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Network Externalities and Dollarization Hysteresis: The Case of Russia

Nienke Oomes

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Prepared by Nienke Oomes*

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Abstract

Dollarization in Russia increased rapidly during the early 1990s, but failed to come down in the second half of the 1990s in spite of exchange rate stabilization. To explain this "dollarization hysteresis," this paper develops a model in which network externalities in the demand for currency can generate multiple stable steady states for the dollarization ratio. The model is estimated using a new source of data on dollar currency holdings in Russia. On the basis of these estimates, which confirm the existence of network externalities, the paper discusses several policies that could result in a permanent decrease in dollarization.

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Keywords: dollarization, currency substitution, ratchet effect, network externalities, Russia

Author's E-Mail Address: noomes@imf.org

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I. Introduction

Dollarization is commonly defined as "the holding by residents of a significant share of their assets in the form of foreign-currency-denominated assets" (Baliño, Bennett, and Borensztein, 1999, p. 1). More specifically, we can distinguish between "currency dollarization," which refers to the holding of foreign currency (cash), and "deposit dollarization," which refers to the holding of foreign-currency deposits.[1] Since data on currency dollarization are usually unavailable, the vast majority of studies on dollarization have focused on deposit dollarization, and typically measure the degree of dollarization by the ratio of foreign-currency deposits to broad money.[2] In many dollarized countries, however, currency dollarization may be at least as important as deposit dollarization. This is particularly true for transition countries, where undeveloped and fragile banking systems, combined with large underground economies, led many residents to prefer foreign cash to foreign-currency deposits in response to periods of high inflation in the early 1990s.[3]

While there exists a substantial empirical literature on dollarization, relatively little attention has been devoted to dollarization in transition economies, most likely due to the lack of data on foreign-currency holdings.[4] This paper presents a new estimate of currency dollarization in Russia, which is based on data collected by the U.S. Customs Service and the Federal Reserve Bank of New York. It focuses on Russia because (1) Russia is generally considered as the country with the second largest holdings of U.S. dollar currency after the United States, with recent estimates varying between $40 billion to $80 billion;[5] and (2) very little research has been done thus far on dollarization in Russia.[6]

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[1]A related distinction is that between currency substitution and asset substitution (Calvo and Végh, 1992). However, currency dollarization is not equivalent to currency substitution, since the latter is defined as the use of foreign currency as a medium of exchange, while the former also includes the use of foreign currency as a store of value. Similarly, deposit dollarization is not equivalent to asset substitution, since the latter is defined as the use of any foreign-currency instruments (including cash) as a store of value, while the former is limited to foreign-currency deposits.

[2]An additional form of dollarization, not discussed in this paper, is the use of foreign currency as a unit of account, which occurs when prices, wages, or debt are indexed in foreign currency (e.g., Ize and Parrado, 2002). The latter case is also referred to as "liability dollarization" (e.g., Reinhart, Rogoff, and Savastano, 2003).

[3]However, Havrylyshyn and Beddies (2003) show that, in recent years, the ratio of foreign-currency deposits to broad money has increased in many transition economies, which they attribute to increased confidence in banking systems.

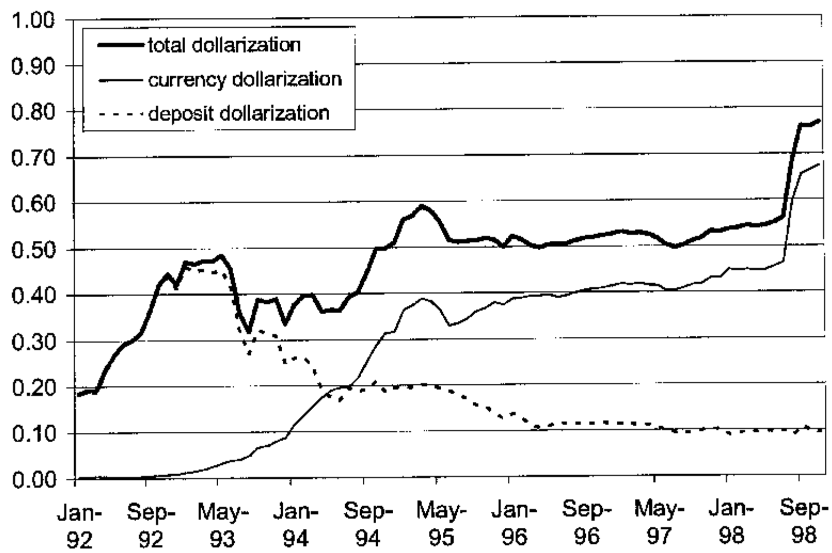
[4]Notable exceptions are Havrylyshyn and Beddies (2003); Feige and Dean (2002); Mongardini and Mueller (1999); Sahay and Vegh (1995a and 1995b); and Van Aarle and Budina (1995).

[5]In April 2000, the Federal Reserve Bank of New York estimated that 70 percent of the world circulation of U.S. dollars (itself estimated at $560 billion) was located outside the United States, with Russia constituting the main destination (*Moscow Times Business Review*, Vol. 8, No. 7, p. 61).

[6]I am aware of only two other studies on dollarization in Russia: Brodsky (1997) and Friedman and Verbetsky (2000). Two related studies are Morrien (1997), who does not provide any empirical analysis, and Choudhry (1998), whose estimates of a Cagan money demand function for Russia

As Figure 1 shows, currency dollarization in Russia increased dramatically during the 1990s, and estimated dollar currency holdings at end-1998 constituted about two-thirds of effective broad money (defined as broad money plus foreign currency in circulation), or about \$60 billion. During the same period, deposit dollarization decreased significantly, and stabilized at about 10 percent of the effective broad money supply.[7] Focusing on deposit dollarization, therefore, as most dollarization studies have done, leads to a serious underestimation of dollarization in Russia, which may explain why this country has not received more attention in the dollarization literature.

Figure 1. Dollarization in Russia, 1992–98 (In percent of effective broad money)



The main goal of this paper is to explain the rise in the demand for dollar currency in Russia, and, in particular, the persistence of this demand. Since our focus is on currency dollarization, the dollarization ratio we study is simply the ratio of dollar currency to total currency in circulation.[8] As Figure 2 shows, this dollarization ratio increased rapidly in the early 1990s, when ruble depreciation was high, but it did not fall back when the exchange rate subsequently stabilized between mid-1995

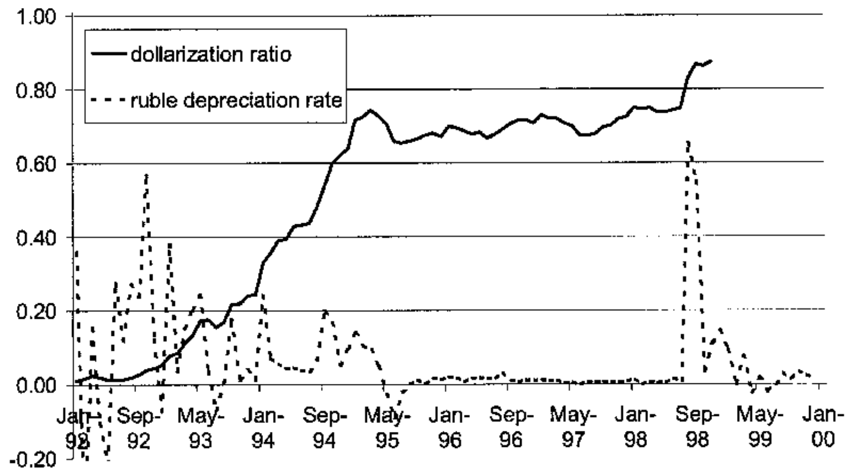
suggest that there is significant currency substitution, but who does not explicitly test for it.

[7]For a description of the data used in Figure 1, see Section IV.B and the Appendix.

[8]While we could have included foreign-currency deposits in both the numerator and denominator of this ratio, simply adding up currency and deposits would assume that these are perfect substitutes, which is not the case. As Ize and Parrado (2002) note, the demand for foreign currency depends on expected inflation differentials (or expected currency depreciation), while the demand for foreign-currency deposits depends on the volatility of these variables (since interest rate differentials should offset predictable inflation differentials, depending on the extent to which interest rate parity holds).

and mid-1998.[9] This phenomenon, which we term *dollarization hysteresis*,[10] has been observed in many other dollarized countries as well, but satisfactory explanations are still lacking.

Figure 2. Currency Dollarization in Russia, 1992–99 (In percent of total currency)



Econometrically, dollarization hysteresis is typically accounted for by including a so-called ratchet variable, e.g., the maximum past depreciation rate, in a money demand function. The statistical significance of such a variable can then be interpreted as reflecting the fact that temporarily high levels of depreciation are long remembered by agents. While acknowledging that long-term effects on expectations have likely played a role in Russia, this paper puts forward an additional explanation for dollarization hysteresis, i.e., the existence of network externalities in the use of currency. Assuming that foreign currency is used at least in part as a means of payment, network externalities arise naturally because the benefits for a given agent of holding a certain currency will increase with the rate at which this currency is accepted as a means of payment by other agents. In other words, when dollar currency holdings grow within a given trade network, this increases the value of holding dollars for each member of the network, irrespective of the depreciation rate or other rate of return considerations. If network externalities are strong enough, then, a high degree of dollarization can persist after exchange rate stabilization, even in the absence of ratchet variables.[11]

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[9]The jump in both depreciation and dollarization at the end of 1998 corresponds to the August 1998 financial crisis, when the ruble lost 65 percent of its value in one month and another 55 percent in September 1998.

[10]The term hysteresis is derived from the Greek $\upsilon\sigma\tau\epsilon\rho\epsilon\omega$, to be behind, and was first applied to scientific phenomena by James Alfred Enwing in 1881: "these curves exhibit, in a striking manner, a persistence of previous state… to this action… the author now gives the name Hysteresis" (Cross and Allan, 1998, p. 26).

[11]In addition, network externalities may help explain why in certain countries (mainly in Latin America and the former Soviet Union) dollarization has taken place in the form of U.S. dollars, while in other countries (mainly in Central and Eastern Europe) people have preferred to hold the deutsche mark,

Standard models of dollarization are portfolio balance models in which a single representative agent chooses domestic and foreign-currency holdings so as to maximize the production of liquidity. Such models cannot account for network externalities, since they typically assume that the share of each currency in producing liquidity is constant over time and independent of the dollarization ratio.[12] As an alternative, this paper presents a multi-agent discrete choice model, inspired by the interactions-based framework of Brock and Durlauf (2001a and 2001b), in which the share of a currency in producing liquidity depends on this currency's rate of acceptance as a means of payment. This implies that one agent's currency choice depends on the currency choices made by other agents. The model shows that such network externalities can lead to multiple steady-state dollarization ratios, and explains dollarization hysteresis as the movement from a low to a high steady state.

