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Abstract

A model of the long run equilibrium real exchange rate based upon macroeconomic fundamentals is employed to calculate real exchange rate misalignments for Poland and Russia during the 1990s using the Beveridge and Nelson (1981) decomposition of macrofundamentals into transitory and permanent components. Short run movements of the real exchange rate are estimated with ARIMA and GARCH error correction specifications. The different nominal exchange rate regimes of the two countries generate different levels of misalignment and different responses to exogenous shocks. The average misalignment in Russia is substantially greater than that in Poland, indicating incipient pressures to devalue the ruble immediately preceding the August 1998 crisis. The half life of an exogenous shock is found to be much shorter for Poland than for Russia in the pre-crisis period. Dynamic forecasts indicate that the movements of the real exchange rate in the post-crisis period are significantly different from those in the pre-crisis period. Thus, the currency crisis in Russia could not be anticipated with the movements of the real exchange rate estimated with the macroeconomic fundamentals.

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Executive Summary

In this paper we examine both short run and long run movements in exchange rates for Poland and Russia. Specifically, we ask 1) can the long run equilibrium real exchange rate for a transition economy be modeled with conventional tools? 2) is the error correction model appropriate for explaining short run behavior of the real exchange rate in these economies? 3) do different nominal exchange rate regimes generate explicitly different equilibrium relationships and are the responses to exogenous shocks different? 4) given the appropriateness of the model to what extent has there been real exchange rate misalignment in these two economies? and 5) to the extent that the misalignment is persistent is it an effective indicator of a potential crisis? A tradable goods non-tradable goods model based upon Elbadawi (1994) and earlier work by Dornbusch (1973) and Rodriguez (1989) specifies the long-run equilibrium exchange rate as a function of macroeconomic fundamentals, such as terms of trade, net capital inflow, government expenditure and the respective governments' openness to free trade. We estimate this model and calculate the exchange rate misalignments for both currencies. To estimate the long run equilibrium equation for the real exchange rate we start with the Engel Granger static OLS procedure, and to correct for potential bias of the coefficients or endogeneity problems we use dynamic OLS for the final specifications. . The number of co-integrating equations is confirmed by the Johansen method and the statistical significance of the macroeconomic fundamentals on the long run equilibrium values is assessed with the relevant statistical tests. Two important findings are confirmed: the real appreciations in the transition economies are due to significant net capital inflow (Brada, 1998; Drabek and Brada, 1998; Liargovas, 1999) and productivity shocks (Richards and Tersman, 1996; Halpern and Wyplosz, 1997; Balazs, 2002; de Broeck and Slok, 2001).

We use the Beveridge-Nelson decomposition to calculate the permanent components of the macrofundamentals. With these and the estimated long run equilibrium exchange rate equation we calculate the long run equilibrium exchange rates. The misalignments are then calculated as short run deviations of the observed real exchange rates from their respective long run equilibrium values. Because the nominal exchange rate regime was more flexible for the zloty the real exchange rate could equilibrate more quickly. The maximum overvaluation and maximum undervaluation were 6% and 10% respectively. However, for the Ruble, with a less flexible exchange rate regime, the maximum overvaluation was 21%, 250% greater than that for the zloty, and the maximum undervaluation was also 21%, 100% higher than that for the zloty. .

Finally, we examine whether movements in the macroeconomic fundamentals, along with other short run factors, in the pre-crisis periods could explain and predict the exchange rates in the post-crisis periods. Two out of sample forecasting exercises are performed for the post-crisis period. First, the real exchange rates are forecast for the post-crisis period with the known values of the exogenous variables and lagged values of the real exchange rate; a one period ahead static forecast. Then the forecasts are performed with the lagged values of the real exchange rate from the previous period forecast and with the known values of the exogenous variables; a one period ahead dynamic forecast. While the static forecasts do reasonably well, the dynamic forecasts indicate that the movements of the real exchange rates in the post-crisis periods are significantly different from that in the pre-crisis periods. Thus, the currency crises in Russia could not be anticipated with the movements of the real exchange rates estimated on the basis of macroeconomic fundamentals alone.

1. Introduction

The role of the real exchange rate in the macroeconomic adjustment mechanism is of central importance in many debates on economic development, growth strategies and stabilization policies. Dornbusch (1982) and Williamson (1985), *inter alia*, discuss the effects of real exchange rate misalignments on macroeconomic stabilization[2] and following Edwards (1994), there is a consensus that persistent misalignments of the real exchange rate imply serious macroeconomic imbalances. Economies with fixed or less than flexible nominal exchange rate regimes without foresight and suitable policies on the part of the government are subject to real exchange rate misalignment that may have disastrous consequences. Accordingly, a successful development strategy for a less developed economy or emerging market economy should include efforts to maintain the real exchange rate at or near the 'equilibrium' level regardless of exchange rate regime. Nonetheless, Asia and Latin America have suffered exchange rate and related banking crises, which have been studied extensively,[3] and several of the transition economies of Eastern Europe and the former Soviet Union have experienced similar problems. Here we examine the implications of the exchange rate regimes of two transition economies, Russia which had a peg or less flexible managed exchange rate regime and experienced a currency and banking crisis in August 1998, and Poland which had a more flexible managed or freely floating exchange rate regime with better macroeconomic performance and virtually no

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[2] Harberger (1986) and Dervis and Petri (1987) discuss the relationship between real exchange rates and economic performance. Serven and Solimano (1991) found that the stability of the real exchange rate has a positive effect on private investment. Edwards (1986a, 1986c), Edwards and Van Wijnbergen (1986, 1987), Mussa (1974, 1978) and Pinto (1988) show the relevance of the real exchange rate to export promotion and generation of optimal output and employment in behavioral models.

[3] Agenor, Bhandari and Flood (1992), Aghion, Bacchetta and Banerjee (2000), Berg and Pattillo (1999a, 1999b), Eichengreen, Rose and Wyplosz (1996), Frankel and Rose (1996), Goldstein, Kaminsky and Reinhart (2000), Kamin and Babson (1999),Kaminsky, Lizondo and Reinhart (1998), Kaminsky and Reinhart (1998, 1999),Krugman (2000), Obstfeld(1994,1996), and Reagle and Salvatore (2000) are representative papers.

currency or banking system management problems. We then ask: 1) can the long run equilibrium real exchange rate for a transition economy be modeled with conventional tools? 2) is the error correction model appropriate for explaining short run behavior of the real exchange rate in these economies? 3) do different nominal exchange rate regimes generate explicitly different equilibrium relationships and are the responses to exogenous shocks different? 4) given the appropriateness of the model to what extent has there been real exchange rate misalignment in these two economies? and 5) to the extent that the misalignment is persistent is it an effective indicator of a potential crisis?

