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Currency Substitution
in Russia

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Due to high inflation and the lack of financial instruments, the Russian economy is currently highly dollarized. The share of dollars in the total amount of cash circulating in the Russian economy constitutes about 80%. What is the degree of this currency substitution phenomenon? What are the implications of dollarization for the possibility of inflationary financing of the budget deficit and for welfare? These questions are studied by the authors using estimations obtained from the Ramsey – Lucas model, which uses two types of money in the utility function.

In this paper, the authors use dynamic money in the utility function model, in which money services are produced both by domestic and foreign money balances, to empirically investigate currency substitution between Russian rubles and U.S. dollars in the Russian economy during the period 1995 to mid 2000. Data supports the hypothesis that foreign currency enters as a variable in the representative consumer's utility function. Our findings indicate considerable currency substitution: most estimates of elasticity of substitution are between 2 and 3. Based on estimated parameters, it is shown that simulated steady state seignorage revenues are close to actual ones for different inflationary periods. The effect of a change in the degree of dollarization on the seignorage/GDP ratio appears to be strong if the economy is highly dollarized. The estimates also demonstrate a sizable welfare impact of inflation and dollarization.

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1. INTRODUCTION

The transition from a centrally planned economy to a market-oriented
one in Russia, as well as in many other formerly planned economies, was
accompanied by high inflation. With the liberalization of foreign trade and
legislation that made foreign currency available to the population, an in-
crease in inflation led to a broad usage of foreign currency (mainly U.S.
dollars) in transition economies. Fig. 1 illustrates the dollarization ratio
(DR) for the Russian economy for the studied period using a standard
measure of this phenomenon: the ratio of foreign cash holdings to the
sum of foreign and domestic cash. It should be mentioned that after the
collapse of various quasi-financial institutions in 1993 – 1994, the popu-
lation preferred to hold foreign cash rather than deposits or commercial
papers. No alternative means of saving such as gold or foreign bonds
had been developed. The financial crisis in August 1998 also affected
the dollarization ratio (DR).

We use two alternative estimates of foreign cash in the Russian economy
(we will discuss this in more detail in the data section); Fig. 1 shows that
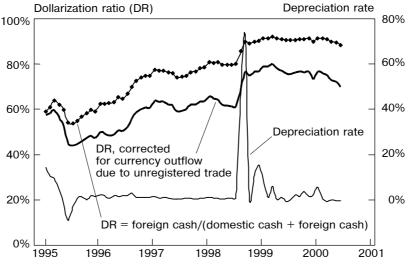the trends are similar for these estimates. The relative sharp in-

Fig. 1. Dollarization ratio (DR) and depreciation in Russia, 1995 – 2000.
Sources: Central Bank of Russia Database.

creases/decreases of DR in mid-1995 and in August 1998 are partly explained by the ruble's appreciation/depreciation.

The phenomenon of dollarization or currency substitution (CS) raises many interesting questions. Since CS reduces monetary independence and influences the demand for domestic real money balances, it should be taken into account when considering such possibilities as inflationary finance or the choice of nominal anchors in inflation stabilization programs. So, it is important to know whether the phenomenon of CS takes place in Russia and to what degree. The main aims of our study are to verify empirically the presence of CS in Russia and analyze some implications of dollarization. We achieve this by using a dynamic money-in-the-utility-function model. Then we analyze the influence of dollarization on the possibility of inflationary financing of the budget deficit (*i.e.*, the effect on seignorage) and study the implications of dollarization for welfare.

2. SURVEY

The term "dollarization" usually captures only two functions of currency: unit of account and a store of value, while currency substitution is understood as the final stage of dollarization when the foreign currency performs also as a medium of exchange. Although in Russia the use of dollars as a medium of exchange officially took place only in 1992 – 1993 and was prohibited afterwards, we are not going to use different terminology in our study.

Since the relevance of CS is an empirical issue, there is a wide variety of econometric papers on this phenomena. Estimation of CS in Latin American countries can be found, for example, in the works of Ramirez-Rojas (1985), Melvin (1988), Melvin and Afcha (1989), Savastano (1996). CS for Canada is studied by Miles (1978), Bordo and Choudri (1982), Cuddington (1983), Imrohoroglu (1994), and there are a lot of studies focusing on other countries.

In the empirical literature CS is defined and estimated in different ways. Several categories of empirical models can be identified.

The models of the first type (called sequential portfolio balance models) divide the problem into two steps: at first, agents choose the optimal mix of monetary and non-monetary assets and then decide how to allocate the monetary assets between the different currencies in their portfolio. This approach was proposed by Miles (1978). Assuming constant elasticity of the substitution money service function, Miles gets the following

equation for the demand for domestic currency (M) relative to the foreign currency (eM^f):

$$\log \frac{M}{eM^f} = \alpha_0 + \alpha_1 \Big[\log(1 + i^f) - \log(1 + i) \Big], \qquad (1)$$

where e is the nominal exchange rate. Coefficient α_1 is the elasticity of currency substitution. This approach was modified by Bordo and Choudri (1982) by adding output to the maximization problem (and so output enters the estimated equation). Both studies were devoted to CS in Canada, but their findings were very controversial. A version of equation (1) was tested by El-Erian (1988) for Egypt and Yemen Arab Republic and by Mueller (1994) for Lebanon.

Models of the second type are based on the static two-period portfolio balance model. In this model an agent allocates his wealth among domestic money, foreign money, domestic bonds and foreign bonds. Demand for each asset is a function of income and asset returns. This approach can be illustrated by the equation for domestic real money balances (M/p) derived by Branson and Henderson (1985):

$$\log \frac{M}{p} = \beta_0 + \beta_1 \log y + \beta_2 r + \beta_3 (r^* + x) + \beta_4 x , \qquad (2)$$

where y is the domestic real income, r is the interest rate on domestic bonds, x is the expected rate of depreciation, and r^* is the interest rate on foreign bonds. In the presence of CS, β_4 should be significantly negative. Cuddington (1983) tested equation (2) for Canada (1970 – 1979) and found that CS isn't important. The model is sometimes modified to include a partial adjustment mechanism; as a result, the lagged dependent variable is included in the right-hand side. With this modification the model was tested by Gruben and Welch (1996) for Mexico, by Baffen and Hafer (1984) for Canada, France, Germany and United Kingdom, and by Marquez (1987) for Venezuela.

Thus, in portfolio models a statistically significant negative coefficient for the rate of depreciation (in the estimated domestic money equation) was taken as evidence of CS. But as Cuddington (1983) shows in a portfolio model with highly developed capital markets, the demand for real domestic money balances depends negatively on the expected rate of depreciation, independently of whether domestic residents hold foreign currency or not. That is, currency substitution and asset substitution were indistinguishable empirically. Optimization models are better from this point of view since the arguments of the money demand function are not chosen arbitrarily. One of the classical models of this type is devel-

oped by Thomas (1985). This model predicts that the ratio of domestic (M) to foreign money (eM^f) should depend negatively on the domestic nominal interest rate (i) and positively on the foreign nominal interest rate (i^f):

$$\frac{M}{eM^f} = f(\overset{-}{i}, \overset{+}{i^f}). \tag{3}$$

Note that econometric specifications that include both nominal interest rates and the rate of depreciation as explanatory variables of the ratio of domestic to foreign money do not follow from this standard optimizing model of CS. In empirical studies, equation (3) is sometimes modified to deal with cases of controlled interest rates. In this case, the expected rate of depreciation (ε) is taken as a proxy for the opportunity costs of holding money:

$$\frac{M}{eM^f} = g(\overset{-}{\varepsilon}). \tag{4}$$

Different variations of equations (3) and (4) were tested by Ramirez-Rojas (1985) for Argentina, Mexico and Urugway, and by Rojas-Suarez (1992) for Peru.