In order to prevent misunderstandings, two caveats should be made up front. First, while this paper focuses on network externalities as an explanation for dollarization hysteresis, the model incorporates two other factors that have previously been put forward as explanations, i.e., transaction costs and expectational adjustment periods. In fact, transaction costs are shown to be a necessary condition for network externalities, while expectational adjustment periods are shown to be an empirically significant factor. The second caveat is that this paper does not assume that the demand for foreign currency is determined only by a transactions motive. While the total demand for money is determined by the value of transactions, the fraction of total money demand that is held in the form of foreign currency is determined, in part, by store-of-value considerations. Nevertheless, this paper does not explicitly model the demand for foreign currency as a store of value. An important suggestion for future research, therefore, is to extend the model so as to explicitly distinguish between the store of value and transactions motive for holding foreign currency.

The remainder of this paper is organized as follows. Section II defines dollarization hysteresis, and discusses several different explanations for this phenomenon. The model is presented in Section III, and is estimated using a new estimate of dollar currency in Russia, which is described in Section IV.B, and in more detail in the Appendix. Section IV describes the estimation procedure and empirical results, which are consistent with the existence of network externalities and multiple steady states. Finally, Section V discusses several policy instruments that could be used to reduce dollarization. In particular, we show that a permanent decrease in dollarization can be obtained by a temporary appreciation of the ruble and by a temporary increase in enforcement of the law that prohibits dollar transactions. Section VI summarizes and concludes.

II. Dollarization Hysteresis

We define dollarization hysteresis as the phenomenon that occurs when dollarization increases with exchange rate depreciation or inflation, but does not decrease with subsequent reductions in these variables. Indeed, the phenomenon of dollarization hysteresis has been observed so often that Mongardini and Mueller (1999), following Mueller (1994), even *define* a dollarized economy as an

and now the euro.

[12] Portfolio balance models of dollarization go back to Miles (1978) and Chetty (1969). For an overview of such models see Mizen and Pentecost (1996).

economy in which "the demand for foreign currency rises when the local currency depreciates, but falls *by a lesser extent* when the local currency appreciates" (Mongardini and Mueller, 1999, fn. 3).

A. Evidence

Interestingly, evidence for dollarization hysteresis has been found most often in cases where estimates of dollar currency in circulation were used instead of, or in addition to, data on dollar-denominated deposits. For example, Kamin and Ericsson (1993), who used data on recorded inflows and outflows of dollar currency between Argentina and the United States,[13] found that a high degree of dollarization persisted in Argentina during the early 1990s, even after inflation had returned to very low rates. A similar phenomenon was observed by Peiers and Wrase (1997), whose estimate of dollar currency in circulation in Bolivia was based on loan data from informal credit markets. They found that the ratio of dollar to domestic bank deposits increased, rather than decreased, following successful monetary and fiscal reform in 1985. Finally, Mongardini and Mueller (1999) found evidence for dollarization hysteresis in the Kyrgyz Republic, based on daily data of flows of foreign currency through foreign exchange offices.[14] They also observed that in many other former Soviet Union republics, including Russia, dollarization ratios remained at high levels even after prices and exchange rates stabilized in the mid-1990s.

The studies mentioned above typically accounted for hysteresis by means of so-called "ratchet variables," which are often included in estimations of money demand functions, as well as in other areas of applied economics.[15] A ratchet variable is defined as the maximum value of a key independent variable (or sometimes of the dependent variable itself) over the past n periods. When such a ratchet variable is found to be significant in a regression, this is interpreted as evidence of a "ratchet effect". For example, Kamin and Ericsson (1993) found that a ratchet variable for inflation was significant in explaining dollarization hysteresis in Argentina, while Peiers and Wrase (1997) found significant ratchet effects for inflation, inflation volatility, and the volatility of exchange rate depreciation in Bolivia. Somewhat unconventionally, Mueller (1994) and Mongardini and Mueller (1999), in their studies of dollarization in Lebanon and the Kyrgyz Republic, respectively, included as a ratchet variable the past maximum value of the dollarization ratio itself, with mixed results.

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[13] These data were derived from the Currency and Monetary Instrument Reports (CMIRs) of the U.S. Customs Service, a source which was used for our estimate of currency dollarization as well (see Section IV.B and the Appendix).

[14] Interestingly, these authors found evidence for hysteresis in the ratio of foreign to domestic deposits, while they did not find such evidence when their estimate of foreign currency was included in the dollarization ratio. However, this result may be partially due to the fact that, prior to 1996, "the data were extrapolated by assuming that foreign cash holdings moved proportionally to foreign currency deposits... [which] is equivalent to assuming that the [dollarization] ratio only moves on account of foreign currency deposits" (Mongardini and Mueller, 1999, p. 6).

[15] For example, in the late 1970s and early 1980s, in order to explain the impact of volatile and high interest rates on the United States, and during the 1980s for various high-inflation countries. See Mongardini and Mueller (1999, Section V) for more examples.

B. Explaining Hysteresis

It is tautological to interpret the finding of a ratchet effect (i.e., a significant ratchet variable) as an explanation for hysteresis. By definition, a ratchet effect occurs when a dependent variable reacts asymmetrically to changes in an independent variable (Mongardini and Mueller, 1999). This is essentially synonymous with our definition of dollarization hysteresis, when the dependent variable is the dollarization ratio, and the independent variable is the rate of exchange rate depreciation or inflation.

The relevant question, therefore, is how to explain the existence of a ratchet, or hysteresis, effect. One explanation is that ratchet variables capture *expectational adjustment periods*: the fact that it takes time before agents become convinced that current macroeconomic stability has permanence (e.g., Peiers and Wrase, 1997). Another explanation is that ratchet effects result from the fact that there are transaction costs associated with switching between currencies (e.g., Guidotti and Rodriguez, 1992), or with learning how to use foreign-currency instruments (e.g., Dornbusch, Sturzenegger, and Wolf, 1990; Sturzenegger, 1992; and Mueller, 1994).[16] Such switching costs can lead to a ratchet or hysteresis effect because they generate a certain range of values for inflation or depreciation within which there is no incentive to de-dollarize. Even if switching costs are one-sided, as in the case of learning costs associated with the use foreign-currency instruments, they can provide an explanation for hysteresis. This is because agents who have learned to use the new instrument may not want to switch back to local currency even when the economy stabilizes, as long as they believe that there is a sufficiently large chance that they will need to switch to foreign-currency instruments again in the future.[17]

The model presented in this paper takes into account both expectational adjustment periods and transaction costs as possible explanations for hysteresis. For example, our specification of exchange rate expectations includes a ratchet variable for depreciation, which is found to be significant, suggesting that expectational adjustment periods seem to have played a role in Russia. In addition, our model includes several transaction or switching costs, including the "shoe-leather cost" of walking to an exchange office. Since the model focuses on currency dollarization, it does not take into account a learning cost (which is negligible for foreign currency), but it does allow for the existence of a one-sided transaction cost, i.e., a tax on foreign currency purchases. In addition, however, the model introduces a different explanation for hysteresis: network externalities.

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[16]Engineer (2000) uses a different interpretation of "currency transaction costs," and assumes that the costs associated with transacting are higher for foreign than for domestic currency because foreign currency is more likely to be counterfeited and costs are incurred in verification. This, however, does not provide an explanation for dollarization hysteresis.

[17]Mueller (1994) gives a slightly different interpretation: "The existence of the ratchet effect is attributed to prolonged periods of financial innovation and the related fixed costs of developing, learning, and applying these new money management techniques to beat inflation. Once these fixed costs are overcome, households and enterprises have little incentive to switch back to domestic currency after the period of instability ends. As a result, the effect on the relative demand for foreign and domestic currency is more long-lasting."

C. Network Externalities

Currency choice is subject to network externalities when the relative returns to holding a given currency increase with the demand for this currency by other agents. The notion that network externalities can lead to the emergence of a dominant currency as a medium of exchange can already be found, to some extent, in the famous Kiyotaki and Wright (1989) model, in which fiat money appears as a self-fulfilling prophecy. In subsequent extensions of this model, it has been shown that it is possible to construct "dual currency regimes" in which multiple fiat monies circulate within a given country with different acceptance rates.[18] As far as we know, however, this framework has never been explicitly used to explain dollarization hysteresis, nor does it appear to have been used in any empirical applications.

An explicit connection between network externalities and dollarization hysteresis was made by Uribe (1997). In his model, externalities exist because an increase in the aggregate level of dollarization reduces a given agent's marginal cost of performing transactions in dollars. He argues that "if the economy is not dollarized (i.e., if agents are not used to receiving foreign currency in exchange for goods) it is more costly for the consumer to carry out transactions in the foreign currency. Conversely, in an environment in which everybody is used to dealing in dollars, it is easier for the consumer to use dollars as a means of exchange" (Uribe, 1997, p. 3). He models this notion of "getting used to" transacting in a foreign currency by assuming that each good purchased using foreign currency is subject to a transaction cost, which is a negative function of what he calls dollarization capital: the knowledge accumulated by the economy up to period t in transacting in a foreign currency. Furthermore, he assumes that this dollarization capital evolves according to a specific law of motion that guarantees the existence of multiple steady states for dollarization. This, then, allows him to explain dollarization hysteresis as the transition from a low to a high steady state.

A somewhat similar model was developed, apparently independently, by Peiers and Wrase (1997). In their model, network externalities also occur because the increased "experience with" dollar-denominated transactions is assumed to reduce the marginal cost of borrowing and transacting in dollars. This is modeled by including the dollarization ratio as a "demand-side externality" among the factors that determine a buyer's transaction costs, where the dollarization ratio is measured empirically as the percentage of daily informal market loans denominated in dollars. This variable is found to be empirically significant, which is interpreted as evidence of hysteresis.

While they offer some interesting insights, the main drawback of the models mentioned above is that they do not easily lend themselves to empirical estimation. Uribe (1997) is able to calibrate his model using actual inflation data for Peru, but only after imposing some specific functional forms and assuming some very specific theoretical parameter values. He also recommends that standard econometric models of money velocity should include a proxy for dollarization capital, but does not carry out any econometric estimation himself. While Peiers and Wrase (1997) do carry out an empirical estimation, this is not a direct estimation of their model.[19]

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[18] See Aiyagari and Wallace (1992); Matsuyama, Kiyotaki, and Matsui (1993); and Kiyotaki and Wright (1993).