We begin with a popular model of long run equilibrium real exchange rate determination applied to developing economies by Elbadawi (1994). The model, based upon earlier work by Dornbusch (1974) and Rodriguez (1989), specifies the long run equilibrium exchange rate as a function of 'sustainable' or 'permanent' values of the macroeconomic fundamentals, such as the terms of trade, net capital inflows, government expenditure and the respective governments' openness to free trade, *inter alia*. We then estimate short run movements of the real exchange rate in an error correction model using GARCH estimation procedures. The responses to exogenous shocks are calculated and we find that the real exchange rate returns to equilibrium much faster in Poland than for Russia. In the pre-crisis period in Russia an exogenous shock takes twice as long to correct as that in Poland, because in Poland the real exchange rate adjusts to the shocks by changes in both the nominal exchange rate and the foreign and domestic price levels. Whereas in Russia the nominal exchange rate is relatively rigid (in the pre-crisis period). Misalignments are calculated as the short run deviations of the real exchange rate from the long run equilibrium values. For Poland, the misalignments in the real exchange rate are relatively small and decline as the nominal exchange rate regime becomes more flexible. The average misalignment in Russia, however, is significantly higher and the misalignment measures in Russia prior to the currency crises in August 1998 clearly indicate incipient pressure to devalue the ruble. The results also indicate that the real appreciations in these transition economies are in part due to significant net capital inflow[4] and productivity shocks[5].

Short run movements of the real exchange rate in the pre-crisis period versus the post August 1998 period are also examined for Russia. Out of sample forecasting exercises are performed for the post-crisis period. The movements of the real exchange rate in the post-crisis period are significantly different from those in the pre-crisis period, indicating that the currency crisis in Russia could not be anticipated by the movements of the real exchange rates as estimated with the macroeconomic fundamentals.

In the next section a brief review of the literature on real exchange rate determination and studies on Eastern Europe in particular are presented. Section 3 outlines the basic model and definitions of the real exchange rate and equilibrium real exchange rate adopted in this paper. In sections 4 and 5 cointegration tests are performed and a model of the determination of the long run equilibrium exchange rate is estimated. The short run error correction model is estimated in section 6 and exogenous shocks examined in section 7. The long run equilibrium real exchange rate and misalignments are calculated in section 8 using a method for decomposing macroeconomic variables into their permanent and transitory components first developed by Beveridge and Nelson (1981). The misalignment results obtained for Russia and Poland are compared and contrasted. While large real exchange rate misalignments were apparent prior to the August 1998 crisis, simple out-of-sample forecasting based upon macro fundamentals,

[4] See Brada (1998), Drabek and Brada (1998), and Liargovas (1999) for a discussion of capital inflows.

[5] See Richards and Tersman (1996), Halpern and Wyplosz (1997), Balazs (2002), de Broeck and Slok (2001) for a discussion of productivity shocks.

presented in section 9, would not forecast a currency crisis. Section 10 provides a summary and conclusions.

2. Exchange Rate Misalignments and Currency Crisis

Real exchange rate misalignment is defined as the difference between the long run equilibrium real exchange rate and the prevailing real exchange rate. However, measurement of the equilibrium real exchange rate is difficult since it is generally unobservable. A common approach to such measurement begins with the notion of purchasing power parity (PPP).[6] In the analysis of transition economies this approach is problematic since an equilibrium period is difficult to identify and productivity and other transition shocks may cause significant changes in the equilibrium real exchange rate. Despite the weaknesses of the PPP approach it has been employed by Barlow and Radulescu (2002), Barlow (2003) and Christev and Noorbakhsh (2000) with mixed results. The real exchange rate is compatible with purchasing power parity in some countries in certain time periods, but not consistently.

Further there were many factors at work during the transition period not typically included in either the absolute or relative PPP model. For example, productivity growth differentials were found to be an important determinant of the exchange rate by Richard and Tersman (1996), Balazs (2002), de Broeck and Slok (2001) Halpern and Wyplosz (1997) and

[6] A representative bundle of goods should cost the same regardless of currency and country (the 'law of one price' or perfect commodity arbitrage holds) and the absolute 'purchasing power parity exchange rate' between any two currencies is the one that ensures the bundle of goods has the same price across countries. In reality this rate is not likely to prevail because of differences in representative commodity bundles, transportation costs, tariffs and other barriers to trade, imperfect or incomplete markets, and imperfect information, *inter alia*. If these factors are held constant and a period in which the economy is at equilibrium can be identified, the notion of relative purchasing power parity defines the equilibrium real exchange rate in the current period as the rate observed in the equilibrium period, adjusting for the cumulative inflation differential since that time (Williamson, 1994).

Lommatzsch and Tober (2005).[7] Desai (1998) suggests that the real appreciations in the transition economies were simply due to the stabilization policies that maintained the nominal rate of depreciation below the rate of inflation. Brada (1998), Drabek and Brada (1998), and Liargovas (1999) observe that the massive capital inflows and high rates of inflation in the transition economies could be the reasons for the real appreciation of the exchange rates. Dibooglu and Kutan (2001) argue that nominal shocks had a major influence on the real exchange rate movements in Poland, but real shocks could explain the movements of the real exchange rate in Hungary.

Therefore, rather than PPP based definitions we employ the definition of the long run equilibrium real exchange rate and analytical approach utilized by Edwards (1989, 1994) and Williamson (1985*), inter alia.* The long run equilibrium real exchange rate is that rate, which, given the permanent values of the macroeconomic fundamentals, ensures the simultaneous attainment of *internal* and *external* equilibrium. Hence, the long run equilibrium real exchange rate may be specified as a function of the 'sustainable' values of the macroeconomic fundamentals under conditions of *internal* and *external* balance.[8] This framework is employed in the exchange rate misalignment literature and the currency crisis literature.

Kemme and Teng (2000) provide a brief review of currency misalignment literature, while examining the determinants of the equilibrium real exchange rate using both purchasing power parity measures and estimates of the real exchange rate as a function of macroeconomic fundamentals for Poland. Balazs and Lahreche-Revil (2003), Kemme and Roy (2003), and

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[7] However, Begg (1998) argues that there might not have been sufficient productivity growth in the Czech Republic to account for the real appreciation.