Recent econometric models deal with representative agent dynamic optimization models of demand for different currencies and authors make estimations based on the first-order condition of optimization rather than on a direct estimation of the money demand function. This category of models is presented by Bufman and Leiderman (1992) and Imrohoroglu (1994). Imrohoroglu considers a stochastic intertemporal CS model and estimates jointly the parameters of consumer preferences using the Generalized Method of Moments. The Bufman and Leiderman model deals with nonexpected utility, and so it allows one to separately estimate intertemporal substitution and risk aversion parameters. Very important features of these models represent intertemporal consideration and the possibility of substitution between consumption and money services, since this allows analyzing the full effect of monetary policy. As was demonstrated by Calvo (1985), the permanent decrease in domestic money growth leads to a temporary appreciation/depreciation of the real exchange rate if the elasticity of CS is larger/smaller than the elasticity of substitution between consumption and liquidity services. Empirical models of Imrohoroglu and Bufman and Leiderman are much closer to the underlying theoretical models than to those discussed before, and we construct our empirical model of CS following this method/approach.

Although there is a wide variety of empirical literature on CS, only a few studies deal with CS in transition economies. Korhonen (1996) made an attempt to explain the dollarization in Lithuania based on Thomas's (1985) portfolio model and found that the degree of dollarization reflected the domestic and foreign interest rate differential, that is, Lithuanian data agreed with the predictions of the theoretical model. Brodsky (1997) considers dollarization in Russia for the period 1994 – 1996. He looks at the dependence of the degree of dollarization on the difference between the growth of the exchange rate and the rate of inflation. Comparative analysis of the extent and evolution of dollarization in 15 economies in transition between 1990 and 1994 is presented in Sahay and Vegh (1995). A study of CS for the case of Kyrgyz Republic for the period 1993 – 1998 is presented in Mongardini and Mueller (1999). They found that both the interest rate differential and depreciation are significant determinants of the CS process in the Kyrgyz economy.

Now let us turn to the implications of CS. There are several policy issues arising from CS that are important for transition economies. The first problem that is widely discussed in economic literature is whether CS should be encouraged or not (Tanzi and Blejer, 1982; Cukierman, Kiguel and Liviatan, 1992; McNelis and Asilis, 1992; Rostowski, 1992; Savastano, 1992). Views differ substantially on this point: from full dollarization to complete dedollarization of the economy. The second problem deals with the choice of nominal anchors in inflation stabilization programs, and particularly the question of the choice of exchange rate regime is discussed (Girton and Poper, 1981; Kareken and Wallace, 1981; Calvo and Vegh, 1990, 1991; Rostowski, 1992). Most authors come to the conclusion that CS makes the exchange rate very volatile in response to policy changes. This observation makes a fixed exchange rate more appropriate in stabilization under a high degree of CS.

Another implication of CS that is very important for countries with high inflation is its effect on inflationary finance. Implications of CS for the optimal rate of inflation are considered in Khan and Ramirez-Rojas (1986), Hercowitz and Sadka (1987), Vegh (1989). Intuitively the higher is CS, the more difficult it is for the government to finance its deficit by printing money. There is a variety of empirical works estimating the effect of CS on seignorage: Bufman and Leiderman (1992) consider the case of Israel, Rojas-Suarez (1992) analyzes the case of Latin America, Imrohoroglu (1994) — the case of Canada. As was shown by Bufman and Leiderman, even a small increase in the dollarization ratio has a significant impact on the ratio of seignorage to GNP.

In our study we consider two effects of CS: following the approach proposed by Bufman and Leiderman (1992), we consider the effect of CS on seignorage, and we also estimate the welfare loss/gain from an increase in CS.

3. THEORETICAL MODEL

We use the dynamic model developed by Imrohoroglu (1994) in which in every period t, a representative agent derives utility from per capita consumption c_t and per capita money services s_t. Money services are provided by both domestic real money balances per capita m_t and foreign real money balances per capita $m_t^F : s_t = s(m_t, m_t^F)$. The household is assumed to maximize the expected value of the discounted utility:

$$max\ E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, s_t),$$

where $\beta < 1$ is the discount factor. Each household's budget constraint for period t in per capita real terms is given by:

$$c_t + m_t + m_t^F + b_t =$$
$$= \frac{m_{t-1}}{(1+\pi_t)(1+n_t)} + \frac{m_{t-1}^F(1+\varepsilon_t)}{(1+\pi_t)(1+n_t)} + \frac{b_{t-1}(1+R_{t-1})}{(1+\pi_t)(1+n_t)} + \overline{m}_t + \overline{m}_t^F,$$

where b_t is the real per capita value of one period bonds that give the nominal interest rate R_t between period t and $t + 1$; $\overline{m}_t$ is real per capita non-asset income in terms of domestic currency and $\overline{m}_t^F$ is real per capita income in terms of foreign currency; π_t, ε_t and n_t stand respectively for the rate of inflation, rate of depreciation and population growth rate from $t - 1$ to t. It should be noted that although it is prohibited to pay wages in foreign currency, this practice is still widely used in the private sector. We do not include labor/leisure choice in our model, assuming that income streams are given exogenously because there are no data on wages as well as employment in the dollarized sector, and so it is impossible to estimate how wages "paid in envelopes" affect the dollarization process.

Rearranging first order conditions, we get the following Euler equations:

$$\beta E_t\left[\frac{u'_{c_{t+1}}}{u'_{c_t}}\frac{1+R_t}{(1+\pi_{t+1})(1+n_{t+1})}\right]=1\,,\tag{5}$$

$$\frac{u'_{m_t}}{u'_{c_t}}=1-\beta E_t\left[\frac{u'_{c_{t+1}}}{u'_{c_t}}\frac{1}{(1+\pi_{t+1})(1+n_{t+1})}\right],\tag{6}$$

$$\frac{u'_{m_t^F}}{u'_{ct}}=1-\beta E_t\left[\frac{u'_{c_{t+1}}}{u'_{c_t}}\frac{1+\varepsilon_{t+1}}{(1+\pi_{t+1})(1+n_{t+1})}\right],\tag{7}$$

where u'_{x_t} is the marginal utility of x at time t.

In order to analyze the empirical implications of this model, we use the following utility function:

$$u(c,s)=\frac{(c^{1-\gamma}s^{\gamma})^{1-\alpha}-1}{1-\alpha}\,,\text{ where }s=[(1-\lambda)m^{-\rho}+\lambda(m^F)^{-\rho}]^{-1/\rho},\tag{8}$$

Coefficient γ (between zero and one) reflects the transaction requirement of money in a broad sense, parameter α ($\alpha > 0$) represents the coefficient of relative risk aversion and at the same time $1/\alpha$ gives the elasticity of intertemporal substitution. The case of $\alpha = 0$ we interpret as a logarithmic specification: $u(c, s) = (1 - \gamma) \log c + \gamma \log s$, that is, in this case the utility is separable across consumption and money services. Parameter ρ of the money services function is larger than minus one, $1/(1 + \rho)$ is the elasticity of substitution between domestic and foreign currency, and so it represents the degree of currency substitutability; λ lies between zero and one and shows the effectiveness of foreign currency in producing money services. The proposed specification of the utility function became widely used in the economic literature following the analysis of Kydland and Prescott (1982). It should be noted that using this function, we obtain a static model of currency substitution as a special case if $\beta = 0$, $\gamma = 1$ and consumption is treated as predetermined (that is, we get exactly the sequential portfolio balance model).