[19] Their model uses a general equilibrium setup to derive demand and supply functions for loans

The model presented in Section III below aims to bridge the gap between the empirical literature on dollarization, which does not take network externalities into account, and the theoretical literature described above, which has empirical shortcomings. The theoretical framework differs somewhat from the models discussed above in the sense that network externalities are not assumed to exist a priori, but occur only if the relative benefits of holding dollars (which depend on transaction costs, the depreciation rate, and confiscation risk) are higher when other agents prefer to hold dollars, and vice versa for rubles. Like in Uribe's (1997) model, network externalities are shown to generate multiple steady states, but without assuming a specific law of motion for the dollarization ratio. The main advantage of our model, however, is that it generates a reduced form that can be estimated, and the existence of network externalities is, in fact, confirmed empirically.[20]

III. The Model

A. Setup and Main Assumptions

Our economy is inhabited by many agents. Time is discrete, and, at $t = 0$, each agent is randomly assigned to be either a buyer (consumer) or a seller (producer) of a composite consumption good. In subsequent periods, all agents are alternately sellers and buyers. At each time t, each buyer is randomly matched with a seller. Buyers are subject to a cash-in-advance constraint: before being matched, they need to hold currency equal to the price of the composite good, which is assumed to be constant, and normalized to one.[21]

There are two types of currency: ruble currency (m) and dollar currency (m^*). Each payment is made either fully in rubles or fully in dollars. The cash-in-advance constraint, therefore, implies that each agent holds either rubles or dollars at any moment in time. When the ruble depreciates relative to the dollar, agents may benefit from holding dollar currency between the time they receive a payment and before making a payment themselves. However, accepting payments in dollars is illegal, and a seller who accepts dollars is punished with probability q by confiscation of the dollar bills involved in the transaction.[22] Purchasing dollars is legal, but it is discouraged by a tax rate τ that is levied on all purchases of foreign currency.[23]

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denominated in foreign and local currency, respectively, which are continuous variables. In the empirical estimation, however, the equilibrium fraction of dollar loans is assumed to follow a probit distribution, which implicitly assumes a very different model, one in which agents make a binary choice between foreign and local currency denominated loans.

[20]Like Peiers and Wrase (1997), we estimate a binary choice equation, but unlike them, we derive this equation directly from an underlying binary choice model.

[21]As noted above, this paper focuses on the demand for foreign currency, and therefore ignores deposits, which are of relatively little importance in Russia. However, including deposits in the choice set of agents would be an interesting extension of the model.

[22]This confiscation risk could be interpreted so as to include the risk of accepting counterfeited dollars (since receiving a counterfeited dollar bill is equivalent to having the dollar bill confiscated).

[23]A tax on purchases of foreign-currency instruments was effective in Russia from July 1997 through

The timing is as follows: consider a given agent i who is a seller at time t and will be a buyer at time $t+1$. The decision problem faced by this agent at time t is to decide which currency to hold after having been paid by a random buyer at time t and before being matched with a random seller j at time $t+1$. The interval between time t and time $t+1$ will be referred to as "period t." As we will show below, i's returns to holding a given currency during period t increase with the probability that j will want to hold this currency in period $t+1$ (i.e., with the average demand for this currency), which implies the existence of network externalities.

Let $m_{i,t} \in \{m, m^*\}$ denote the currency choice of agent i, where the subscript t indicates that the choice is made at time t (while the currency is held during period t). Table 1 represents the costs for agent i associated with each currency choice, conditional on the currency choice $m_{j,t+1}$ of seller j at time $t+1$. These costs are net of the cost of the good itself, which is normalized to unity.

Table 1. Cost Matrix for Agent i

	$m_{j,t+1} = m$	$m_{j,t+1} = m^*$
$m_{i,t} = m$	e	$e + \sigma + \tau$
$m_{i,t} = m^*$	σ	q

Suppose i decides to hold rubles, and j prefers to be paid in rubles (or, more precisely, j prefers to hold rubles in the next period). In this case, which corresponds to the upper left cell of the matrix, the payment is made in rubles, and the cost for i associated with holding rubles is simply the rate of ruble depreciation, e, during the period that rubles are held. (If the ruble appreciates, then this cost is, in fact, a benefit.)[24]

If i holds rubles but j prefers to hold dollars in the next period, then i still faces the cost e. However, in addition, there are now transaction costs associated with the fact that either i or j will have to exchange rubles for dollars. These transaction costs consist of two elements: first, the "shoe-leather cost" σ of walking to an exchange office, standing in line, etc., and second, the foreign-currency tax τ that must be paid when dollars are purchased. If i were to exchange the rubles in order to pay j in dollars, the total costs for i would thus be $e + \sigma + \tau$. However, in this case the transaction would be carried out in dollars, which is risky for j since the amount of the transaction can be confiscated with probability q, thus leading to an expected cost equal to q, which would be borne by the seller.[25] In order to avoid this cost, the seller could either accept dollars and charge the buyer a markup over the price of the good equal to q, or the seller could choose to accept rubles while charging a markup

December 2002. The initial rate of 0.5 percent was increased to 1 percent in 1998.

[24]We could have alternatively assumed, as in, e.g., Calvo and Vegh (1995), that the opportunity cost of holding rubles is the domestic interest rate r, while the opportunity cost of holding dollar currency is the foreign interest rate r^*. Under the assumption of uncovered interest rate parity ($r - r^* = e$), this would yield identical results.

[25]Since the price of the good is normalized to unity, the total tax amount that needs to be payed equals the tax rate τ, and the expected total cost of confiscation equals the probability of confiscation q. In reality, the expected cost of confiscation may well be higher, e.g., because sellers may risk losing their license.

equal to $\sigma + \tau$ to compensate for the transaction costs. In the first case, the total cost for the buyer is $e + \sigma + \tau + q$, while in the second case it is only $e + \sigma + \tau$. Since the latter is always less than the former, it is optimal for the buyer to pay in rubles, while compensating the seller for the transactions costs $\sigma + \tau$.

Now consider the reverse case, where buyer i is holding dollars while seller j prefers to hold rubles in the next period (i.e., the lower left cell of Table 1). In that case, i avoids the potential cost associated with ruble depreciation, but again, someone will have to change the dollars into rubles. Since no tax is charged when dollars are sold, the transaction costs in this case are simply equal to σ. Following a similar logic as before, it is always optimal for the buyer to exchange dollars for rubles and pay only the transaction costs, as opposed to compensating the seller for both the transaction costs and the risk of confiscation.

Finally, consider the case where i holds dollars and j prefers to hold dollars in the next period as well. In this case, which corresponds to the lower right cell of Table 1, buyer and seller could either decide to exchange currencies twice, or they could decide to violate the law and carry out the transaction in dollars. The transaction costs associated with the first strategy equal $2\sigma + \tau$, while the cost of the second strategy equals the confiscation risk q. We will assume that the confiscation risk is sufficiently low to satisfy $q < 2\sigma + \tau$, so that this is the only situation in which it is optimal to conduct the transaction in dollars.[26]

By definition, network externalities exist when (1) i is better off holding rubles when j prefers to hold rubles; and (2) i is better off holding dollars when j prefers to hold dollars. Using the information in Table 1, these two conditions translate to (1) $e < \sigma$ and (2) $q < e + \sigma + \tau$. Combining these two conditions yields $q < 2\sigma + \tau$, i.e., the condition assumed above is satisfied whenever network externalities exist. Note, however, that the reverse is not true: i.e., the fact that we assume that $q < 2\sigma + \tau$ does not guarantee the existence network externalities. Nevertheless, as will be shown in the next Section, our empirical estimates do confirm that network externalities were present during virtually the entire sample period in Russia (with the exception of the 1998 financial crisis months, when holding dollars was a dominant strategy), hence the condition $q < 2\sigma + \tau$ was, in fact, satisfied.

B. Best Response Functions

So far, it may have seemed as if e, σ, τ, and q were all known to agents at the time of decision making. In reality, the decision which currency to hold during period t (i.e., between time t and time $t+1$) has to based on the expected rate of ruble depreciation during period t (denoted by $\widehat{e}_t$); the expected shoe-leather cost at time $t+1$ (denoted by $\widehat{\sigma}_{t+1}$); the expected tax rate at time $t+1$ (denoted by $\widehat{\tau}_{t+1}$); and the expected confiscation risk (denoted by $\widehat{q}_{t+1}$).

Let $\widehat{p}_{t+1}$ denote the probability, expected by i, that a randomly chosen seller j prefers to hold dollars

[26] An interesting extension of this model would be to allow for different types of markets with different types of confiscation risk q. For example, the confiscation risk in highly visible marketplaces (e.g., supermarkets) is likely to exceed the cost of exchanging currencies twice, which could explain why transactions in supermarkets typically take place in rubles.

during period $t+1$, i.e., prefers to be paid in dollars at time $t+1$. Since the seller is selected at random, $\widehat{p}_{t+1}$ could be alternatively interpreted as the expected proportion of agents holding dollars during period $t+1$, that is, the expected dollarization ratio in period $t+1$. Using the information contained in Table 1, the expected cost associated with holding rubles during period t can then be expressed as

$$c(m_t) = (1-\widehat{p}_{t+1})\widehat{e}_t + \widehat{p}_{t+1}(\widehat{e}_t + \widehat{\sigma}_{t+1} + \widehat{\tau}_{t+1}). \tag{1}$$

Similarly, the expected cost associated with holding dollars is

$$c(m_t^*) = (1-\widehat{p}_{t+1})\widehat{\sigma}_{t+1} + \widehat{p}_{t+1}\widehat{q}_{t+1}. \tag{2}$$

Assuming that agents minimize cost, it would be straightforward to conclude that they will choose to hold dollars whenever $c(m_t^*) < c(m_t)$, and will choose to hold rubles otherwise. However, it should be acknowledged that there may be other reasons why agents prefer a given currency than the ones captured in this model. For example, agents' currency choice may depend on their moral values, which affect their willingness to violate the law and accept payments in foreign currency; it may depend on agents' confidence in the Russian economy; on the types of goods they purchase; and on various other variables that are unobservable to us but are observable to each individual agent. Let $\epsilon_{i,t}$ and $\epsilon_{i,t}^*$ represent these unobserved variables, and let φ measure the impact of these variables on the total expected cost. The probability $p_{i,t}$ that a given agent i will hold dollars during period t can then be written as

$$\begin{aligned} p_{i,t} &= \Pr\{c(m_t^*) + \varphi\epsilon_{i,t}^* < c(m_t) + \varphi\epsilon_{i,t}\} \\ &= \Pr\{\epsilon_{i,t}^* - \epsilon_{i,t} < \frac{1}{\varphi}[\widehat{e}_t - \widehat{\sigma}_{t+1} + (2\widehat{\sigma}_{t+1} + \widehat{\tau}_{t+1} - \widehat{q}_{t+1})\widehat{p}_{t+1}]\}. \end{aligned} \tag{3}$$

To make the model econometrically estimable, we can now follow standard discrete choice theory by assuming that $\epsilon_{i,t}^*$ and $\epsilon_{i,t}$ are identically and independently distributed across i and t according to the extreme value distribution, which implies that the difference between $\epsilon_{i,t}^* - \epsilon_{i,t}$ is logistically distributed.[27] This gives the following "best response function":

$$p_{i,t} = (1 + \exp\{-\frac{1}{\varphi}[\widehat{e}_t - \widehat{\sigma}_{t+1} + (2\widehat{\sigma}_{t+1} + \widehat{\tau}_{t+1} - \widehat{q}_{t+1})\widehat{p}_{t+1}]\})^{-1}. \tag{4}$$

This best response function has many interesting properties. First of all, it says that the probability that a given buyer i will hold dollars, *conditional on* $\widehat{p}_{t+1}$, increases with the expected depreciation rate $\widehat{e}_t$, just as is predicted by standard portfolio balance models.