[8] This notion was originally proposed by Nurske (1944) and has been employed extensively, e.g., by Baffes, Elbadawi, and O'Connell (1999), Barrell and Wren-Lewis (1989), Bayoumi, Clark, Symansky and Taylor, (1994), Church (1992) Currie and Wren Lewis (1989), Edwards (1989), (1994), , Elbadawi (1994), , Elbadawi and O'Connell (1990), Elbadawi and Soto (1994, 1995), Williamson (1985, 1991, 1994), Williamson and Miller (19870, inter alia.

Taylor and Sarno (2001) estimate the equilibrium real exchange rate for different sets of transition economies. They find varying degrees of misalignment and emphasize interest rate differentials and productivity differentials as determinants of the real exchange rate.

An examination of the currency crises in the transition economies also argues for adopting the Edwards-Williamson definition of the equilibrium real exchange rate and specifying it as a function of macroeconomic fundamentals. Chapman and Mulino (2000), Chiodo and Owyang (2002), Desai (2000) and Kharas, Pinto and Ulatov (2001) argue that the Russian crisis has features in common with "first generation" models emphasizing policy inconsistencies.[9] The collapse of the Ruble in August 1998 appeared to be caused by exogenous factors related to the unanticipated financial crisis in Asia, inappropriate fiscal policy and capital inflows. Karfakis and Moschos (2004) conclude that macroeconomic fundamentals played a significant role in explaining speculative attacks in Poland and the Czech Republic. Dobrinsky (2000) examines the currency crisis in Bulgaria emphasizing historic roots, the evolution of fiscal, banking and currency crises, and the political economy of the transition in Bulgaria while Chionis and Liargovas (2003) argue that deteriorating fundamentals underlie the currency crises in Bulgaria, Romania, Russia, and Ukraine.[10]

Overall, the literature indicates deteriorating fundamentals and inconsistent fiscal policies have played an important role in the currency crises in Russia and Eastern Europe. Therefore, when examining the determinants of the real equilibrium exchange rate, the role of the exchange rate regime, measuring exchange rate misalignment and determining whether or not

[9] "First generation" models, beginning with Krugman (1979), explain currency crises in terms of macroeconomic policy inconsistencies. "Second generation" models, Obstfeld (1994, 1996), Eichengreen, et al. (1996a, 1996b) emphasize herd behavior and self-fulfilling expectations. In "third generation" models moral hazard takes on a central role (McKinnon and Pill (1996), *inter alia*). See Krugman (2000) and Sarno and Taylor (2002).

[10] Liargovas (1999) also provides an excellent assessment of the factors, mainly macrofundamentals, influencing real exchange rate movements in Eastern and Central Europe in the early 1990s.

misalignment may be an indicator of impending crises, a model of exchange rate determination based on macrofundamentals should be the starting point.

3. Exchange Rate Determination

Economists concerned with developing countries, small open economies, often use theoretical models that involve the *internal real exchange rate,* the relative price of traded goods to non-traded goods produced in the domestic economy:

$$e^{i} = P_T / P_N \ , \qquad (1)$$

where P_T is the domestic currency price index of traded goods and P_N is the domestic currency price index of non-traded goods. [11] This, the 'dependent economy' definition of the real exchange rate, is the internal relative price of producing and consuming traded goods at the cost of non-traded goods. In a developing or emerging market economy where growth of the traded goods sector relative to the non-traded goods sector is crucial to development,[12] the internal real exchange rate is an important indicator of the incentive to reallocate domestic resources, and a useful device to capture Balassa-Samuelson effects explicitly[13] For these reasons this definition has been adopted or referred to for transition economies (Barlow (2003), De Boroeck and Slok (2000), Egert, et al (2003), Kemme and Teng (2000), Kemme and Roy (2003), Liagrovas (1999), Graffe and Wyplosz (1999), *inter alia*) which are opening to the world economy and

[11] See Montiel and Hinkle (1999) and Hinkle and Nsengiyumva (1999)

[12] See Hinkle and Nsengiyumva (1999). This definition was utilized by Dornbusch (1973, 1982), Devarajan, Lewis, and Robinson (1993), Edwards (1989, 1994), Elbadawi (1994), *inter alia* for developing economies.

[13] When productivity increases in the traded goods sector, demand for labor and thus wage rates increase. This raises labor costs and prices in the non-traded goods sector. Hence, the real exchange rate appreciates. See Egert, et al (2003) for a recent application analysis of the Balassa Samuelson effect in Central and Eastern Europe.

experiencing significant growth in traded goods relative to non-traded goods.[14] Thus, in this context the long run equilibrium real exchange rate is the relative price of tradables to nontradables which, for given sustainable values of other relevant variables such as taxes, international terms of trade, commercial policy, capital and aid flows and technology, results in the simultaneous attainment of *internal* and *external* equilibrium.[15]

A major drawback to using the internal exchange rate is data availability. Data on prices of tradable and non-tradable goods are not readily available, and therefore for the purpose of empirical analysis, the *external* real exchange rate is used as a proxy for the *internal* real exchange rate.[16] It is defined as the nominal exchange rate adjusted for differences in price levels, i.e. the ratio of the aggregate foreign price level to the home country's aggregate price level, measured in terms of a common currency. Thus, the external real exchange rate is

$$e^e = E\,(P_f / P_d)\,, \qquad (2)$$

where E is the nominal exchange rate, defined as the domestic price of the foreign currency, and P_f and P_d are the foreign and domestic aggregate price indexes, respectively. In most empirical analysis the inverse of equation (1) is considered the internal real exchange rate and this is proxied by the inverse of the external exchange rate, equation (2), for measurement purposes. Therefore, we also use this as our definition of the exchange rate henceforth.

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[14] Graffe and Wyplosz (1999) develop a model to explain the trend currency appreciation and the weak link between nominal exchange rate movements and real exchange rate movements in transition economies which focuses on the traded goods – non-traded goods sectors and the decline in the state sector. Liargovas (1999) adopts the definition and in Table 1 presents a nice summary of factors which have affects on the real exchange rate in the case of a small country with traded and non-traded goods. De Broeck and Slok (2001) use a traded goods non-traded goods framework to show that for EU accession countries there is strong evidence of productivity-based exchange rate movements.

[15] Again, from Edwards (1989). Internal equilibrium is a condition where the market for non-tradable goods clears or is expected to clear in current and future periods. External equilibrium is attained when current and future current account balances and long-run sustainable capital flows are consistent with each other.