The model we use as well as the whole framework of our study obviously do not take into account all factors that could possibly influence the dynamics of dollarization. One of the stylized facts that remains beyond our work that we would like to discuss specifically is the phenomenon of hysteresis.

Most models of currency substitution predict that a successful stabilization program should lead to a de-dollarization process. However, this has usually not been the case in Latin American countries (such as Bolivia, Mexico, Peru and Uruguay). In Russia, dollarization levels were stable despite the low rates of inflation and ruble depreciation in 1995-mid 1998 and in late 1999 – 2000. Thus, the dollarization process exhibit "hysteresis," *i.e.*, dollarization ratios do not fall once inflation has been reduced. For the same level of inflation, the public holds less domestic money than before.

Explanations of the hysteresis of the dollarization process vary. The role of financial adaptation is discussed by Dornbusch and Reynoso (1989). Switching to a new currency (dollar) in the period of high inflation is costly and requires a learning process. In Russia, this process included a range of so-called "gray" schemes of business performance as well as double bookkeeping. Once this "investment" has been done, the public will continue to use these new financial schemes even if inflation falls.

Another explanation (Giovannini and Turtelboom, 1992) is linked to the degree of liquidity of a currency. If the domestic currency has low expected returns, the foreign currency becomes a significant liquid investment for domestic residents. Subsequently, the less the aggregate share of domestic currency, the less likely it is for a consumer to find a counterpart willing to accept it in payment for a good or a service. This externality can be used to explain hysteresis. However, we think that in the case of the Russian economy, the ruble remained fairly liquid as a means of payment.

Melvin and Fenske (1992) point out that the absence of de-dollarization could reflect the lack of credibility in the sustainability of the stabilization plan. We consider this factor applicable to the Russian case, too, but our model does not incorporate a variable reflecting the credibility of the financial system.

Inclusion of money services in the utility function reflects the role of both currencies in reducing transaction costs, but we do not take into account the special type of transaction costs that deals with foreign currency sales tax and other costs of converting currencies. The research could benefit from explicit inclusion of such costs in the model since, for example, a difference between buyers' and sellers' exchange rates is not stable and may help to explain the dynamics of dollarization. These costs were not included in the model mainly due to the absence of regular data on the difference between buyers' and sellers' exchange rates for the considered time period.

4. ESTIMATION METHODOLOGY

We rearrange equations (6) − (7), taking into account utility specification (8), and define the disturbances of the model as

$$d_{t+1} = \beta \left(\frac{c_{t+1}}{c_t} \right)^{\alpha(\gamma-1)-\gamma} \left(\frac{m_{t+1}}{m_t} \right)^{\gamma(1-\alpha)} \times$$

$$\times \left[\frac{1 - \lambda + \lambda(m_{t+1}^F / m_{t+1})^{-\rho}}{1 - \lambda + \lambda(m_t^F / m_t)^{-\rho}} \right]^{\gamma(\alpha-1)/\rho} \frac{1 + R_t}{(1 + \pi_{t+1})(1 + n_{t+1})} - 1,$$

$$d_{2t+1} = \frac{\gamma(1-\lambda)c_t / m_t}{1 - \lambda + \lambda(m_t^F / m_t)^{-\rho}} - (1 - \gamma) \times$$

$$\times \left\{ 1 - \beta \left(\frac{c_{t+1}}{c_t} \right)^{\alpha(\gamma-1)-\gamma} \left(\frac{m_{t+1}}{m_t} \right)^{\gamma(1-\alpha)} \times \right.$$

$$\left. \times \left[\frac{1 - \lambda + \lambda(m_{t+1}^F / m_{t+1})^{-\rho}}{1 - \lambda + \lambda(m_t^F / m_t)^{-\rho}} \right]^{\gamma(\alpha-1)/\rho} \frac{1}{(1 + \pi_{t+1})(1 + n_{t+1})} \right\},$$

$$d_{3t+1} = (1 - \lambda)(m_t^F / m_t)^{-\rho} - \lambda - \beta \left(\frac{c_{t+1}}{c_t} \right)^{\alpha(\gamma-1)-\gamma} \left(\frac{m_{t+1}}{m_t} \right)^{\gamma(1-\alpha)} \times$$

$$\times \left[\frac{1 - \lambda + \lambda(m_{t+1}^F / m_{t+1})^{-\rho}}{1 - \lambda + \lambda(m_t^F / m_t)^{-\rho}} \right]^{\gamma(\alpha-1)/\rho} \frac{(1 - \lambda)(m_t^F / m_t)^{-\rho}(1 + \varepsilon_{t+1}) - \lambda}{(1 + \pi_{t+1})(1 + n_{t+1})}$$

(a detailed description of the rearrangements is presented in Appendix A).

We estimate the vector of parameters $Q = (\beta, \alpha, \gamma, \lambda, \rho)$ by applying Hansen's (1982) generalized method of moments (GMM). The true vector of parameters $Q°$ should satisfy orthogonality conditions between disturbances $d_{t+1} = (d_{t+1}, d_{2t+1}, d_{3t+1})'$ and a set of instrumental variables I_t: $E(d_{kt+1}(Q°) I_{jt}) = 0$ for $k = 1, 2, 3$, where I_{jt} is any variable that belongs to the information set at time t. The GMM estimator selects parameter estimates so that the sample correlations between the instruments and the disturbances are as close to zero as possible by minimizing the quadratic form $g_T(Q)'W_T g_T(Q)$, where

$$g_T(Q) = \frac{1}{T} \sum_{t=1}^{T} I_t \otimes d_{t+1}(Q)$$

and W_T is a symmetric positive definite weighting matrix.

In estimating the model, we use two sets of instruments:

$$I_t^1 = \left\{1, m_t/m_{t-1}, (m_t^F/m_{t-1}^F)/(m_t/m_{t-1})\right\}$$

and

$$I_t^2 = \left\{1, c_t/c_{t-1}, m_t/m_{t-1}, (m_t^F/m_{t-1}^F)/(m_t/m_{t-1})\right\}.$$

5. DATA DESCRIPTION

The sample period extends from the beginning of 1995 to the middle of 2000; the following monthly data are used. Consumption is measured using the data from the Russian State Committee on Statistics (Goskomstat) monthly bulletin "Social and Economic Situation in Russia." Monthly CPI as a measure of inflation and data on the population that is necessary to obtain per capita figures are taken from the same bulletin. As a measure of domestic money, we use the base money from the "Banking Statistics Bulletin" published monthly by the Bank of Russia. For the exchange rate, we use the monthly average of the official daily CBR exchange rates taken from the same bulletin. We use different interest rates: interest rates on government bonds, interest rates on domestic currency deposits and interest rates on foreign currency deposits. These data are available from the Central Bank database.