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[27] See Anderson, DePalma, and Thisse (1992, p. 39); and Brock and Durlauf (2001a and 2001b). Assuming a normal (probit) distribution, as in Peiers and Wrase (1997), would give similar results.

Second, the conditional probability that i holds dollars decreases with the expected risk of confiscation $\widehat{q}_{t+1}$, which seems natural, but increases with the expected tax rate $\widehat{\tau}_{t+1}$, which seems less intuitive. Upon reflection, however, the latter result follows from the fact that the tax is borne only by buyers who are holding rubles but are matched with sellers who prefer dollars. As can be seen from equations 1 and 2, a rise in $\widehat{\tau}_{t+1}$ increases the expected cost of holding rubles, $c(m_t)$, but does not affect the expected cost of holding dollars, $c(m_t^*)$. Therefore, rather than discouraging dollarization, the foreign-currency tax encourages it, by punishing agents who prefer to hold rubles, and rewarding agents who prefer to hold dollars.[28]

Third, the effect of the expected shoe-leather cost, $\widehat{\sigma}_{t+1}$, is ambiguous and depends on $\widehat{p}_{t+1}$. When the expected dollarization ratio in period $t+1$ is relatively low (i.e., $\widehat{p}_{t+1} < 0.5$), an increase in expected shoe-leather cost $\widehat{\sigma}_{t+1}$ will have a negative effect on $p_{i,t}$, thus reducing the demand for dollars. However, when $\widehat{p}_{t+1} > 0.5$, an increase in $\widehat{\sigma}_{t+1}$ will have the opposite effect and will increase $p_{i,t}$.

Finally, given our assumption that $2\widehat{\sigma}_{t+1} + \widehat{\tau}_{t+1} > \widehat{q}_{t+1}$ (i.e., the cost of exchanging currencies twice exceeds the confiscation risk), the best-response function is upward-sloping, i.e., $p_{i,t}$ is increasing in $\widehat{p}_{t+1}$. Note, however, that an upward-sloping best-response function is not yet a guarantee for network externalities, although the reverse is true.

C. Expectations

The analysis above provides us with a sense of how the currency choice by a given agent depends on various variables, including the expected dollarization ratio $\widehat{p}_{t+1}$. This does not yet say, however, what determines the actual dollarization ratio, denoted by p_t. Assuming that the number of agents is large enough for the law of large numbers to hold, we can answer this question by using the fact that the average fraction of dollar holdings in the economy, i.e., the overall dollarization ratio, must equal the probability that a random agent holds dollars: $p_{i,t} = p_t$ for all i, t.

In order to close the model, it is necessary to make some assumptions on the formation of expectations. One possibility is to assume perfect foresight, that is, $\widehat{x}_t = x_t$ for all x, t. This assumption, combined with the law of large numbers, would imply that p_t is a function of p_{t+1}:

$$p_t = (1 + \exp\{-\frac{1}{\varphi}[e_t - \sigma_{t+1} + (2\sigma_{t+1} + \tau_{t+1} - q_{t+1})p_{t+1}]\})^{-1}. \tag{5}$$

Yet for agents to correctly predict the dollarization ratio p_{t+1} one period ahead, they must also know all other variables one step ahead, including p_{t+2}:

$$p_{t+1} = (1 + \exp\{-\frac{1}{\varphi}[e_{t+1} - \sigma_{t+2} + (2\sigma_{t+2} + \tau_{t+2} - q_{t+2})p_{t+2}]\})^{-1}. \tag{6}$$

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[28]Note that the effect of $\widehat{\tau}_{t+1}$ increases with the expected dollarization ratio $\widehat{p}_{t+1}$. That is, the larger the (perceived) chance of being matched with a "dollarized" seller, the larger the expected transaction costs associated with changing rubles into dollars. In the special case that $\widehat{p}_{t+1} = 0$, the tax will have no effect.

And in order to correctly predict p_{t+2}, they must know p_{t+3}, and so on and so forth. Clearly, this is unrealistic.

An alternative suggestion, then, would be to assume that agents have myopic or static expectations: they predict each variable to remain at its previous value. This assumption is generally considered reasonable in cases where agents repeatedly encounter similar situations, as is the case in this model. Myopic expectations imply $\widehat{x}_{t+1} = x_t$ for all variables, except for the expected dollarization ratio, for which we get $\widehat{p}_{t+1} = p_{t-1}$, since agents who are sellers at time $t+1$ are expected to behave in the same way as they did during the previous period when they were sellers, which is time $t-1$.[29]

While the assumption of myopic expectations seems reasonable for variables such as the shoe-leather cost, the foreign-currency tax rate, and the confiscation risk, this assumption seems less reasonable for the rate of ruble depreciation, which can be predicted to some extent on the basis of information on the rate of money growth, the spread in the yields on ruble-denominated and dollar-denominated assets, etc. Without attempting to explicitly model this exchange rate formation process, we will simply assume, for now, that the expected rate of ruble depreciation is, in fact, the actual rate.[30] This gives the following law of motion:

$$p_t = (1 + \exp\{-\frac{1}{\varphi}[e_t - \sigma_t + (2\sigma_t + \tau_t - q_t)p_{t-1}]\})^{-1}. \tag{7}$$

This equation allows us to predict how dollarization evolves over time, given the values of the "fundamental" variables, e_t, σ_t, τ_t, and q_t. As long as those fundamentals remain fixed, the dollarization ratio will converge to a steady state p^*, which solves $p_t = p_{t-1}$ for all t. When the fundamentals change, the steady state level of dollarization will change as well. While there is no closed-form solution for p^*, we can plot equation (7) in a graph and vary the values of one or more fundamentals in order to see how the steady-state dollarization ratio is affected. Interestingly, as we will show below, p^* is not monotonically increasing with depreciation, as portfolio balance models would suggest. In fact, for a given level of depreciation, there may exist multiple steady-state dollarization ratios. It is this feature of the model that provides us with an explanation for dollarization hysteresis.

D. Steady States and Dynamics

In order to illustrate the nonlinear relationship between dollarization and depreciation, Figure 3 plots equation (7) for three different depreciation rates ($e_t \in \{-0.05, 0, 0.05\}$), while keeping the other variables fixed at $\sigma_t = 0.25$, $\tau_t = 0.01$, $q_t = 0$, and $\varphi = 0.1$. Since this choice of values satisfies the

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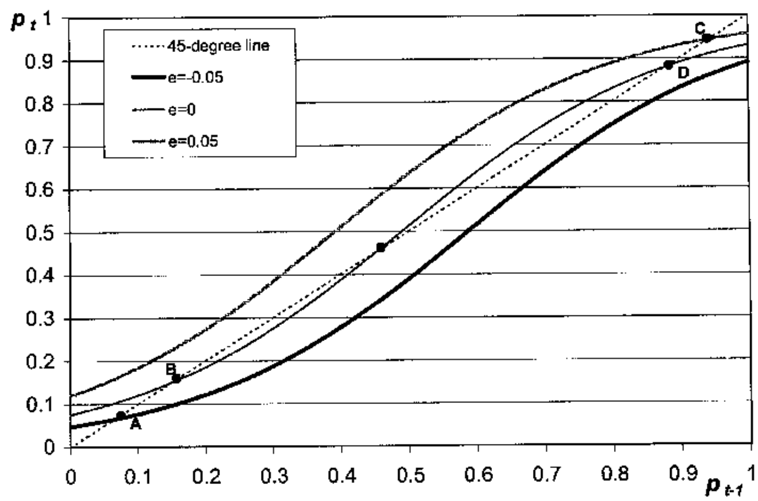
[29]Given the problems involved with measuring dollar currency holdings, described in Section IV.B, agents may even have a hard time finding out the true value of the past dollarization ratio, p_{t-1}. An interesting extension of the model, therefore, would be to introduce a search process by which agents gradually come to learn the correct dollarization ratio in the economy.

[30]This assumption will be relaxed in Section IV, where we account for the existence of a ratchet variable.

conditions for network externalities ($e_t < \sigma_t$ and $q_t < e_t + \sigma_t + \tau_t$), the resulting laws of motion (which can be interpreted as best-response functions) are all upward sloping.

Figure 3. Dollarization Dynamics



The lower curve assumes $e_t = -0.05$, i.e., an appreciation rate of 5 percent. This provides an example of a set of parameter values for which the model has a unique stable steady state, corresponding to a low degree of dollarization. This steady state is denoted by the letter A and lies at the intersection with the 45-degree line, where $p_t = p_{t-1}$.

Now consider a gradual increase in depreciation, or a decrease in appreciation, from $e_t = -0.05$ to $e_t = 0$. This gradually shifts the curve upward, and generates a "phase transition" by which two additional steady states emerge. Of the resulting three steady states, both the lower and upper one (B and D) are stable,[31] but given that the economy started out in A, the steady state selected is B.

As the depreciation rate continues to increase, a second phase transition occurs by which the lower and intermediate steady states disappear, and the economy ends up in a high-dollarization steady state. This is illustrated by point C on the curve corresponding to $e_t = 0.05$. When depreciation now falls back to $e_t = 0$ again, dollarization falls only slightly and stabilizes at the steady-state ratio D. This, then, is how network externalities can lead to dollarization hysteresis: even when the increase in depreciation is temporary, the increase in dollarization can become permanent.