[16] See Hinkle and Nsengiyumva (1999) for the exact relationship between the two definitions.

Now following Montiel (1999b), and Baffes, Elbadawi, and O'Connell (1999) the equilibrium real exchange rate, e_t^{eq}, is specified as a single equation, the reduced form solution of a small simultaneous equation model:

$$\log (e_t^{eq}) = \boldsymbol{\beta}'\mathbf{F}^{\mathbf{p}}_t \qquad (3)$$

where $\mathbf{F}_t^p$ is a vector of the permanent components of macro fundamentals, and $\boldsymbol{\beta}'$ is a vector of parameters to be estimated.[17] We must estimate both $\boldsymbol{\beta}$ and $\mathbf{F}_t^p$. $\boldsymbol{\beta}$ may be estimated from the long run steady state relationship between the observed values of the fundamentals and the exchange rate:

$$\log (e_t) = \boldsymbol{\beta}'\mathbf{F}_t + \varepsilon_t , \qquad (4)$$

where, e_t is the real exchange rate and $\mathbf{F}$ is the vector of fundamentals. ε_t is assumed to be a stationary stochastic variable with zero mean.

An important condition for the existence of the relationship given by equation (3) is that $\mathbf{F}_t$ is stationary in first differences [i.e. I(1)]. Only then will equation (3) be a candidate for a cointegrating relationship. Kaminsky (1988) showed that equation (3) is a cointegrating relationship when the reduced form equation of the structural model expresses the equilibrium real exchange rate as a function of current and expected permanent components of the macroeconomic fundamentals. If the cointegrating relationship in equation (3) holds and we have an estimate of $\boldsymbol{\beta}'$, B say, then there exists a dynamic error correction equation consistent with (3), which can be written as:

$$D(\log(e_{t+1})) = \boldsymbol{\gamma}_0 (\log e_t - B'\mathbf{F}_t) + \boldsymbol{\gamma}'_1 D(\mathbf{F}_{t+1}) + \boldsymbol{\gamma}'_2 D(\mathbf{X}_{t+1}) \qquad (5)$$

where D(.) stands for the first difference of the corresponding variable or vector; ($\log e_t - B'\mathbf{F}_t$) is the error correction *(EC_t)* term; and $\mathbf{X}$ is a vector of exogenous variables that are either

[17] See also Maeso-Fernandez, Osbat and Schnatz (2004) for a review of methodological issues in estimating equilibrium real exchange rates for Central and East European countries. See Baffes, Elbadawi and O'Connell (1999) for the rationale behind the single equation approach, which we employ here.

stationary or stationary in first differences and have short run effects on the real exchange rate. D(**F**) captures the short run effects of the temporary components of the macroeconomic fundamentals. $\boldsymbol{\gamma_0}$, $\boldsymbol{\gamma'_1}$ and $\boldsymbol{\gamma'_2}$ are the corresponding parameter vectors to be estimated.

Equation (5) is useful in interpreting short run fluctuations and for forecasting purposes. The error correction term is the short run forward-looking self-correcting mechanism. If there is a real under-valuation in the current period, then the error correction term is negative. Hence, if γ_0 is negative, there will be a real appreciation in the next period, thereby self-correcting the under-valuation. Similarly, if there is an overvaluation, the positive error correction term and the negative γ_0 will imply a real depreciation in the next period. The speed of such adjustments will depend on the value of γ_0, with $0<|\gamma_0|<1$, and the closer the value is to 1, the faster the speed of adjustment.

To specify **F** we follow Elbadawi (1994) and Montiel (1999b). The equilibrium real exchange rate is determined by the equilibrium conditions in the traded goods and non-traded goods markets described by a vector of fundamentals:

$$\mathbf{F} = [\underset{(+/-)}{\log(\text{TOT})}, \underset{(-)}{\log(\text{OPEN})}, \underset{(+)}{(\text{FLOW})}, \underset{(+/-)}{\log(\text{GOV})}] \ , \qquad (6)$$

where TOT is the terms of trade, OPEN is equal to the ratio of the sum of export and import to GDP, a proxy for the country's openness to trade, FLOW is the ratio of net capital inflows to GDP, GOV is the ratio of total government expenditures to GDP. [18] The equilibrium real exchange rate is then found by substituting the vector of the permanent values of the macroeconomic fundamentals, $\mathbf{F}^{\mathbf{p}}_t$, into equation (3) along with B, the estimates of $\boldsymbol{\beta}$. The error

[18] Elbadawi (1994) also includes the ratio of public expenditure on non-traded goods to total government expenditure. However, since data on public expenditures on non-traded goods are not available, for estimation purposes, he discards this variable. We also considered oil prices, but Rautava (2004), p. 325, found movements in the Ruble real exchange rate were not affected by oil prices.

correction specification, equation (5), includes **F** and, in addition, other exogenous variables, **X**, which includes the nominal effective real exchange rate, NEER, and the ratio of domestic credit to GDP, DCRE, to capture the effects of nominal devaluation and expansionary macroeconomic policy, respectively, on the short run movements of real exchange rate. A time trend, TREND, is also included. As Dufrenot and Egert (2005) and Taylor and Sarno (2001, p.157) note, the time trend is intended to capture several factors that may cause an appreciation of the real exchange rate in addition to productivity changes, including increased demand for tradable goods relative to non-tradables as income increases during transition, changes in the composition of the CPI which may cause the CPI to increase and the real exchange rate to appreciate, and productivity changes not captured elsewhere. [19]

The sign beneath each variable in (6) indicates the expected sign of the partial derivative in both equations (4), the steady state relationship, and (5), the short run error correction specification. The theoretical model indicate that an increase in the terms of trade will raise purchasing power and so, the domestic demand for all goods increases. Under the small country assumption, the price of the traded goods remains constant, but the price of non-traded goods rises. Thus, the equilibrium real exchange rate increases. This is the income effect. However, an increase in the terms of trade will also have substitution effects on both demand and supply sides. Consumers will shift from the consumption of exportables and non-traded goods to the consumption of importables. This increases imports, and lowers the price of non-traded goods, causing a fall in the real exchange rate. On the other hand, producers will increase production of exportables and decrease production of non-traded goods. This will raise the real exchange rate.

[19] Dufrenot and Egert (2005) estimate a slightly different specification for the real exchange rate in the Czech Republic, Hungary, Poland, Slovakia and Slovenia in a two equation structural vector autoregressive model in order to determine whether the trend appreciations in the real exchange rate exhibited in transition economies were movements toward the equilibrium rate or there was still potential disequilibrium.

