Exports	4.26%	16.38%	14.99%	8.2%
(Res-Surpl)/Exp	22.46%	18.39%	12.18%	17.7%
CPI Inflation	1.2%	4.0%	1.6	1.3%

[a] All variables in billions of US Dollars, source: IMF.

for 2001-2005 in what follows. If one extends the Table 5 back by a number of years, it would also show aggressive reserve-building in the 1990s as well.

As our model was designed and calibrated with the Russian economy in mind, it cannot be applied directly to the Chinese situation. Chinese exports are predominantly manufactured goods produced with relatively inexpensive labor drawn from a vast agrarian sector. The prices of manufactured goods and the prices of domestic non-tradable goods should be linked to the wage level, and their ratio must be constant and determined by relative technology similar to our equation (12). At the same time, the relative price of exports and imports must be determined by the world markets, which means that none of the relative prices in China can be influenced by policy

in the long run. Our above result for Russia rests on the special feature of the Russian economy that most exports are raw materials, so their world prices are unrelated to the wage level. Thus, to justify the claims that the People's Bank of China is influencing the RER at all, one needs to produce a model of the Chinese economy that breaks the free flow of labor between sectors and thus decouple prices, or, alternatively, makes major deviations from perfect competition. For example, one can argue that China's abundant labor resources are similar to Russia's oil resources, so China collects the rent equal to the difference between the world price of its exports and the domestic labor cost. This rent is similar to the endowment of export revenues in our model.

This critique notwithstanding, we proceed with estimating the effect of the Chinese policy on their RER and inflation. We adjust the equilibrium shares to equal $\frac{P_N C_N}{PC} = 0.41$, and $\frac{P_H C_H}{P_M C_M} = 0.55$. These numbers are obtained, using the 2004 China Statistical Yearbook of the National Bureau of Statistics of China. According to these statistics, the share of services ("tertiary industry") and construction has been 0.4 of the GDP, while total absorption (private and public consumption and investment) has been 97.5% of GDP over 2001-2003. The share of domestic goods in manufactured good consumption, in turn, is then deduced using these parameters and the ratio of imports over the GDP, which, according to the IFC statistics, has been 26% in 2001-2004.

With these parameters, using the above model we obtain that purchases of 26% of export revenues should lead to an undervaluation of 13.7%.

Before estimating predicted inflation, we note that the People's Bank of China has been sterilizing a substantial amount of issued money by requiring commercial banks to purchase its debt in the form of bonds [Frankel (2005)]. Table 5 shows the central bank used this means of sterilization aggressively in 2004-2005, achieving essentially the same effect as Russia's direct taxation and sequestering of funds in stabilization fund. The figures indicate that about 8%

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out of the 26% of purchased export revenues were sterilized in this manner. Hence, the end results of the policies in the two countries are strikingly similar — only 18% of export revenue purchases have been inflationary.

Using the same money velocity as in Russia, we get a predicted inflation rate of 47% per annum.

China is distinctly different from Russia, however, when it comes to the extensive monetization of its economy. While M2 has averaged around 25% of the Russian GDP in recent years, the corresponding figure for China was 174% during 2001-2005! At the same time, the money multiplier (M2 divided by the monetary base) is about 4, or twice that of Russia. This makes the parameter Vm for China equal 2.3, not 8, as in Russia, and this parameter multiplies the rest of the formula for inflation (see equation (20)). Therefore, the estimate for inflation after this adjustment is 3.5 times lower — 13.5% per annum.

Finally, Chinese official GDP growth has been about 10% over the last few years. As the recent revision of the size of the service sector suggests, this may even be an underestimate. Subtracting 10% growth, the inflation prediction becomes 3.5%, which is quite close to actual observations.

We see that the extensive monetization of the Chinese economy, together with rapid economic growth and sterilization mechanisms, has allowed the Chinese authorities to keep the yuan undervalued by almost 14% without much inflation. Of course, this number needs to be treated with caution as it was obtained in a model geared to the Russian economy. As argued above, due to the nature of the Chinese export sector, China may have a harder time influencing their exchange rate, and therefore 13.7% may be an overestimate.

5 Conclusions

In this paper, we derived a clear long-run trade-off between the depreciated level of the real exchange rate and inflation in case when the real exchange rate is targeted by the policy of the accumulation of the foreign exchange reserves. A three-sector model with non-tradable service and import-substituting manufacturing sectors was calibrated using the parameters relevant for the Russian economy. The results of our simulations suggest that the policy of the real exchange rate targeting by an active policy of reserves accumulation can have a minor impact on the real exchange rate. However, there is a risk of severe inflationary consequences where the level of monetization of the economy is low as in Russia. Notably, the People's Bank of China has managed to make its currency cheaper by almost 13.7% while avoiding high inflation, mostly thanks to the extensive monetization of the Chinese economy.

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К. Сосунов, О. Замулин

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(*на английском языке*)

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