[31] To see this, observe that, when the dollarization ratio at time $t-1$ is slightly above its intermediate steady-state level, it will fall in the next period and will continue to decrease until the lower steady state is reached. Conversely, when the dollarization ratio at time $t-1$ is slightly above its intermediate steady-state level, it will rise in the subsequent period and will continue to increase until the upper steady state is reached. This implies that the intermediate steady state is unstable. In a similar way one can see that, when dollarization is below its lower steady-state level, it will increase again, and when it is above its upper steady-state level, it will fall back to this steady state. This implies that the two outer steady states are stable.

This example shows that the steady-state dollarization ratio p^* does not monotonically increase with exchange rate depreciation, as standard portfolio balance models would have it. In fact, one can come up with similar examples in which depreciation falls but dollarization increases, as in Russia during the 1990s. Going back to Figure 2 on page 6, one can see that dollarization in Russia increased rapidly during the early 1990s, when the rate of ruble depreciation was high, and fell only slightly when depreciation returned to low levels by mid-1995. It then stabilized at around 70 percent, in spite of the fact that depreciation remained close to zero during the subsequent three years. This strongly suggests a movement from a lower steady state (consistent with high depreciation) to an upper steady state (consistent with low depreciation). The next section tests this hypothesis, by estimating equation (7) and plotting the resulting "best response functions".

IV. Empirical Estimation

A. Estimation Procedure

While the structural-form equation of the model (equation 7) is nonlinear, it can be linearized by a simple logistic transformation:

$$\ln\left(\frac{1-p_t}{p_t}\right) = -\frac{1}{\varphi}[e_t - \sigma_t + (2\sigma_t + \tau_t - q_t)p_{t-1}]. \tag{8}$$

Whereas p_t is bounded between 0 and 1, the "log odds ratio" $\ln\left(\frac{1-p_t}{p_t}\right)$ has unbounded support. It therefore can in principle be estimated by ordinary least squares (OLS), provided a few more assumptions are made:

First, since data on the confiscation risk q_t are not available, we will assume for simplicity that $q_t = q$ for all t, that is, the confiscation risk is assumed to be constant throughout the sample period. This assumption allows us, first, to get an estimate of q, and second, to conduct policy experiments by studying the effects of changes in q on the dollarization ratio.

Second, while we do not have data on σ_t either, assuming a constant shoe-leather cost does not seem realistic. Instead, we will assume that the shoe-leather cost is decreasing with the dollarization ratio. This assumption is supported by the empirical observation that, as dollarization in Russia increased, more and more exchange offices started to emerge, which resulted in a lower cost of having to find and walk to an exchange office. To capture this idea, we assume the following functional form:

$$\sigma_t = 1 - \gamma p_{t-1}, \tag{9}$$

where the parameter γ should to satisfy the condition $0 \leq \gamma \leq 1$. This guarantees that σ_t cannot be negative, while allowing for the possibility of a positive shoe-leather cost even when the economy is completely dollarized.

Third, in order to account for expectational adjustment periods (see Section II.A), we will assume that agents predict the ruble depreciation rate correctly with probability α, while with probability

$(1-\alpha)$ they believe that depreciation will equal its maximum rate of the recent past. This gives as the expected rate of ruble depreciation

$$\widehat{e}_t = \alpha e_t + (1-\alpha)e_t^{\max}, \tag{10}$$

where $e_t^{\max} = \max\{e_t, \ldots, e_{t-n}\}$ is the ratchet variable.

Finally, a noise term ξ_t will be added to the regression to allow for unobservable variables and data mismeasurements. With these four modifications, we obtain the following estimable reduced-form equation:

$$\ln\left(\frac{1-p_t}{p_t}\right) = \lambda_0(-1 + e_t + \tau_t p_{t-1}) + \lambda_1(e_t^{\max} - e_t) + \lambda_2 p_{t-1} + \lambda_3 p_{t-1}^2 + \xi_t, \tag{11}$$

which, in turn, can be written as

$$\ln\left(\frac{1-p_t}{p_t}\right) = \beta_0 + \beta_1 e_t + \beta_2 e_t^{\max} + \beta_3 \tau_t p_{t-1} + \beta_4 p_{t-1} + \beta_5 p_{t-1}^2 + \xi_t, \tag{12}$$

where

$$\begin{aligned}
\beta_0 &= -\lambda_0 = \frac{1}{\varphi} \\
\beta_1 &= \lambda_0 - \lambda_1 = -\frac{1}{\varphi}\alpha \\
\beta_2 &= \lambda_1 = -\frac{1}{\varphi}(1-\alpha) \\
\beta_3 &= \lambda_0 = -\frac{1}{\varphi} \\
\beta_4 &= \lambda_2 = -\frac{1}{\varphi}(2+\gamma-q) \\
\beta_5 &= \lambda_3 = \frac{1}{\varphi}(2\gamma).
\end{aligned}$$

It is interesting to note that several authors have estimated an equation very similar to equation (12) without, however, deriving this from an underlying model. For example, Mongardini and Mueller (1999) regress $\ln\left(\frac{1-p_t}{p_t}\right)$ on a number of variables, including the lagged dollarization ratio, exchange rate depreciation, and a ratchet variable, but do not justify this particular functional form. The value-added of the present paper is that it provides such a justification and shows that this functional form is consistent with the existence of multiple steady states. Moreover, the structural-form parameters can be identified from the reduced-form parameter estimates, after the necessary restrictions (i.e., $\beta_0 = -\beta_3$ and $\beta_1 + \beta_2 = \beta_3$) have been imposed.

B. Data

Our estimate of foreign currency in circulation in Russia (m^*) is based on the Currency and Monetary Instrument Reports (CMIRs) collected by the U.S. Customs Service. By law, all currency transporting agents, except Federal Reserve banks, are required to file a CMIR form. The data thus include all wholesale bulk shipments of dollar currency by large financial institutions specializing in international currency transport to and from commercial banks, and all reported retail currency shipments exceeding $10,000 that are physically transported by currency retailers, nonfinancial businesses, and individuals.[32]

With the cooperation of the U.S. Customs Service and the U.S. Treasury Department Financial Crimes Enforcement Network (FinCEN), Edgar Feige (1996 and 1997) combined the information contained in the millions of accumulated confidential CMIR forms by aggregating CMIR inflows and outflows by mode of transportation, origin, and destination. In addition, Feige supplemented the CMIR data with data from the New York Federal Reserve Bank, which is the only Federal Reserve bank that directly ships currency abroad. Using these supplemented CMIR data, the stock of foreign currency in circulation (m^*) can be approximated as cumulative net dollar flows from the United States into Russia.[33] Given that virtually all foreign currency in Russia in the 1990s was held in the form of U.S. dollars,[34] this does not seem a bad approximation. In the Appendix, we compare our estimate of m^* with another estimate, obtained from the Central Bank of the Russian Federation (CBR), and we conclude that, while both are subject to limitations, the (supplemented) CMIR data constitute the best estimate available.

Monthly data for the other variables were obtained from the IMF's *International Financial Statistics* (*IFS*) and from *Russian Economic Trends* (*RET*). Since the CMIR data were available only for the period January 1992 – November 1998, and since the model includes a lagged value of the dollarization ratio as an explanatory variable, the sample period used for all variables was February 1992 – November 1998 (except for e, since exchange rate data back to March 1991 were used to construct the ratchet variable $e^{\max}$). The data sources for each variable are described below:

- m : Ruble currency (M0), published in *RET*.
- e : Ruble depreciation rate, measured as the growth rate in the nominal end-of-month ruble/dollar exchange rate, published in *RET* and originally provided by the Moscow Interbank Currency Exchange (MICEX).

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[32] For a more detailed discussion of the CMIR data, see the Appendix. See also Feige (1996 and 1997), Krueger and Ha (1995), Savastano (1996), and Kamin and Ericsson (1993).

[33] In order to arrive at the stock estimate from the flow estimates, we assumed that foreign currency holdings before 1992 were negligble, as trade in foreign currency was illegal during Soviet times. If some foreign currency was in fact in circulation before 1992, this would lead to even higher estimates of currency dollarization, but the results would most likely not be affected.

[34] For example, in 1998 U.S. dollars constituted on average 95.2 percent of all foreign currency purchases, and an average 95.9 percent of all foreign currency sales by exchange offices. The remaining purchases and sales were mainly in deutsche mark. (Source: CBR, 1998, *Byulleten Bankovskoy Statistiki*, Table 3.2.4.)

- $e^{\max}$: Maximum ruble depreciation rate over the past 12 months.
- τ : Tax rate on purchases of foreign currency (or, more precisely, of foreign monetary instruments). This tax was first introduced on July 21, 1997, at at initial rate of 0.5 percent. On July 2, 1998, the tax rate was increased to 1 percent, and remained 1 percent until January 1, 2003, when the tax was eliminated altogether. Hence, we have $\tau = 0$ from January 1992 through July 1997, $\tau = 0.005$ from August 1997 through June 1998, and $\tau = 0.01$ from July 1998 until the end of the sample.
- d^* : Dollar-denominated deposits (used only in Figure 2); approximated by the series "foreign-currency deposits" in *IFS*.
- d : Ruble-denominated deposits (used only in Figure 2); measured as the difference between M2 and M0.[35] Two different M2 series are available from *RET*: an "old series" from December 1990 to December 1997, and a "new series" from December 1996 onwards. Since the differences between the two series were small, the old series was used until November 1996, and the new series from its earliest possible date, i.e., December 1996.

C. Results

The estimated reduced-form parameters, their standard errors, and the results of several residual tests are given in Tables 2 and 3.

Table 2. Estimated Parameters and Standard Errors

Variable	Coefficient	Std.Error	T-statistic	P-value
β_0	4.325	0.311	13.916	0.000
β_1	-3.311	0.546	-6.060	0.000
β_2	-1.014	0.449	-2.258	0.027
β_3	-4.325	0.311	-13.916	0.000
β_4	-12.144	1.225	-9.917	0.000
β_5	7.214	1.338	5.393	0.000

At first sight, each variable appears to be highly significant. Moreover, the p-value for the Jarque-Bera test is essentially zero, suggesting that the residuals are approximately normal. However, the residual tests give some evidence of autocorrelation and heteroscedasticity. First of all, the Breusch-Godfrey serial correlation LM test indicates significant autocorrelation in the residuals when 12 lags are included, which is most likely due to the nonstationarity of some variables. However, when 24 lags are included, this test statistic is no longer significant at the 5 percent level.

Second, the White heteroscedasticity test shows a highly significant F-statistic. Since the null hypothesis underlying this test is that the errors are both homoscedastic and independent of the regressors, and that the linear specification of the model is correct, the rejection of the null implies that at least one of these conditions is violated.