The sign of the coefficient of TOT in the long run equilibrium relationship is, therefore, indeterminate.

An increase in net capital inflows is expected to raise the real exchange rate by increasing the supply of foreign currency and putting inflationary pressure on the domestic market. Thus the sign of FLOW is expected to be positive. As the openness of a country increases, with increased supply of foreign goods the demand for non-traded goods is likely to fall, thereby decreasing the real exchange rate. Hence, the expected sign for the OPEN variable is negative. To the extent that government expenditure increases in the non-traded goods sector, it is expected to have a positive effect on the real exchange rate by raising the price of the non-traded goods, and the sign of GOV is positive. However, if the share of government spending on non-traded goods falls even though government expenditure increases, then the real exchange rate is likely to decrease.

In the error correction equation, equation (5), the signs of both DCRE and NEER are expected to be positive. An expansionary macroeconomic policy generates inflationary pressures increasing the price of non-traded goods and the exchange rate. In the short run a nominal devaluation will cause a real devaluation as well and the expected sign would be positive.

Thus, equations (3), (4) and (5) with the vector of fundamentals given in (6), and the additional variables in **X**, constitute the entire model for exchange rate determination. The parameters, $\boldsymbol{\beta}$, are estimated from equation (4). The long run equilibrium real exchange rate, e_t^{eq}, is found by substituting the permanent values of the fundamentals, $\mathbf{F^p}$, and the estimates of $\boldsymbol{\beta}$ into equation (3). Short run fluctuations in the exchange rate may be examined with equation (5), also estimated after substituting the estimates of $\boldsymbol{\beta}$. Then, misalignments are calculated as the short run deviations of the exchange rate from the long run equilibrium value corresponding to the sustainable or permanent values of the macroeconomic fundamentals.[20] In order to calculate the permanent values of the macroeconomic fundamentals the time series decomposition technique introduced by Beveridge and Nelson (1981) and simplified by Cuddington and Winters (1987) is utilized in Section 8, below.

The model is particularly relevant to the transition economies, since with more liberal policies, the growth of the traded goods sector relative to that of the non-traded goods sector may have significant implications for the determination of the equilibrium real exchange rate. It allows: (1) testing the empirical findings by Halpern and Wyplosz (1997), Balazs (2002) and de Broeck and Slok (2001) that much of the real appreciations of the exchange rates in the transition economies were due to changes in productivity conditions, and (2) confirming the observation by Brada (1998), Drabek and Brada (1998) and Liargovas (1999) that significant net capital inflows caused real appreciations of the exchange rates. Moreover, the model is simple in terms of data requirements.

In the following section the estimation results for equations (4) and (5) for Russia and Poland are presented and discussed (sections 4-7). Given the estimates of the permanent values of the macro fundamentals and $\boldsymbol{\beta}$, the exchange rate misalignments can then be calculated (section 8), and out of sample forecasts can be made (section 9) to examine the potential for exchange rate crises.

4. Tests for Stationarity

To verify whether the long run equilibrium equation can be specified as a cointegrating relation, the order of integration (i.e. whether stationary, or stationary in the first or higher

[20] See equation (7) in section 8.

difference) of each variable for each country is determined with suitable unit root tests.[21] Then, given the unit root tests, the long run equilibrium relationship, equation (4), is estimated. Then the error correction equation (5) is specified for each country.

All data are from *International Financial Statistics* (IFS) and the Institute for Economic Research, Halle, Germany. The individual variables and the corresponding data sources are discussed in the appendix. Monthly data from January 1995 to December 2001 are employed for each country. By 1995 the economies were more stable and more reliable data were available.[22] During the early transition period, prior to 1995 it is widely argued that the currencies were significantly undervalued. Beginning the sample in 1995 avoids this period of instability and the real currency appreciations that prevailed during the early period in most transition economies.[23] In addition the exchange rate regime in Poland was less flexible prior to 1995. In 1995 a managed float was introduced and in 1996 a very wide band (15%) was introduced and the regime gradually became a free float.[24]

The results from Augmented Dicky-Fuller and Phillips-Perron unit root tests are presented in Table 1 for Poland and Table 2 for Russia.[25] The tests are conducted for the series in levels, as well as first differences. All the variables, except *FLOW*, are in logarithmic terms. For both tests,

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[21] As mentioned earlier, each variable in the long run equilibrium relationship has to be either I(0) or I(1).

[22] Further, data for several of the variables we include in the model below were not available until 1995.

[23] The causes of this appreciation are debatable. Liargovas (1999) discusses several potential causes for the appreciation. Dufrenot and Egert (2005) look at the determinants of the real exchange rate for Hungary and Poland with data from 1992:1 to 2002:12 and the Czech Republic, Slovakia and Slovenia for 1993:1 to 2002:12. They concluded that macro fundamentals were an important factor in the real appreciations that took place in these countries.

[24] See Orlowski (2000) for a brief description of the exchange rate regime in Poland at this time.

[25] ADF tests are expected to perform satisfactorily even when the number of observations is small (Hamilton (1994)). However, Perron (1989) argued that structural breaks in the data would invalidate the conventional unit root tests. Therefore we use the Phillips-Perron test to confirm the ADF tests. For details see Hamilton (1994).

the null hypothesis is the existence of a unit root, i.e. the series (at the level or at the first difference) is non-stationary. A low p-value indicates stationarity.

Table 1
Poland: summary results for unit root tests[1]

Variable	ADF(k)[2]	P-Value	S/N[3]	Phillips-Perron(b)[4]	P-Value	S/N
log(e)	-3.07(1)	0.12	N	-2.38(3)	0.38	N
Δlog(e)	-6.03(0)	0.00	S	-5.59(9)	0.00	S
log(TOT)	-1.15(11)	0.69	N	-7.14(4)	0.00	S
Δlog(TOT)	-3.10(11)	0.00	S	-16.07(3)	0.00	S
FLOW	-2.34(1)	0.40	N	-2.27(2)	0.44	N
ΔFLOW	- 7.30(0)	0.00	S	-7.30(3)	0.00	S
log(OPEN)	-5.92(0)	0.00	S	-5.92(0)	0.00	S
Δlog(OPEN)	-2.37(11)	0.01	S	-17.05(32)	0.00	S
log(GOV)	-1.93(9)	0.63	N	-4.22(5)	0.00	S
Δlog(GOV)	-14.85(8)	0.00	S	-12.53(3)	0.00	S
log(NEER)	-2.06(2)	0.26	N	-2.08(5)	0.25	N
Δlog(NEER)	-6.80(1)	0.00	S	-5.70(16)	0.00	S
log(DCRE)	-2.02(0)	0.58	N	-1.98(2)	0.60	N
Δlog(DCRE)	-10.00(0)	0.00	S	-10.00(0)	0.00	S

[1] Test equations were chosen with or without intercept and/or trend terms depending on the P-value of the t-statistics in the test equation.