There are some problems with the data on foreign currency holdings that complicate the measurement of the actual amount of CS. It should be mentioned that this is a common problem for the majority of studies on this subject. To get a good measure of CS, we should know the amount of foreign banknotes circulating in the economy (as a medium of exchange and as a store of value). There are no official data on foreign banknotes in circulation; however, as a lower estimate the Central Bank of Russia uses the figure of 10 billon U.S. dollars in cash held by non-bank residents on 01.01.95. As an alternative we use another figure estimated by several independent experts for 01.01.92: it amounts to 5 billon U.S. dollars. To obtain additional figures, we use the balance of payments data for 1992 − 1993, and starting from 1994 there are official Central Bank of Russia data on net foreign currency purchases by the population. However, not all purchases are officially registered (because there is a 1% tax on buying foreign currency and people try to evade it).

It should be noted that even if we take some initial estimate of the foreign banknotes in circulation and add *net* foreign currency purchases, the resulting figures do not perfectly represent the dynamic of foreign currency banknotes in the non-bank sector. There are at least two other very important flows that affect foreign currency in circulation. The first one deals with wages paid in dollars. Since it is officially prohibited to pay in dollars, there are no official statistics on the dynamics of dollar wage payments. There are some unofficial point estimates but no regular data that allows us to get a consistent measure of this phenomenon. That is why it was impossible to take these unofficial "payments in envelopes" into account while measuring CS. The other flow that directly affects foreign currency banknotes in the non-bank sector deals with unregistered imports. In Russia there is a certain amount of people who physically import goods by themselves without any firms or companies (so-called "shuttle-traders" or "chelnoki"). Those people have to buy a lot of dollars, but then they take these dollars out of the country. We will refer to this activity as unregistered imports. As it was pointed out in the work by Nikolaenko (1998), in order to get a correct estimate of foreign currency holdings, we should correct data on net purchases of foreign currency by the outflow of foreign currency due to unregistered import. As a result we decided to use the following four different definitions of foreign currency (FC) holdings:

1) The Central Bank's estimate of initial FC holdings plus net purchases of FC (denoted by CB);

2) The Central Bank's estimate of initial FC holdings plus net purchases of FC minus net outflow of FC due to unregistered imports (denoted by CB_im);

3) Experts' estimate of initial FC holdings plus net purchases of FC (denoted by EX);

4) Experts' estimate of initial FC holdings plus net purchases of FC minus net outflow of FC due to unregistered imports (denoted by EX_im).

It should be also noted that in our work we use data on foreign currency holdings, although most studies are based on foreign currency deposits since usually information on cash holdings of foreign currency is unavailable. So the estimates that we obtain reflect *currency* substitution, not *assets* substitution, as in most of the other works on CS.

One should take into consideration that the data series we are using are not long enough (because of the structural break in August 1998 we had to divide the period under study into two: before the crises and after the crises) to fully use the possibilities of GMM estimation.

6. ESTIMATION RESULTS

The model estimation results for four different definitions of foreign currency holdings and different interest rates are presented in Tables 1 and 2. It should be noted that when we consider foreign currency deposits instead of domestic currency deposits, the budget constraint of our model should be modified, and this is reflected in the Euler equations. The modification of orthogonality conditions for this case is presented in Appendix B.

For each estimate of foreign currency holdings we consider three interest rates: the domestic deposit interest rate (R), the interest rate on foreign currency deposits (R^F), and the interest rate on GKO. The time period for estimation differs among these cases. Due to the collapse of the GKO market in August 1998, GKO interest rates are available only before this date. In the case of domestic deposits we also look at the pre-crisis period, but the reason for that is different. Starting from August 1998, interest rates on domestic deposits were lower than the exchange rate depreciation for several periods. According to the presented theoretical model under such circumstances, a rational agent should convert his wealth from domestic deposits to other assets (*i.e.*, foreign currency) since foreign currency in this case gives a higher return and also provides liquidity services. In reality there were no sharp falls in domestic deposits. This can be explained by the fact that it was difficult (or even impossible) to withdraw money from the commercial banks. In the case of the interest rate on foreign currency deposits, we estimate the model separately for the pre-crisis and after-crisis periods.

Since in each case the number of orthogonality conditions exceeds the number of parameters, there are overidentifying restrictions, and we can test the validity of these restrictions using the J_T-statistic, reported at the bottom of the table. The J_T-statistic is the minimized value of the objective function times the number of observations. Under the null hypothesis that the overidentifying restrictions are satisfied, the J_T-statistic is asymptotically χ^2 with degrees of freedom equal to the number of overidentifying restrictions (Hansen, 1982). When we use instrument set I^1 we have three instruments with three Euler equations, so we get nine orthogonality conditions. Since we have 5 parameters to be estimated, there are four overidentifying restrictions. In instrument set I^2 we add one more instrumental variable for each equation, and as a result we get seven overidentifying restrictions in this case.

Although some variables entering the Euler equations $(5) - (7)$ are not stationary, we rearranged these equations in such a way that these

Table 1. GMM estimates of the model under alternative assets return.

	Instrument set I^1				Instrument set I^2			
	CB	CB_im	EX	EX_im	CB	CB_im	EX	EX_im
	Return: interest rate on domestic deposits							
β	0.989 (0.004)	0.989 (0.002)	0.989 (0.003)	0.988 (0.004)	0.993 (0.001)	0.990 (0.003)	0.991 (0.002)	0.993 (0.001)
α	−0.196 (0.109)	0.358 (0.248)	0.363 (0.272)	0.911 (0.257)	−0.095 (0.098)	0.649 (0.175)	0.175 (0.188)	0.236 (0.057)
γ	0.085 (0.007)	0.055 (0.005)	0.081 (0.007)	0.071 (0.004)	0.060 (0.006)	0.060 (0.004)	0.053 (0.004)	0.037 (0.004)
λ	0.524 (0.036)	0.387 (0.037)	0.494 (0.041)	0.386 (0.024)	0.442 (0.036)	0.384 (0.024)	0.460 (0.047)	0.398 (0.012)
ρ	−0.476 (0.128)	−0.571 (0.142)	−0.606 (0.140)	−0.512 (0.125)	−0.796 (0.283)	−0.765 (0.279)	−0.287 (0.152)	−0.753 (0.198)
J	4.243 [0.374]	3.525 [0.474]	3.403 [0.493]	4.744 [0.315]	5.594 [0.588]	7.215 [0.407]	6.804 [0.449]	6.710 [0.460]
	Elasticity of currency substitution							
	1.908	2.331	2.538	2.049	4.902	4.255	1.403	4.049
	Elasticity of intertemporal substitution							
	—	2.793	2.755	1.098	—	1.541	5.714	4.237
	Return: interest rate on GKO							
β	0.990 (0.006)	0.987 (0.005)	0.982 (0.006)	0.985 (0.007)	0.972 (0.004)	0.987 (0.008)	0.997 (0.004)	0.991 (0.009)
α	0.747 (0.170)	0.827 (0.277)	0.610 (0.183)	1.748 (0.420)	0.251 (0.197)	1.362 (0.303)	0.602 (0.174)	1.582 (0.372)
γ	0.135 (0.008)	0.122 (0.006)	0.140 (0.010)	0.111 (0.008)	0.140 (0.006)	0.115 (0.005)	0.157 (0.006)	0.116 (0.007)
λ	0.552 (0.036)	0.430 (0.011)	0.567 (0.046)	0.468 (0.017)	0.518 (0.018)	0.430 (0.003)	0.463 (0.012)	0.469 (0.013)
ρ	−0.459 (0.145)	−0.667 (0.066)	−0.484 (0.170)	−0.580 (0.130)	−0.608 (0.059)	−0.574 (0.089)	−0.547 (0.037)	−0.494 (0.099)
J	4.283 [0.369]	5.781 [0.216]	4.662 [0.324]	4.212 [0.378]	5.442 [0.606]	7.088 [0.420]	5.388 [0.613]	5.963 [0.544]
	Elasticity of currency substitution							
	1.848	3.003	1.938	2.381	2.551	2.347	2.208	1.976
	Elasticity of intertemporal substitution							
	1.339	1.209	1.639	0.572	3.984	0.734	1.661	0.632