[35] Official CBR deposit data (as published in its *Byulleten Bankovskoy Statistiki)* or the *IFS* series on "demand deposits" were not available since commercial banks were not required to report deposit data before 1996.

Table 3. Goodness of Fit and Residual Tests

R^2	0.917		
Adjusted R^2	0.913		
Jarque-Bera normality test	120.718	Prob.	0.000
Serial correlation LM (12) test	3.291	Prob.	0.001
Serial correlation LM (24) test	1.640	Prob.	0.067
White heteroscedasticity test	46.038	Prob.	0.000

Assuming that the model specification is correct, the OLS parameter estimates are still consistent even in the presence of heteroscedasticity and autocorrelation. However, if some of the variables are indeed nonstationary, which seems likely, the conventionally computed standard errors are no longer valid, and, without knowing the true processes of those nonstationary variables, we have no way of determining the correct standard errors. Whether this is a problem, however, depends on whether one believes that the true standard errors could possibly be so large that the parameter estimates would become insignificant. Given that the OLS standard errors are essentially zero for almost all parameters, this seems quite unlikely.[36]

Using the reduced-form parameter estimates, we can now solve for the structural-form parameters. First of all, we find that $\alpha = -\frac{\beta_1}{\beta_0} = 0.77$, suggesting that there is indeed some sluggishness in the formation of exchange rate expectations (i.e., agents believe that, with probability 0.23, the ruble will depreciate by a rate equal to the maximum depreciation rate of the past year). Second, we find $\gamma = \frac{\beta_5}{2\beta_0} = 0.83$, implying that the shoe-leather cost is still 0.17 even in the extreme case of full dollarization.[37] Finally, the estimated confiscation risk is $q = \frac{2\beta_0+\beta_4+0.5\beta_5}{\beta_0} = 0.03$; that is, sellers who accept dollars have an estimated chance of 3 percent of being caught and having the dollars confiscated (or of being paid in worthless, counterfeited dollars).

The estimated structural-form parameters are broadly consistent with the hypothesis of network externalities. That is, the first condition for network externalities, $\widehat{e}_t < \widehat{\sigma}_{t+1}$, which translates to $0.77e_t + 0.23e_t^{\max} < 1 - 0.83p_{t-1}$, is satisfied for all t with the exception of August and September 1998. In these financial crisis months, the monthly depreciation rate was so high (65 percent and 55 percent respectively) that it was optimal for buyers to hold dollars even if they expected sellers to prefer rubles. In all other months, however, an expected preference for rubles by sellers induced a demand for rubles by buyers. The second condition for network externalities, $\widehat{q}_{t+1} < \widehat{e}_t + \widehat{\sigma}_{t+1} + \widehat{\tau}_{t+1}$, which translates to $0.03 < 0.77e_t + 0.23e_t^{\max} + 1 - 0.83p_{t-1} + \tau_t$, is satisfied for all t, implying that an expected preference for dollars by sellers induced a demand for dollars by buyers at all times.

[36] Reestimating the model using White (heteroscedasticity consistent) and Newey-West (heteroscedasticy and autocorrelation consistent) covariance estimates still produced highly significant parameter estimates for all parameters.

[37] Unless the U.S. dollar were to become legal tender, it is unlikely that a 100 percent dollarization ratio could ever be reached, since salaries and taxes would continue to be paid in local currency.

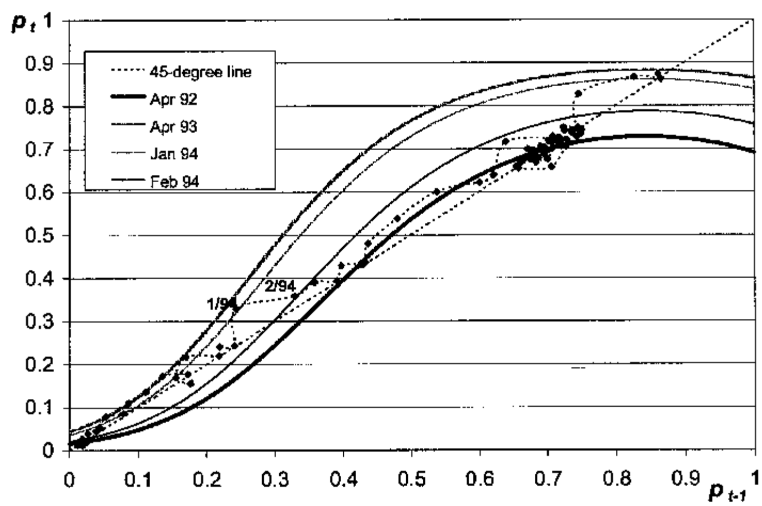
D. Interpretation

The estimated reduced-form equation,

$$p_t = (1 + \exp\{4.3 - 5.3e_t - e_t^{\max} - 4.3\tau_t p_{t-1} - 12.1p_{t-1} + 7.2p_{t-1}^2\})^{-1}, \tag{13}$$

is plotted in Figures 4 and 5 for several time periods (i.e., several combinations of $e_t^{\max}$, e_t, and τ_t). Also shown are the actual data points (p_{t-1}, p_t), connected by a dotted line, which allows us to track the evolution of the dollarization ratio over time.

Figure 4. Estimated and Actual Relationship Between p_t and p_{t-1} (a)

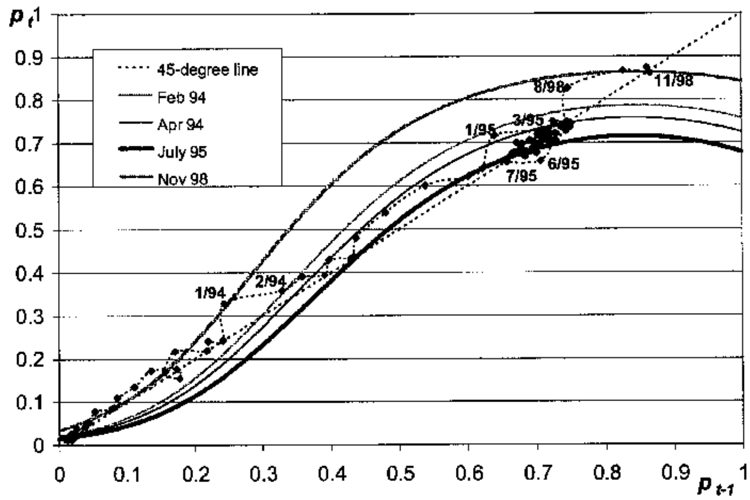


For most periods (i.e., for most combinations of $e_t^{\max}$, e_t, and τ_t), the estimated curve crosses the 45-degree line at three points, implying the existence of three steady states of which only the outer two are stable. The low-dollarization steady states are all close to zero, fitting the data points of 1992, while most high-dollarization steady states correspond to dollarization ratios of 65–75 percent, fitting the cluster of data points from mid-1995 until mid-1998.

How did the economy move from one steady state to another? The estimates suggest the following explanation. Following a history of virtually zero inflation (to the extent that prices were often printed on the product itself) and of serious restrictions on foreign-currency purchases (including sentencing by capital punishment), the Russian economy started out in a low-dollarization steady state at the beginning of the 1990s. With the collapse of the Soviet Union in 1991 and the liberalization of prices in 1992, the ruble started to depreciate. As Figure 4 shows, this increase in depreciation caused the low-dollarization steady state to disappear by means of a phase transition. To see this, compare the estimated curves drawn for April 1992 and April 1993 in Figure 4, and note that, while the lower steady state was still stable in April 1992, it had disappeared by April 1993, which set off the increase in dollarization.

Between December 1993 and January 1994, dollarization increased from 24 percent to 33 percent

Figure 5. Estimated and Actual Relationship Between p_t and p_{t-1} (b)



(this point is marked as "1/94" in Figure 4). Then, in February 1994, both depreciation and the ratchet variable fell, causing the curve to shift down and the lower steady state to reappear. However, as indicated in the graph, point "2/94" lies above the unstable intermediate steady state of the curve, thus causing the dollarization ratio to move in the direction of the upper rather than the lower steady state.

The story continues in Figure 5. Between February 1994 and March 1995, dollarization increased rapidly on its way to the upper steady state, and in the process more than doubled, increasing from 36 percent to a whopping 73 percent in one single year.[38] By March 1995, a new steady state of about 73 percent had been reached. Around this time, however, the CBR started to take measures to stabilize monetary and credit policy by ending the inflationary financing of the budget deficit. This lead to a decrease in depreciation, and even to an appreciation of the ruble (by 3 percent in March, 9 percent in June, and 2 percent in July 1995). As a result, the dollarization ratio fell slightly, to 65 percent in July 1995.

In order to further stabilize the exchange rate and exchange rate expectations, a "crawling peg" exchange rate regime was introduced in July 1995. While the new regime was successful in that it managed to keep the depreciation rate close to zero for the subsequent three years, it did not succeed in making the upper steady state disappear. As a result, Russia remained dollarized for about 70 percent from mid-1995 to mid-1998.

The exchange rate regime collapsed during the August 1998 financial crisis. Under the pressure of a rapidly increasing debt-to-GDP ratio and a rapidly decreasing stock of foreign reserves, the Russian government announced on August 17, 1998 a significant widening of the bandwidth within which the exchange rate was allowed to "crawl" (Buchs, 1999). This was immediately perceived as a de

[38] On "Black Tuesday," October 11, 1994, the ruble lost 27 percent of its value in one single day, further fueling the growth of dollarization.

facto devaluation and caused the ruble to lose 65 percent of its value in August alone (and another 55 percent in September). By November 1998, the dollarization ratio had increased to 87 percent, and Russia had reached a new upper steady state, as indicated by point "11/98" in Figure 5.

V. Policy Implications

There are many costs associated with a high currency dollarization ratio, including the loss of seigniorage revenue[39]; possible loss of tax revenue;[40] a possible increase in crime and corruption;[41] and the lack of control over monetary policy by the national central bank.[42] However, currency dollarization also has benefits: for example, it limits governments' efforts to use inflationary financing as a method of implicit taxation, and it allows residents to diversify their portfolios and protect themselves against inflation, which may reduce capital flight.

While it is beyond the scope of this paper to carry out a full-fledged cost-benefit analysis,[43] a simple approach would be to compare the costs associated with a zero-dollarization steady state (i.e., a situation in which both sellers and buyers prefer rubles) to those associated with a full dollarization steady state (in which both prefer dollars). As was shown in Table 1, the former costs equal the depreciation rate e, while the latter costs equal the confiscation risk q. We can roughly say, therefore, that it is suboptimal for agents to be in a high-dollarization steady state whenever $e < q$, or $e < 0.03$. Since this condition held true for most of the period from mid-1995 to mid-1998, we can speak of a coordination failure: Russians would have been better off in a low-dollarization steady state during that period.