[2] k is the optimal lag length indicated by the Schwartz Information criterion from a maximum length of 12.

[3] S is 'stationary' and N is 'non-stationary', as indicated by the corresponding test statistic at 5% level of significance.

[4] b is the bandwidth chosen by the Newey-West bandwidth criterion.

Table 2
Russia: summary results for unit root tests[1]

Variable	ADF(k)[2]	P-Value	S/N[3]	Phillips-Perron(b)[4]	P-Value	S/N
log(e)	-1.90(1)	0.32	N	-1.82(4)	0.37	N
Δlog(REER)	-6.58(0)	0.00	S	-6.55(2)	0.00	S
log(TOT)	-3.00(0)	0.14	N	-2.85(3)	0.18	N
Δlog(TOT)	-11.27(0)	0.00	S	-11.33(1)	0.00	S
FLOW	-1.44(0)	0.56	N	-1.72(3)	0.73	N
ΔFLOW	-9.11(0)	0.00	S	-9.11(3)	0.00	S
log(OPEN)	-1.99(0)	0.60	N	-2.15(4)	0.50	N
Δlog(OPEN)	-5.68(5)	0.00	S	-9.12(3)	0.00	S
log(GOV)	-0.64(11)	0.43	N	-8.62(1)	0.00	S
Δlog(GOV)	-5.28(10)	0.00	S	-43.31(8)	0.00	S
log(NEER)	-1.78(1)	0.70	N	-1.77(4)	0.71	N
Δlog(NEER)	-7.02(0)	0.00	S	-7.04(3)	0.00	S
log(DCRE)	-2.29(3)	0.17	N	-2.20(5)	0.20	N
Δlog(DCRE)	-2.30(11)	0.02	S	-11.20(5)	0.00	S

[1] Test Equations were chosen with or without intercept and/or trend terms depending on the P-value of the t-statistics in the test equation.

[2] k is the lag length chosen by Schwartz Information criterion from a maximum length of 12.

[3] S is 'stationary' and N is 'non-stationary', as indicated by the corresponding test statistic at 5% level of significance.

[4] b is the bandwidth chosen by the Newey-West bandwidth criterion.

Tables 1 and 2 indicate that the series are either stationary or difference stationary. The real exchange rate is found to be difference stationary for both countries, and the macroeconomic fundamentals are either stationary or difference stationary. For a few variables, the results obtained from the ADF test and that from the Phillips-Perron test differ. Since for each country the real exchange rate along with some other macroeconomic fundamentals are found to be non-stationary in levels and stationary in first differences, the long run equilibrium equations for each country can be estimated, provided the real exchange rate and the fundamentals are cointegrated.

5. Estimation of the Long Run Real Equilibrium Exchange Rate Equation

Finding the long run equilibrium relation (equation (3)) involves two separate but related tasks: testing for the existence of a cointegrating relation, and estimation of the coefficient vector. The Engel-Granger (1987) method applies OLS to a static regression of the real exchange rate on its fundamentals in levels (equation (4)). If the residuals from the regression are found to be stationary, then the estimated parameters are cointegrating parameters.[26] However, in finite samples the static OLS (henceforth SLOS) estimators are biased if the regressors are not strictly exogenous (Banerjee et al., 1986, and Stock, 1987). Strict exogeneity would be violated if there is serial correlation (Hamilton, 1994, pp. 608 – 612, and Hayashi, 2000, pp. 650 - 655). Yet another drawback of SOLS is that the asymptotic distributions of the t-ratios depend on 'nuisance parameters' (Hayashi, 2000). To correct this Saikkonen (1991), Phillips and Loretan (1991), Stock and Watson (1993), and Wooldridge (1991) suggest dynamic OLS (henceforth DOLS), in which the regressors would be strictly exogenous. In this case, first differences, as well as first differences with lags and leads of the regressors are considered along with the

[26] When testing for a unit root in the residuals more restrictive critical values should be employed than in the univariate unit root tests.

regressors in levels. Accordingly, the t-ratios are adjusted to test hypotheses on the coefficients. [27]

A second alternative is of course the Johansen (1988) procedure, in which a full vector autoregressive system is estimated. However, in finite samples this procedure has the serious problem of "the curse of dimensionality." Monte Carlo evidence suggests that the performance of this procedure is very poor in small samples. It generates frequent outliers and large mean bias and the power of the tests are very low. More importantly, however, the procedure is less effective than the single equation approach if the system parameters are misspecified (e.g. in terms of lag length), and if there are problems like serial correlation in the equilibrium error (Hargreaves, 1994, and Baffes, Elbadawi, and O'Connell, 1999). Thus, while in our case the Johansen method is not suitable for estimation purposes, we do employ it to determine the number of cointegrating vectors. To estimate the cointegrating vectors we employ DOLS. Then the existence of cointegrating vectors is confirmed with relevant unit root tests of the residuals obtained from the DOLS procedure.

In Tables 3 and 4, the test results from the Johansen procedure are reported. The trace statistics for both Poland and Russia suggest the existence of one cointegrating vector at 1% as well as 5% levels of significance. The maximum eigen value statistics suggest the existence of one cointegrating vector for Poland and two cointegrating vectors for Russia at both 1% and 5% levels of significance.

[27] Descriptions of this procedure and the related adjustment methods can be found in Hamilton (1994, pp. 608 - 612) and Hayashi (2000, pp. 650 – 655).