Table 2. GMM estimates of the model for the pre-crisis and after-crisis periods.

| | Return: interest rate on foreign currency deposits | | | | | | | |
| | Before crisis | | | | After crisis | | | |
	CB	CB_im	EX	EX_im	CB	CB_im	EX	EX_im
β	0.989 (0.004)	0.982 (0.005)	0.990 (0.003)	0.994 (0.002)	1.002 (0.004)	1.009 (0.002)	1.005 (0.003)	1.005 (0.004)
α	−0.262 (0.187)	−0.255 (0.210)	−0.249 (0.191)	0.680 (0.079)	0.067 (0.070)	0.404 (0.024)	−0.055 (0.032)	0.086 (0.060)
γ	0.060 (0.008)	0.062 (0.007)	0.058 (0.007)	0.038 (0.001)	0.058 (0.014)	0.042 (0.003)	0.050 (0.019)	0.030 (0.010)
λ	0.545 (0.031)	0.454 (0.017)	0.575 (0.006)	0.378 (0.019)	0.247 (0.050)	0.203 (0.034)	0.270 (0.074)	0.286 (0.064)
ρ	−0.471 (0.116)	−0.392 (0.134)	−0.370 (0.326)	−0.801 (0.184)	−0.803 (0.047)	−0.738 (0.041)	−0.749 (0.079)	−0.799 (0.096)
J	4.673 [0.323]	4.576 [0.334]	4.850 [0.303]	4.252 [0.373]	2.678 [0.613]	2.889 [0.683]	2.641 [0.620]	3.346 [0.502]
Elasticity of currency substitution = $1/(1+\rho)$								
	1.890	1.645	1.587	5.025	5.076	3.817	3.984	4.975

The instrument set I^1 was used in estimating the model.

variables enter the modified equations as ratios (one plus growth rates) and indicate the lack of significant trends. So we can apply the GMM estimation that assumes stationarity of all variables in the estimated equations and instrumental variables.

Now let's look at the estimation results presented in Tables 1 and 2. All of the estimates of discount factor β exceed 0.95 and are quite similar across the different estimated systems. Most estimates of β are less than unity, but some estimates for the after-crisis period exceed one (see Table 2). A large value of the discount factor is a common problem in empirical studies of intertemporal Euler equations (see Eichenbaum, Hansen and Singleton, 1998). The coefficient of relative risk aversion α (which at the same time is the inverse of the intertemporal elasticity of substitution) varies significantly across different systems, and in most cases it was not precisely estimated. In some cases it was even negative, that is, it goes into the region where the utility function is not concave. For positive α the implied intertemporal elasticity of substitution ranges from 0.7 to 5.7.

The estimates of the share of liquidity services in the utility function (γ) change from 0.04 to 0.16 and are significant. The estimate of γ depends mainly on the return used: it is about 0.06 in the case of the interest rate on domestic deposits, about 0.05 in the case of the interest rate on foreign currency deposits and is larger (about 0.13) when the return on GKO is used. Note that the evidence does not support the case in which $\beta = 0$ and $\gamma = 1$, which corresponds to the static portfolio model of currency substitution (if consumption is treated as predetermined).

The estimate of the share of foreign money balances in the production of money services (λ) is large relative to its estimated standard errors in all considered systems and depends mainly on the time period. Estimates of λ for the pre-crisis period range from 0.38 to 0.57, and on average domestic and foreign currencies were almost equally productive in generating liquidity services in the pre-crisis period. If we look at after-crisis estimates of the relative effectiveness of foreign currency, we can observe a fall in λ. Estimates of λ range from 0.20 to 0.29, indicating that foreign currency becomes much less productive than the domestic one in generating liquidity services. These results seem to be counterintuitive: it is reasonable to expect an increase in the liquidity services of foreign currency under high inflation.

We can try to explain this paradox by several observations. First, it can be noted that there was rather short period of high inflation after the crisis, and we did not include the crisis itself in the considered time period. Second, the crisis brings a sharp decline in individuals' incomes, and during several periods after the crisis people dissave by selling dollars. This is not obvious from Fig. 1 because while constructing the graph we took into account a ruble value of dollar holdings (to make them comparable with ruble holdings). This approach is sometimes misleading since if the exchange rate goes up sharply, then the ruble value of foreign currency will also increase dramatically, while foreign currency holdings may stay the same or even decrease. To clarify this point we redraw Fig. 1 under the assumption of a constant exchange rate instead of taking the actual exchange rate. The results are presented in Fig. 2, which demonstrates that the dollarization ratio calculated under a constant exchange rate falls after the crises. Finally, after the 1998 crisis there was great uncertainty about the expected returns on financial assets, and people preferred to put money into physical assets by buying storable goods.

The estimated value for ρ, the parameter that determines the currency substitutability, varies from -0.29 to -0.8. Accordingly, the implied elasticity of currency substitution ranges from 1.4 to 5, and most of the es-
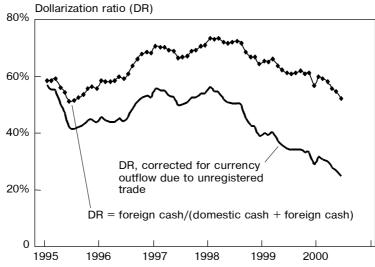
Dollarization ratio (DR)

Fig. 2. Dollarization ratio (DR) in Russia under constant exchange rate, 1995 – 2000.

timates of ρ give an elasticity of CS of about 2 or 3. So we can conclude that the ruble and the dollar are good substitutes in Russia for producing liquidity services.

Estimates of almost all parameters are rather close for different definitions of foreign currency holdings as well as for different asset returns and instrument sets used.

The values of Hansen's J_T chi-square statistic for testing the overidentifying restrictions of the model are small relative to the degrees of freedom for all considered cases. (Note that the number of overidentifying restrictions depends on the instrument set used: it equals four when I^1 is used, and equals seven when I^2 is used.) In all estimated systems the model's overidentifying restrictions are not rejected at the standard significance level, which means that the data provide support for the considered model.

7. CURRENCY SUBSTITUTION AND SEIGNORAGE REVENUES

One of the main policy issues arising from currency substitutability is its effect on the revenue from inflation. Bufman and Leiderman (1992) showed for the case of Israel that small increases in dollarization might

have a large impact on the seignorage. Following the work of Bufman and Leiderman we analyze the effect of an increase in the liquidity services of foreign money (that can be caused by institutional changes or by corresponding government policies) on seignorage. This change in liquidity services of foreign money is modeled by a change in λ.