[39] The amount of forgone seigniorage revenue should not be underestimated. If the ratio of U.S. dollar currency to GDP in Russia is 100 percent, which may not be far from the truth, then seigniorage losses as a percent of GDP are equal to the growth rate of monetary aggregates, which could be around 10 percent per year.

[40] Feige and others (2001) argue that dollarization leads to an increase in the size of the underground economy, where transactions remain unrecorded and taxes are therefore evaded. However, tax evasion does not necessarily increase with dollarization if unrecorded foreign-currency transactions substitute for unrecorded local-currency transactions, or if dollar transactions simply get recorded as ruble transactions, a practice that appears to be quite widespread in Russia.

[41] Feige and others (2001) note that dollarization reduces the cost of enterprise theft, and may facilitate greater corruption and rent seeking. In addition, the knowledge that many individuals and businesses hold most of their wealth in the form of dollar currency will increase the expected rewards of burglary. However, these problems could be overcome if agents were to shift from dollar currency to dollar-denominated deposits.

[42] However, Reinhart and others (2003) and Havrylyshyn and Beddies (2003) find no empirical evidence that monetary policy in dollarized economies is less successful in stabilizing money demand or reducing inflation.

[43] For more on this, see, e.g., Fischer (1982), Sturzenegger (1997), Baliño and others (1999), Berg and Borensztein (2000), and Schmitt-Grohe and Uribe (2001). However, most of this literature discusses the costs and benefits of deposit dollarization or "full dollarization" (accepting the U.S. dollar as legal tender), not of currency dollarization.

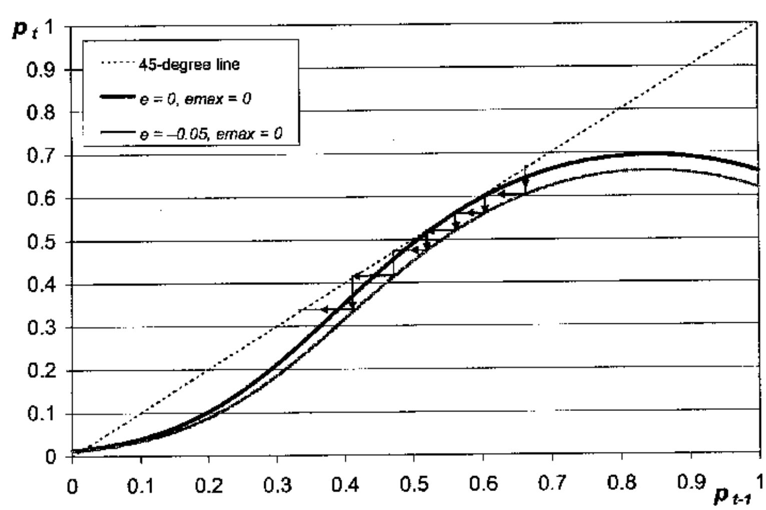
The condition $e < 0.03$ has also largely been satisfied since early 1999, yet anecdotal evidence suggests that the Russian economy has continued to be in a high-dollarization steady state. To the extent that this is, indeed, a suboptimal situation, as our model suggests, it is worthwhile to consider what the Russian government could do to reduce dollarization. To this end, we discuss three possible policy measures: (1) exchange rate policy; (2) fiscal policy; and (3) enforcement policy.

A. Exchange Rate Policy

If de-dollarization is the goal, a natural policy instrument to consider is the exchange rate. In particular, our model and empirical results suggest that an appreciation of the ruble, if sustained long enough, could bring about a "reverse phase transition" that would make the high dollarization steady state disappear. Intuitively, an appreciation of the local currency will reduce the incentives for holding foreign currency, and once a sufficient percentage of agents has switched from foreign to local currency, network externalities ensure that the local currency will continue to be favored. Moreover, when agents see the local currency appreciate for several months in a row, this will affect their exchange rate expectations through the ratchet variable.

As the middle curve in Figure 6 illustrates, a mere exchange rate stabilization ($e = 0$) would not be sufficient to induce a reverse phase transition, even if stabilization were maintained long enough so that $e^{\max} = 0$. However, as soon as the appreciation rate becomes positive (i.e., the depreciation rate becomes negative), the upper steady state disappears, and a dynamic adjustment process is set in motion that eventually makes the dollarization ratio return to its lower steady state.

Figure 6. Reducing Dollarization by Temporary Appreciation



Note that the appreciation policy does not need to be maintained until the lower steady state is actually reached. In fact, dollarization would need to be reduced only by an amount that is sufficient large to ensure that, when the exchange rate stabilizes again and the economy returns to the $e = 0$ curve, the dollarization ratio is below its intermediate, unstable steady-state level. This would then be enough for the dollarization ratio to continue to decrease until it has reached the lower steady state.

To see this, consider a situation with both e and $e^{\max}$ close to zero and a foreign-currency tax rate of 1 percent, as was the case at the end of the 1990s (this would correspond to a dollarization ratio of about 65 percent). Following the arrows in Figure 6, it can be seen that a temporary appreciation of the ruble by 5 percent per month, if maintained for at least four months, is sufficient to permanently reduce dollarization. That is, after four months, represented by the four vertical arrows, dollarization is reduced to about 47 percent, which is below the intermediate steady state of the $e = 0$ curve, and therefore sufficient to induce a return to the lower steady state.[44]

B. Fiscal Policy

A second natural instrument that could potentially be used to achieve de-dollarization is the foreign-currency tax rate. As noted before, this tax was introduced in July 1997 at an initial rate of 0.5 percent, and was raised to 1 percent in July 1998. On January 1, 2003, it was eliminated altogether, for reasons unrelated to dollarization.[45] It is interesting to see, however, to what extent the tax could have been used to reduce dollarization, and what the effect of the elimination on dollarization will be.

As noted earlier, a somewhat surprising implication of our model is that an increase in the foreign-currency tax rate leads to an increase, rather than a decrease, in the conditional probability of holding dollars (i.e., the probability that a given agent holds dollars, given the demand for dollars by other agents). This implies that an increase in the tax rate shifts the curve upward, while a decrease in the tax rate implies a downward shift. The question, therefore, is whether the elimination of the tax will lead to a downward shift that is sufficiently large to induce a phase transition that will make the upper steady state disappear.

Figure 7 suggests that the answer is no. Merely reducing the tax rate from $\tau = 0.01$ to $\tau = 0$ has a virtually unnoticeable effect on the position of the curve and, hence, on dollarization.[46] In other words, based on our estimates we predict that, assuming all else remains the same, the elimination of the foreign-currency tax will have a negligible effect on dollarization in Russia. In fact, one would be tempted to conclude that, in order to make the upper steady state disappear, the tax rate would need to be further reduced to a negative rate of, for example, $\tau = -0.05$, so that agents would receive

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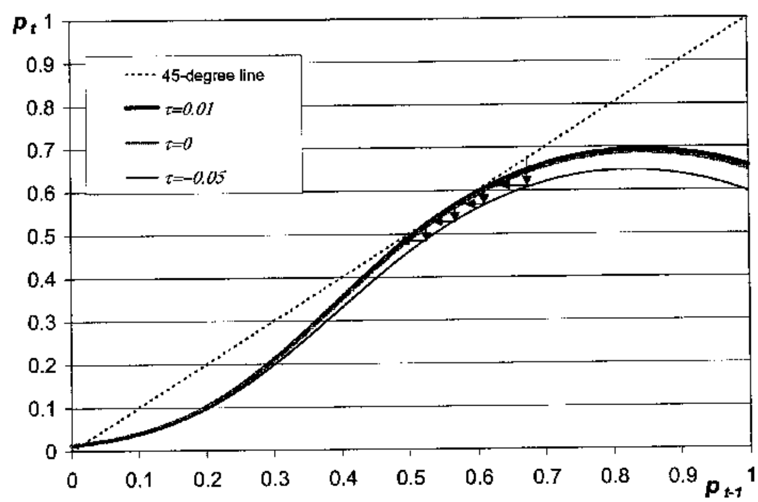
[44] An appreciation by 5 percent per month for four months in a row amounts to a total appreciation rate of almost 22 percent. One might argue that such a policy is too costly, as it would significantly harm external competitiveness. However, this is not necessarily the case. It can be shown, for example, that an appreciation rate of 5 percent for six months could be followed by a subsequent depreciation rate of 5 percent for six months, without thereby making the dollarization ratio return to its upper steady state.

[45] Federal law 193-F3. The official reasons for the elimination were that (1) it fit in with the overall policy to eliminate all turnover taxes in Russia; (2) tax administration was too costly; and (3) tax evasion and tax avoidence were widespread.

[46] Both curves assume that $e = e^{\max} = 0$, and both still intersect the 45-degree line. It is possible that there exists a small range of (slightly negative) values for e or $e^{\max}$ such that the $\tau = 0.01$ curve has three steady states while the $\tau = 0$ curve has only one (lower) steady state. Only in such an exceptional case could the elimination of the foreign-currency tax have a drastic effect on dollarization.

a "subsidy" of 5 dollar cents for each dollar purchased.[47] The estimates would seem to suggest that this subsidy would need to be maintained for only four months in order to permanently reduce dollarization. That is, if the tax rate were again set to zero after those four months, the dollarization ratio at that point would be below the intermediate steady state of the $\tau = 0$ curve, and therefore would continue to decrease until it has reached the lower steady state.

Figure 7. Reducing Dollarization by Eliminating the Foreign-Currency Tax



Intuitively, it seems of course highly implausible that a subsidy on foreign currency purchases would lead to a reduction in dollarization. In practice, such a policy would indeed not work since it would create unlimited arbitrage opportunities, as agents could change rubles into dollars, receive the subsidy, change the dollars back into rubles, and repeat this procedure indefinitely. Nevertheless, our finding that a foreign-currency tax encourages rather than discourages dollarization still holds, and the elimination of such a tax should therefore contribute to de-dollarization. Since the estimated effects for Russia are quite small, however, a substantial and permanent reduction in dollarization would require additional measures, such as the exchange rate policy discussed above or the enforcement policy discussed below.

C. Enforcement Policy

A final way for the Russian government to decrease dollarization would be to increase enforcement of the law that forbids foreign-currency transactions. This will increase the risk of confiscation, q, and, therefore, the markup buyers would have to pay if they wanted to pay in dollars, thus diminishing the demand for dollar currency.