Table 3: Poland: Johansen Cointegration test; with linear deterministic trend and lag interval (in first differences) 1 to 2

Unrestricted Cointegration Rank Tests

Hypothesized No. of CE's	Eigen-value	Trace Statistic	5 Percent Critical Value	1 percent Critical Value
None	0.437694	97.77270	87.31	96.58
At most 1	0.250301	51.14031	62.99	70.05
At most 2	0.224773	27.80552	42.44	48.45
At most 3	0.060982	7.18299	25.32	30.45
At most 4	0.025429	2.08642	12.25	16.26

Hypothesized No. of CE's	Eigen-value	Max-Eigen Statistic	5 Percent Critical Value	1 percent Critical Value
None	0.437694	46.63240	37.52	42.36
At most 1	0.250301	23.33479	31.46	36.65
At most 2	0.224773	20.62253	25.54	30.34
At most 3	0.060982	5.09656	18.96	23.65
At most 4	0.025429	2.08642	12.25	16.26

Table 4: Russia: Johansen cointegration test; with linear deterministic trend and lag interval (in first differences) 1 to 2

Unrestricted Cointegration Rank Tests

Hypothesized No. of CE's	Eigen-value	Trace Statistic	5 Percent Critical Value	1 percent Critical Value
None	0.524723	122.95190	87.31	96.58
At most 1	0.371151	62.69944	62.99	70.05
At most 2	0.139696	25.12649	42.44	48.45
At most 3	0.100898	12.93849	25.32	30.45
At most 4	0.051976	4.32339	12.25	16.26

Hypothesized No. of CE's	Eigen-value	Max-Eigen Statistic	5 Percent Critical Value	1 percent Critical Value
None	0.524723	60.25245	37.52	42.36
At most 1	0.371151	37.57296	31.46	36.65
At most 2	0.139696	12.18800	25.54	30.34
At most 3	0.100898	8.61509	18.96	23.65
At most 4	0.051976	4.32339	12.25	16.26

In Tables 5 and 6, the estimated cointegrating equations for the logarithm of real exchange rate for Poland and Russia are presented. The t-statistics are in parentheses. Specification 1 in each table is the initial specification. In order to correct for possible serial correlation and simultaneity bias the equations are re-specified with DOLS. Specification 2 is the final result. To confirm that the vector of the estimated coefficients is a cointegrating vector, ADF and Phillips-Perron unit root tests are conducted on the residual series. The relevant critical values are obtained from Philips and Ouliaris (1990, Table IIc). The tests strongly reject the null hypothesis of the existence of a unit root and, therefore, the residual series are stationary. Thus, these equations characterize the long-run equilibrium real exchange rate as a function of the sustainable values of the macroeconomic fundamentals.

Table 5
Poland: long run equilibrium relation (equation (3)) for real exchange rate
(1995:01 2001:12)

	Coefficients estimates (t-statistic)	
Variable	Specification 1 Static OLS (1995:01 – 2001:12)	Specification 2[1] Dynamic OLS (1995:06 – 2001:09)
Constant	3.985652	2.212040
	(26.67)	(2.67)
TREND	0.005244	0.005543
	(16.40)	(9.92)
log(TOT)	-0.072145	-0.792039
	(-1.48)	(-3.26)
FLOW	0.565288	0.933904
	(6.30)	(4.77)
log(OPEN)	-0.041937	-0.181601
	(-0.76)	(-1.48)
log(GOV)	-0.034432	-0.825301
	(-0.48)	(-2.09)
R^2	0.87	0.92
Adjusted R^2	0.86	0.88
Unit Root Tests for residual[2]		
ADF Statistic	-3.67(1)	-8.09(0)
Phillips-Perron Statistic	-2.93(7)	-8.09(2)
1% Critical Value	-5.04	-5.04
5% Critical Value	-4.20	-4.20

[1] Dynamic OLS corrects for serial correlation and endogeneity of the regressors, as recommended by Hamilton (1994, pp. 608 – 612) and Hayashi (2000, pp. 650 – 665). Along with the fundamentals in levels, the first differences as well as first differences with up to three period lags and four period leads were also considered. Here, for lack of space only the

coefficients of the fundamentals in levels are reported. The t-statistics are adjusted, as recommended by Hamilton (1994, pp. 610) and Hayashi (2000, pp. 656 – 658).

[2] The residuals are calculated as the differences between the observed values and the corresponding fitted values (given by the fundamentals in levels). The critical values are from Philips and Ouliaris (1990, Table IIc).

Table 6
Russia: long run equilibrium relation (equation (3)) for real exchange rate
(1995:01 2001:12)

	Coefficients estimates (t-statistic)[1]	
Variable	Specification 1 Static OLS (1995:01- 2001:12)	Specification 2[1] Dynamic OLS (1995:06 – 2001:08)
Constant	3.750018	4.795579
	(8.21)	(5.27)
TREND	0.003611	0.004066
	(8.29)	(7.90)
log(TOT)	-0.040222	-0.437624
	(0.70)	(4.04)
FLOW	0.504464	1.952449
	(1.46)	(3.30)
log(OPEN)	-0.901751	-0.436329
	(-8.86)	(-1.73)
log(GOV)	0.068315	0.440516
	(2.26)	(2.39)
R^2	0.88	0.99
Adjusted R^2	0.87	0.97
Unit Root Tests for residual[2]		
ADF Statistic	-6.73(0)	-8.26(0)
Phillips-Perron Statistic	-6.81(4)	-8.26(1)
1% Critical Value	-5.04	-5.04
5% Critical Value	-4.20	-4.20

[1] Dynamic OLS corrects for serial correlation and endogeneity of the regressors, as recommended by Hamilton (1994, pp. 608 – 612) and Hayashi (2000, pp. 650 – 665). Along

with the fundamentals in levels, the first differences as well as first differences with up to four period lags and four period leads were also considered. Here, for lack of space only the coefficients of the fundamentals in levels are reported. The t-statistics are adjusted by a factor, as recommended by Hamilton (1994, pp. 610) and Hayashi (2000, pp. 656 – 658).

[2] The residuals are calculated as the differences between the observed values and the fitted values (given by the fundamentals in levels). The critical values are from Philips and Ouliaris (1990, Table IIc).