Consider some hypothetical steady state, where per capita consumption, home and foreign per capita real money balances grow at a constant rate $\mu > 0$, the population grows at a constant rate n, and all real variables do not depend on changes in the inflation rate π. Using these assumptions together with first-order conditions, we get the steady state demand for per capita real money balances m:

$$m = \frac{\gamma}{1-\gamma} \frac{R_b c}{(R_b - R_m) + (R_b - R_{mf})\left(\dfrac{\lambda}{1-\lambda}\dfrac{R_b - R_m}{R_b - R_{mf}}\right)^{1/(1+\rho)}} , \tag{9}$$

where $R_b = (1 + R)/(1 + \pi)$, $1 + R = (1 + \pi)(1 + n)(1 + \mu)^\alpha/\beta$, $R_m = 1/(1 + \pi)$ and $R_{mf} = (1 + \varepsilon)/(1 + \pi)$.

The ratio of seignorage to GDP is given by

$$\frac{SE_t}{Y_t} = \frac{H_t - H_{t-1}}{H_t} \frac{H_t}{p_t Y_t} ,$$

where H_t is the monetary base. Under our assumptions the growth rate of money and monetary base can be expressed as

$$\frac{H_t}{H_{t-1}} = (1 + n)(1 + \mu)(1 + \pi)$$

and

$$\frac{H_t}{p_t Y_t} = \frac{H_t / p_t N_t}{Y_t / N_t} = \frac{m}{y} ,$$

where m is the steady state per capita real money balances and y is the per capita GDP. So, we get the following expression of the steady state seignorage/GDP ratio:

$$\frac{SE}{Y} = \left(1 - \frac{1}{(1+n)(1+\mu)(1+\pi)}\right)\frac{c}{y}\frac{m}{c} . \tag{10}$$

Now we can estimate the effect of an increase in the degree of dollarization (or an increase in λ) on the seignorage/GDP ratio for any given level of inflation.

Based on the estimates of the preference parameters discussed in the previous section, we will use the following values of these parameters in further simulations:

$\beta = 0.995$, $\alpha = 0.3$, $\gamma = 0.08$, $\rho = -0.5$, $c/y = 0.5$.

Other parameters are set equal to respective averages over the considered period: the rate of population growth is negative and equal to -0.03 percent per month, the rate of real per capita consumption is also negative and equal to -0.12 percent per month.

Table 3 contains steady state seignorage/GDP ratios calculated for different rates of inflation and different degrees of dollarization (*i.e.*, the relative effectiveness of foreign currency in producing liquidity services).

Table 3. Simulated Seignorage/GDP ratios (%).

π, %	Relative effectiveness of foreign currency (λ)				
	0.2	0.3	0.4	0.5	0.6
0.2	0.3	0.3	0.2	0.2	0.1
0.5	1.3	1.2	1.1	0.8	0.6
1.0	2.1	1.9	1.5	1.1	0.7
2.0	2.5	2.2	1.6	1.1	0.6
3.0	2.7	2.2	1.5	0.9	0.5
4.0	2.7	2.1	1.4	0.8	0.4
5.0	2.7	2.0	1.3	0.7	0.4
6.0	2.7	1.9	1.2	0.6	0.3
8.0	2.6	1.7	1.0	0.5	0.3
10	2.5	1.6	0.9	0.5	0.2
15	2.2	1.3	0.7	0.3	0.2
20	2.1	1.1	0.6	0.3	0.1

The results presented in this table were calculated using the following parameter values: $\beta = 0.995$, $\alpha = 0.3$, $\gamma = 0.08$, $\rho = -0.5$.

If we look at the last two columns of Table 3, we can note that if dollarization is high (λ is about 0.5), then a relatively small increase in the degree of dollarization may have a large negative effect on the revenue

from seignorage. In particular, as it can be seen from the Table 3, a 10 percent increase in λ from 0.5 to 0.6 leads to a 50 percent decrease in the seignorage/GDP ratio for almost all inflation rates. We can look at the results presented in the above table from a different perspective. If the relative effectiveness of foreign currency stays constant but the inflation rate changes, how does this affect the seignorage/GDP ratio? The resulted figures show that the higher is the relative effectiveness of foreign currency, the faster the economy reaches the inefficient part of the Laffer curve. Since in the previous section the parameter of risk aversion (α) was not precisely estimated in a number of systems, we look at the stability of the seignorage/GDP ratio with respect to different risk aversion parameters used. We recalculate the seignorage ratios for $\alpha = 0.6$ and present the corresponding results in Appendix C. As we can see, the results are not sensitive to the value chosen for parameter α. It should be noted that the actual levels of the seignorage/GDP ratio may differ from the steady state levels. In reality the growth rate of the real per capita monetary base do change, and as a result actual seignorage will fluctuate more than a steady state one.

In Table 4 we present the results for the simulated seignorage/GDP ratio for different inflationary periods. We start from 1995 and divide the pre-crisis period into two subperiods: before stabilization (January 1995 of 1996) and stabilization (February 1996 – July 1998). The after-crisis pe-

Table 4. Simulated Seignorage/GDP ratios for different inflationary periods.

Period	Annual rate of inflation, %	Simulated Seignorage/GDP ratio, %	Value of parameter λ used	Actual Seignorage/GDP ratio, %
01.95 − 01.96	105	1.9 1.2	0.3 0.4	2.05
02.96 − 07.98	10	1.0	0.5	0.90
08.98 − 07.99	126	2.6 2.2	0.2 0.25	2.51
08.99 − 07.00	19	2.2 2.1	0.25 0.3	2.02

The results presented in this table were calculated using the following parameter values: $\beta = 0.995$, $\alpha = 0.3$, $\gamma = 0.08$, $\rho = -0.5$.

riod is also divided into two subperiods: the first includes the crisis itself and the first year after the crisis (August 1998 – July 1999) and the second one is from August 1999 to July 2000. For each subperiod we use the value of parameter λ, based on estimates obtained in the previous section. For the pre-crisis period estimates of λ range from 0.38 to 0.57 and for the after-crisis period, from 0.2 to 0.29.

As we can see, the actual values of the Seignorage/GDP ratio do not change much although inflation is very different across the considered subperiods. The simulated values of revenues from seignorage, as it can be seen from Table 4, fit the data quite well.