From the fact that q enters equation (8) in exactly the same (but opposite) way as τ_t, we can predict

[47] Interestingly, this is essentially equivalent to an appreciation rate of 5 percent, which coincides with the policy suggested in the previous subsection.

that a decrease in the foreign-currency tax by 0.06 (from $\tau = 0.01$ to $\tau = -0.05$) would have exactly the same effect as an increase in enforcement by 0.06, which would triple the confiscation risk (from $q = 0.03$ to $q = 0.09$). The graph in this case would look exactly the same as Figure 7. As before, enforcement would need to increase only temporarily (in this case, four months) in order to permanently decrease dollarization.

VI. Conclusion

The ratio of U.S. dollar currency to total currency in Russia increased rapidly during the early 1990s, but failed to come down in the second half of the 1990s in spite of exchange rate stabilization. This puzzling persistence, or hysteresis, in the dollarization ratio, has been observed in other dollarized countries as well. Econometrically, hysteresis is typically accounted for by so-called ratchet variables, e.g., the maximum past rate of exchange rate depreciation, which can be interpreted as measuring the long-term effect that a temporary shock to depreciation can have on agents' expectations.

This paper showed that an additional explanation for dollarization hysteresis is the existence of network externalities in the demand for currency. These externalities arise because an individual's demand for a given currency depends not only on rate of return considerations, but also on the extent to which this currency is accepted by other agents as a means of payment. Intuitively, when exchange rate depreciation leads to an increase in the dollarization ratio, this increase in dollarization itself makes dollars more valuable as a means of exchange. Therefore, a temporary shock to depreciation can have permanent effects even if agents do not continue to "remember" the shock for a long time.

We developed a theoretical model to show that network externalities can lead to multiple steady-state dollarization ratios. We then estimated this model using a new source of data on dollar currency holdings in Russia. The results are consistent with the hypothesis of network externalities, and suggest that dollarization hysteresis in Russia can be explained as a phase transition from a low-dollarization to a high-dollarization steady state.

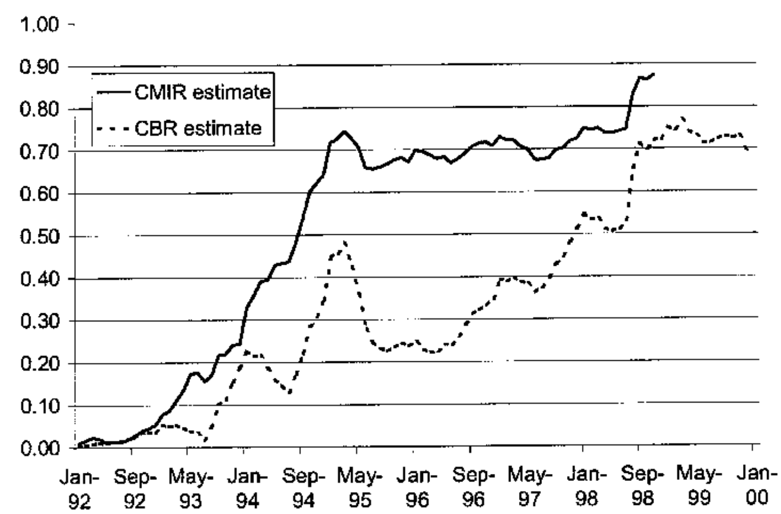
While the overall costs and benefits of dollarization are subject to debate, a simple welfare analysis suggests that the high-dollarization steady state was suboptimal from mid-1995 to mid-1998, in the sense that Russians would have been better off holding rubles during this period. The paper discussed several strategies to reduce dollarization, and concluded that de-dollarization could be attained by (1) an appreciation of the ruble; and (2) an increase in enforcement of the law that prohibits foreign-currency transactions. Interestingly, the presence of network externalities implies that these policies would need to be implemented only temporarily in order for a permanent decrease in dollarization to result. While the recent elimination of the foreign-currency tax is also predicted to contribute to de-dollarization, its quantitative impact on the dollarization ratio was estimated to be negligible. In summary, we may conclude that, while dollarization in Russia has been very persistent, it need not be irreversible.

ESTIMATING DOLLAR CURRENCY IN RUSSIA

Two possible data sources are available for estimating the amount of dollar currency in circulation in Russia. In addition to the "CMIR data" described in Section IV.B, which are based on both CMIR and New York Federal Reserve records, the Central Bank of the Russian Federation (CBR) provides data on reported purchases and sales of foreign currency by authorized banks.[48] Two previous studies of dollarization in Russia (Brodsky, 1997; Friedman and Verbetsky, 2000) used these CBR data to construct a series on accumulated net purchases of foreign currency as an approximation of dollar currency circulating in Russia.[49]

Following the Russian Bureau of Economic Analysis (Nikolaenko, 1998), we can combine the CBR series with balance of payments data published in *Vestnik Banka Rossii* in order to adjust for dollars spent abroad by Russian tourists and for unregistered imports by so-called shuttle traders (*chelnoki*). The latter tend to use large amounts of dollar currency to purchase goods abroad, mainly in Asia and the Middle East, with a view to reselling them in Russia. Subtracting these additional outflows (measured by the categories "unregistered imports" and "travel abroad expenses" in Nikolaenko, 1998) from the CBR series on net purchases of foreign currency, we obtain an adjusted CBR estimate, which we call "CBR estimate" for short in Figure 8 below.

Figure 8. Two Estimates of Dollarization in Russia, 1992–99



In some sense, the CMIR and CBR data represent two sides of the same coin. That is, when Russian residents purchase more dollars from Russian banks, these banks will eventually have to order more dollar currency from the United States (typically, they order from one of the large wholesale shippers

[48]These data are published in the CBR's *Byulleten Bankovskoy Statistiki*, Table 3.2.4. Since August 1997, they have been supplemented with data on individuals' net withdrawals from foreign currency deposits.

[49]Brodsky (1997), however, used only a very short time series (May 1994 – June 1996) and, therefore, was unable to get any reliable empirical estimates.

who transport the bulk currency directly to them). Similarly, when residents sell more dollars to Russian banks, this will eventually lead to a decrease in the amount of currency shipped from the United States to Russia.[50]

In practice, however, the CMIR and CBR data differ for several reasons, and both have advantages and disadvantages. The main advantage of the CMIR estimate is that it accounts for any registered amount of dollar currency that is physically carried into or out of Russia, whereas the CBR estimate includes only that part of dollar currency that is exchanged for rubles. The main disadvantages of the CMIR estimate, however, are that (1) it does not include dollar flows between Russia and countries other than the United States, and (2) it does not account for dollar flows below $10,000. While the latter two types of flows are partially accounted for by the (adjusted) CBR data, the main drawback of the CBR estimate is that it is based on reports produced by the currency exchange offices of banks, which are commonly known to underreport the number and value of transactions in order to evade taxes. Not surprisingly, therefore, the dollarization ratio estimated on the basis of the CBR data is significantly lower than the estimated dollarization ratio based on the CMIR data, as Figure shows 8.

While the CBR estimate is thus likely to understate the true amount of dollar currency in Russia, the CMIR estimate is not necessarily an overstatement. First, it excludes both dollar outflows and dollar inflows to and from countries other than the United States. Second, it may underestimate dollar flows from the United States to other countries, as U.S. Customs monitors individuals traveling abroad less carefully than individuals returning to the United States from abroad. Third, it excludes currency flows that fall below the CMIR reporting requirement of $10,000, and correspond mostly to immigrant remittances by Russians living in the United States, and to tourist expenditure by individuals traveling between the United States to Russia.[51] Given that the United States has a far larger GDP per capita than Russia, it seems likely that more dollars are carried into Russia from the United States than are carried into the United States by Russians. If this is true, then that would be another reason why the CMIR data may understate, rather than overstate, the true amount of dollar currency in Russia.[52]

Finally, we can compare the CMIR and CBR estimates to an independent estimate of dollar currency in Russia, based on a survey on financial assets held by Russian households (Rimashevskaya, 1998). This survey, which was financed by the CBR, was conducted in October 1996, and covered almost 8,000 households in 13 Russian regions. To prevent selection bias (people in the top of the income distribution often do not participate in polls), 70 additional personal interviews were conducted with "rich" and "very rich" inhabitants of four regional centers (Moscow, St. Petersburg, Rostov-on-Don

[50]If the decrease continues, Russian banks may eventually find themselves with a surplus of dollars, in which case wholesale bulk shippers will be enlisted to transport the excess currency back to the United States.

[51]On the basis of data on travelers' expenditures and net remittances, Feige (1996 and 1997) found that cumulative net outflows of dollars below $10,000 constitute a relatively small fraction of total estimated net outflows.

[52]Of course, the CMIR estimate could still be overstated to the extent that there are unrecorded flows of dollar currency out of Russia that circumvent any legal reporting requirements. However, since traveling with large amounts of dollar currency is risky, most capital flight is likely to take place in the form of electronic transfers rather than cash.

and Ufa).[53] The different types of financial assets included ruble and foreign currency; personal accounts in Russian banks; and securities. For the "very rich" group, corporate accounts and accounts abroad were also taken into account.

As Table 4 shows, the survey's estimate of the amount of foreign currency holdings in Russia in October 1996 is about $56 billion.[54] This is much closer to the CMIR estimate, which is $45 billion for October 1996, than to the CBR estimate, which is only $10 billion for that period.[55] This confirms our hypothesis that the CBR data seriously underestimate the true amount of dollar currency in Russia.

Table 4. Financial Assets of Russian Households, 1996

TYPE OF ASSET	In billions of U.S. dollars	In percent of total
Accounts in Russian banks (personal)	19.8	11.6
Accounts in Russian banks (corporate)	22.5	13.2
Securities	31.8	18.7
Ruble currency	17.7	10.4
Foreign currency	56.0	32.9
Accounts abroad (personal and corporate)	36.7	19.9
TOTAL	184.5	100.0

Source: Rimashevskaya (1998)

[53]The category "rich" was defined as those people who earned 9 to 10 times the minimum living allowance (MLA), and this group was estimated to constitute about 3 percent of the population. The "very rich" were defined as individuals with more than 10 times the MLA, constituting an estimated 2 percent of the population.

[54]Two other interesting results of the survey are that 80 percent of foreign currency is held by the "rich" and "very rich" groups, which together account for 5 percent of the population, and that 75 percent of foreign currency is located in Moscow.

[55]Assuming that about 90 percent of all foreign currency was held in dollars, the survey's estimate of dollar currency in Russia would be about $50 billion, which is even closer to the CMIR estimate.

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