8. WELFARE EFFECT OF DOLLARIZATION

An increase in the effectiveness of foreign money in generating liquidity services has two effects: it decreases revenues from inflationary finance (decreases seignorage) and affects the utility of a representative agent. To find the welfare implication of dollarization, we need to estimate both effects. We have discussed how to estimate the change in seignorage. Now let us consider the change in household welfare. To estimate the change in utility due to an increase in λ, we compute the change in per capita consumption that would compensate an individual for the change in the degree of dollarization from λ_0 to λ_1, so that the individual will be indifferent between the utility under the initial degree of dollarization and the utility he obtains under a new level of dollarization with compensation:

$$u(\lambda_1,\, c + \Delta c) = u(\lambda_0).$$

One period utility is given by

$$u(c,\, s) = [(c^{1-\gamma} s^{\gamma})^{1-\alpha} - 1]/(1 - \alpha),$$

where

$$s = [(1 - \lambda)\mathrm{m}^{-\rho} + \lambda(m^F)^{-\rho}]^{-1/\rho}.$$

Since parameter α was not precisely estimated, it makes sense to consider the positive monotonic transformation of one period utility $v(c,\, s) = c^{1-\gamma} s^{\gamma}$. By plugging the expression for money services (s) into this function and making some rearrangements we get

$$v(c,s) = c\left(\frac{m}{c}\right)^{\gamma(1+1/\rho)}\left[(1-\lambda)\frac{\gamma}{1-\gamma}\frac{R_b}{R_b-R_m}\right]^{-\gamma/\rho} = c\,\varphi(\lambda)\,, \tag{11}$$

where $R_b = (1+R)/(1+\pi)$ and $R_m = 1/(1+\pi)$. So we get

$$v(\lambda_1, c+\Delta c) = (c+\Delta c)\varphi(\lambda_1) = v(\lambda_1) + \Delta c\varphi(\lambda_1) = v(\lambda_0).$$

From compensation, in terms of consumption, we can proceed to the equivalence in terms of income if we assume a constant consumption/GDP ratio. So, we get the following expression for income compensation as a share of GDP:

$$\frac{\Delta y^{comp}}{y} = \frac{\Delta c}{c} = \frac{\varphi(\lambda_0)}{\varphi(\lambda_1)} - 1\,.$$

The overall change in welfare due to a change in the degree of dollarization from λ_0 to λ_1 can be calculated as

$$\frac{\Delta W}{Y} = \left(\frac{SE}{Y}(\lambda_1) - \frac{SE}{Y}(\lambda_0)\right) - \frac{\Delta Y^{comp}}{Y}\,. \tag{12}$$

By summing up the change in seignorage and the money equivalent of a change in utility, we implicitly assume that it is possible to use the additional revenue from money, resulting from a decrease in λ, to compensate individuals in case of losses by providing lump sum subsidies. It should be noted that the same methodology could be used to assess the welfare cost of inflation for a given degree of dollarization. Our welfare costs/benefits of inflation and dollarization may depend on the degree of distortiveness of inflation taxes relative to other taxes.

So, for each given value of λ, we can find the welfare cost of an increase in dollarization/dedollarization. As it follows from (10), an increase in λ leads to fall in real per capita money demand and so brings a decline in the steady state revenues from seignorage since the rate of money growth in the steady state is constant. The effect of a change in λ on the welfare of a representative individual, that is, on his income compensation, is ambiguous. For an infinitely small change in λ, we can write down income compensation in the following way:

$$\frac{\Delta Y^{comp}}{Y} = \frac{\varphi'_\lambda}{\varphi} = \frac{\gamma}{\rho}\frac{1-(m^F/m)^{-\rho}}{1-\lambda+\lambda(m^F/m)^{-\rho}}\,.$$

As it follows from this formula (if elasticity of currency substitution exceeds unity, which means that ρ is negative), compensation is positive if $m^F / m < 1$ and is negative in the opposite case. This result can be interpreted in the following way. If the considered currencies are substitutable (with elasticity of substitution exceeding one), then agents gain from an increase in relative effectiveness of foreign currency (λ), and so compensation is negative in the case when the economy is initially highly dollarized, that is when the ratio of foreign to domestic currency exceeds one. If initially dollarization was not big enough ($m^F / m < 1$), then agents suffer from an increase in λ, and compensation has to be positive.

Going back to the welfare gains/losses from a change in the degree of dollarization, we can say that a small change in λ will definitely lead to welfare losses if $m^F / m \leq 1$. In this case, both seignorage and welfare of the representative agent decreases. In the opposite case an increase in λ may lead to welfare gains rather than losses. In the Table 5 we represent the numerical results for welfare gains/losses resulting from a change in λ from 0.45 to 0.55. As we can see, an increase in dollariza-

Table 5. Welfare costs/benefits of an increase in λ from 0.45 to 0.55 for different rates of inflation.

Inflation rate per month, %	Change in Seignorage/GDP ratio, %	Compensation in terms of GDP, %	Welfare Gains/Losses, %
0.3	−0.13	1.03	−1.16
0.5	−0.26	0.67	−0.94
1.0	−0.43	0.01	−0.45
2.0	−0.52	−0.79	0.27
3.0	−0.51	−1.26	0.75
4.0	−0.48	−1.57	1.09
5.0	−0.45	−1.79	1.34
10.0	−0.32	−2.33	2.01
15.0	−0.25	−2.55	2.30
20.0	−0.21	−2.67	2.46
50.0	−0.12	−2.90	2.78
100	−0.08	−2.98	2.90

The results presented in this table were calculated using the following parameter values: $\beta = 0.995$, $\alpha = 0.3$, $\gamma = 0.08$, $\rho = -0.5$.

tion brings losses under very low inflation and increases welfare under higher inflation rates, since in this case losses from a fall in seignorage revenue are outweighed by the gain in welfare of the representative agent. We can also look at these figures as at an opposite process (*i.e.*, a decrease in λ or dedollarization). If the government tries to reduce dollarization by implementing some institutional changes that affects λ, then society faces welfare costs unless inflation is very low (less than or equal to 1% per month). The value of these welfare costs is rather large: about $1 - 2$ percent of GDP, which is comparable with actual revenue from seignorage.

Using the same methodology, we can estimate the welfare cost of inflation at a given degree of dollarization. The corresponding results are presented in Table 6. We considered a change in the inflation rate from almost zero inflation ($\pi = 0.015\%$ per month) to the rate of inflation given in the first column. We present the corresponding change in the seignorage/GDP ratio, the percentage change in income that compensates the representative consumer for a given increase in inflation, and the last column presents the overall welfare cost of inflation. For example, we can see that monthly inflation equal to 1% causes a steady state welfare loss of about 3% of GDP. The welfare cost of an inflation rate of 3.5% per month (the average rate for the considered period, from 1995 to mid of 2000, in Russia) is about $6 - 7\%$ of GDP.

Table 6. Welfare cost of inflation.

Inflation rate per month, %	Change in Seignorage/GDP ratio, %	Compensation in terms of GDP, %	Welfare Gains/Losses, %
0.015	—	—	—
0.5	0.8	2.5	−1.6
1.0	1.1	4.4	−3.3
2.0	1.1	6.3	−5.3
3.0	0.9	7.3	−6.4
4.0	0.8	7.9	−7.1
5.0	0.7	8.3	−7.6
10.0	0.5	9.2	−8.7
15.0	0.3	9.5	−9.2
20.0	0.3	9.7	−9.4
100	0.1	10.2	−10.1
1000	0.1	10.3	−10.2

The results presented in this table were calculated using the following parameter values:
$\beta = 0.995$, $\alpha = 0.3$, $\gamma = 0.08$, $\lambda = 0.5$, $\rho = -0.5$.

CONCLUSIONS

In this paper we found that dollar cash holdings in Russia provide a good substitute for rubles in terms of a reduction in transaction costs. Most of the estimates for the elasticity of currency substitution are between 2 and 3. Moreover, the estimate of the share of foreign currency in producing money services are significantly different from zero and vary from 0.38 to 0.57 for the pre-crisis period and from 0.2 to 0.29 for the after-crisis period.

It is interesting to compare our parameter estimates to the empirical findings for CS in other countries, obtained using similar methodology. Bufman and Leiderman (1991) estimated a similar model with non-expected utility (a special type of utility function that allows one to separate intertemporal substitution and degree of risk aversion) for Israel for the period 1978 – 1988. The elasticity of CS for Israel is also greater than one (most of the estimates are about 3) and the share of foreign currency in the money services function was a bit less than 0.5. The other work that deals with GMM estimates of CS was done by Imrohoro-glu (1991) for the case of Canada. He finds that the elasticity of CS is about 0.3 and the share of foreign currency in the production of liquidity services is also very small. So CS appears to be important in high inflation countries like Russia and Israel and is not so important in low inflation economies like Canada.

Applying the estimated parameters to the hypothetical steady-state we found that a small change in the relative effectiveness of foreign currency has a sizable effect on the seignorage/GDP ratio if the degree of dollarization is large enough. The welfare analysis shows that for a given rate of inflation, an increase in the degree of dollarization leads to a fall in seignorage but ambiguously affects a representative agent's utility. The overall effect appears to be negative for low inflation and positive for other inflation rates. We can conclude that if the government undertakes some measures to reduce the degree of dollarization, the result will be welfare losses of about 2% of GDP unless inflation is very low.

This analysis could be extended in a number of directions. First, the model can be modified to include costs of converting currencies directly. These costs (reflecting tax on purchases of foreign currency and buying/selling exchange rate differentials) may add explanatory power to the considered model. Second, we considered only steady state effects of inflation and dollarization on seignorage and welfare. But the results may

differ for periods with volatile inflation. Had the analysis been extended
for an equilibrium path then, for example, changes in the degree of dol-
larization might affect not only the monetary base, but the rate of money
growth as well, which is important for calculating seignorage revenues.
Third, in calculating welfare costs/benefits of changes in inflation and
degree of dollarization, we do not take into account the distortions in-
duced by inflation tax. Finally, it would be interesting to make a similar
analysis for other transition economies.

APPENDIX A

Using utility specification (8), we can rewrite equations (5) − (7):

$$\beta E_t \left\{ \begin{array}{l} \left(\dfrac{c_{t+1}}{c_t}\right)^{\alpha(\gamma-1)-\gamma} \left(\dfrac{m_{t+1}}{m_t}\right)^{\gamma(1-\alpha)} \times \\[2mm] \times \left[\dfrac{1-\lambda+\lambda(m_{t+1}^F/m_{t+1})^{-\rho}}{1-\lambda+\lambda(m_t^F/m_t)^{-\rho}}\right]^{\gamma(\alpha-1)/\rho} \dfrac{1+R_t}{(1+\pi_{t+1})(1+n_{t+1})} \end{array} \right\} = 1, \qquad \text{(A1)}$$

$$\frac{\gamma}{1-\gamma}\frac{(1-\lambda)c_t/m_t}{1-\lambda+\lambda(m_t^F/m_t)^{-\rho}} =$$

$$= 1 - \beta E_t \left\{ \begin{array}{l} \left(\dfrac{c_{t+1}}{c_t}\right)^{\alpha(\gamma-1)-\gamma} \left(\dfrac{m_{t+1}}{m_t}\right)^{\gamma(1-\alpha)} \times \\[2mm] \times \left[\dfrac{1-\lambda+\lambda(m_{t+1}^F/m_{t+1})^{-\rho}}{1-\lambda+\lambda(m_t^F/m_t)^{-\rho}}\right]^{\gamma(\alpha-1)/\rho} \dfrac{1}{(1+\pi_{t+1})(1+n_{t+1})} \end{array} \right\}, \quad \text{(A2)}$$

$$\frac{\gamma}{1-\gamma}\frac{\lambda c_t/m_t^F}{(1-\lambda)(m_t^F/m_t)^{\rho}+\lambda} =$$

$$= 1 - \beta E_t \left\{ \begin{array}{l} \left(\dfrac{c_{t+1}}{c_t}\right)^{\alpha(\gamma-1)-\gamma} \left(\dfrac{m_{t+1}}{m_t}\right)^{\gamma(1-\alpha)} \times \\[2mm] \times \left[\dfrac{1-\lambda+\lambda(m_{t+1}^F/m_{t+1})^{-\rho}}{1-\lambda+\lambda(m_t^F/m_t)^{-\rho}}\right]^{\gamma(\alpha-1)/\rho} \dfrac{1}{(1+\pi_{t+1})(1+n_{t+1})} \end{array} \right\}. \quad \text{(A3)}$$

In order to preserve econometric identification of parameter ρ under $\lambda = 0$ or $\gamma = 0$, we divide (A2) by (A3) and after some rearrangements

obtain

$$(1-\lambda)(m_t^F/m_t)^{-\rho} - \lambda =$$

$$= \beta E_t \left\{ \begin{array}{l} \left[\left(\dfrac{c_{t+1}}{c_t}\right)^{\alpha(\gamma-1)-\gamma} \left(\dfrac{m_{t+1}}{m_t}\right)^{\gamma(1-\alpha)} \times \\[4mm] \times \left[\dfrac{1-\lambda+\lambda(m_{t+1}^F/m_{t+1})^{-\rho}}{1-\lambda+\lambda(m_t^F/m_t)^{-\rho}}\right]^{\gamma(\alpha-1)/\rho} \dfrac{(1-\lambda)(m_t^F/m_t)^{-\rho}(1+\varepsilon_{t+1})-\lambda}{(1+\pi_{t+1})(1+n_{t+1})} \end{array} \right\}. \quad (A4)$$

APPENDIX B

When we consider foreign bonds instead of domestic ones, then the budget constraint becomes

$$c_t + m_t + m_t^F + b_t^F =$$

$$= \frac{m_{t-1}}{(1+\pi_t)(1+n_t)} + \frac{m_{t-1}^F(1+\varepsilon_t)}{(1+\pi_t)(1+n_t)} + \frac{b_{t-1}^F(1+R_{t-1}^F)(1+\varepsilon_t)}{(1+\pi_t)(1+n_t)} + \overline{m}_t + \overline{m}_t^F,$$

where b_t^F stands for foreign bonds and R_{t-1}^F — corresponding interest rate.

The Euler equations (6) and (7) are still valid, but equation (6) now takes the form

$$\beta E_t \left[\frac{u'_{c_{t+1}}}{u'_{c_t}} \frac{(1+R_t^F)(1+\varepsilon_{t+1})}{(1+\pi_{t+1})(1+n)} \right] = 1,$$

and similar modification appears in the disturbance for this equation: in (A1) we should replace $(1+R_t)$ by $(1+R_t^F)(1+\varepsilon_{t+1})$.

APPENDIX C

Table 7. Simulated Seignorage/GDP ratios (%) for alternative values of risk aversion: $\alpha = 0.6$.

π, %	Relative effectiveness of foreign currency (λ)				
	0.2	0.3	0.4	0.5	0.6
0.2	0.3	0.3	0.3	0.2	0.2
0.5	1.4	1.3	1.1	0.9	0.6
1.0	2.1	1.9	1.6	1.1	0.7
2.0	2.6	2.2	1.6	1.1	0.6
3.0	2.7	2.2	1.5	0.9	0.5
4.0	2.7	2.1	1.4	0.8	0.4
5.0	2.7	2.0	1.3	0.7	0.4
10.0	2.5	1.6	0.9	0.5	0.2
15.0	2.2	1.3	0.7	0.3	0.2
20.0	2.0	1.1	0.6	0.3	0.1

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