All of the coefficient estimates (except that of OPEN) in the final specifications are statistically significant at 5% levels, and have the expected signs. The OPEN variable is statistically significant at the 10% level for both countries. The TREND variable essentially accounts for the effects of productivity growth. To the extent productivity growth takes place in the non-traded goods sector, the real exchange rate is expected to fall. However, if productivity increases in the traded goods sector instead, then the demand for labor in this sector increases, wages rise, and as a result, the price of non-traded goods increases and the real exchange rate rises (a positive Balassa-Samuelson effect). For both the countries, TREND is found to be significant with a positive sign, thus indicating productivity growth in the traded goods sector. With the transition economies opening to the world markets, the domestic producers of traded goods face increased competition on the world market. The result confirms the suggestion by Halpern and Wyplosz (1997), *inter alia*, that changes in demand and productivity conditions contributed to the real appreciations of the exchange rates in the transition economies. The coefficient for the terms of trade, TOT, has a negative sign for both countries. This indicates that in these countries the substitution effects are larger than the income effect of a change in the terms of trade. Capital flows, FLOW, is found to be statistically significant for both countries with a positive sign. This is important since Brada (1998)) and Drabek and Brada (1998) point out that all the transition economies liberalized capital accounts, and this resulted in massive capital inflows in the pre-crisis period. This was accompanied by domestic inflation and real appreciation of the exchange rate. However, around the time of the August 1998 crisis, all transition economies experienced capital flow reversals along with a depreciation of the respective real exchange rate. The openness of the economy, OPEN, is negative and statistically significant for both countries. The implication is that trade liberalization may not be viable without currency depreciation. The share of government expenditure in GDP, GOV, is statistically significant for both Poland and Russia. A priori the sign may be either positive or negative. And indeed it is positive for Russia, but negative for Poland. During this period GOV exhibits a downward trend and the real exchange rate has an upward trend in both countries. This implies that government expenditures in Russia were biased toward non-tradables and as GOV falls, expenditures on non-traded goods falls faster than expenditures on tradables and therefore the price of non-tradables falls faster than the price of tradables and the real exchange rate decreases as GOV decreases (or increases as GOV increases). The opposite occurs in Poland if government expenditures are biased toward traded goods.

6. Short Run Exchange Rate Estimates

In Tables 7 and 8 the error correction equations are presented. $\Delta(.)$ denotes the first difference of the relevant variable, and the p-value is in parentheses beneath each coefficient. These equations describe short run changes in the real exchange rate as a function of short run changes of the relevant fundamentals, TOT, FLOW, OPEN and GOV, other exogenous variables, DCRE and NEER, and the error correction term, EC(-1), the difference between the actual real exchange rate and the estimated long-run real exchange rate, one period lagged. Specification 1 is the initial specification, with some coefficients statistically insignificant. For both Poland and Russia the White test for heteroscedasticity and the test for serial correlation and ARCH type errors indicate we cannot reject heteroscedasticity, serial correlation, and ARCH. As a result we then estimate the models with exponential generalized autoregressive conditional heteroscedasticity (EGARCH) procedures,[28] with lags of the first differences of the fundamentals and the exogenous variables. The coefficient estimates of the mean equation are presented as specification 2 in Table 7 for Poland and Table 8 for Russia. In these specifications, all the coefficients are statistically significant.[29]

Russia underwent a regime change immediately following the currency crisis. The structural break in the long run equilibrium real exchange rate appears obvious and the Chow break-point test on the cointegrating equation (specification 1, Table 6)[30] for Russia with the crisis month (August 1998) as the break point strongly rejects the null hypothesis of no structural change. Thus, in order to capture the distinctive features of the pre-crisis period, another error correction equation is specified for Russia with the inclusion of a dummy variable equal to zero in the pre-crisis period, and equal to one from the crisis period onward. Specification 3 in Table 8 presents the modified equation. The dummy is significant and all variables that are significant in specification 2 of Table 8 are significant in specification 3, Table 8.[31]

Specification 4 in Table 8 reports the coefficient estimates of the mean equation for the error correction model for Russia in the pre-crisis period. Like the other specifications, the final

[28] In the tables EGARCH(m, n) is exponential GARCH, with m lags of the variance term and n lags of the error term in the conditional variance equation.

[29] For Russia we drop TOT due to colinearity.

[30] The Chow break point test could not be conducted on specification 2 due to insufficient number of observations. The Chow break point test also confirms a structural break in the short run error correction models reported in Table 8.

[31] We also tried another specification with cross terms involving dummy that produced mixed results.

specification is an EGARCH specification with suitable lags of the variables in first differences. Comparison of equations 2, 3 and 4 in Table 8 indicates that the set of variables found significant for the pre-crisis period is nearly the same as that for the entire period. The coefficient of the error correction term in Specification 4 is much smaller than in specification 2 and 3, likely because Russian monetary authorities had less liberal policies for the exchange rate in the pre-crisis period.[32] Specification 4 will be utilized in Section 9 for out of sample forecasting.

Table 7
Poland: error correction equations (equation (5)) for real exchange rate

	Coefficients Estimates (p-value)	
Variable	Specification 1 OLS (1995:07 – 2001:09)	Specification 2 EGARCH(7, 4) (1995:07 – 2001:09)
EC(-1)	-0.026933 (0.21)	-0.042708 (0.00)
Δlog(TOT)	-0.025976 (0.04)	-0.018804 (0.00)
ΔFLOW	-0.130739 (0.06)	-0.103030 (0.00)
Δlog(OPEN)	0.035170 (0.02)	0.016684 (0.00)
Δlog(GOV)	0.030413 (0.18)	0.013732 (0.02)
Δlog(DCRE)	0. 170624 (0.01)	0.076929 (0.00)
Δlog(NEER)	1.012465 (0.00)	0.938424 (0.00)
Δlog(TOT(-1))		-0.003272 (0.00)
ΔFLOW(-1)		-0.069762

[32] The results on misalignment in section 8 below indicate that this rigid policy for the exchange rate contributed to the currency crisis.

		(0.00)
Δlog(OPEN(-1))		0.008083
		(0.00)
Δlog(GOV(-1))		0.018307
		(0.00)
Δlog(DCRE(-1))		0.264572
		(0.00)
Δlog(NEER(-1))		0.034350
		(0.00)
Δlog(TOT(-2))		-0.023987
		(0.00)
ΔFLOW(-2)		-0.026870
		(0.00)
Δlog(OPEN(-2))		0.014910
		(0.00)
Δlog(GOV(-2))		-0.012399
		(0.00)
Δlog(DCRE(-2))		0.207265
		(0.00)
Δlog(NEER(-2))		0.021085
		(0.14)
MA(1)		0.546202
		(0.00)
R^2	0.84	0.90
Adj. R^2	0.83	0.80
Root Mean Sqd. Error	0.008	0.006
Mean Absolute Error	0.006	0.004
Mean Absolute % Error	0.140	0.096
Durbin Watson	0.80	1.52
Breusch-Godfrey Stat.	7..00	
Probability (B-G)	0.00	
White Statistic	53.11	
Probability(White)	0.02	
ARCH Statistic	5.18	0.31
Probability (ARCH)	0.02	0.57

Table 8
Russia: error correction equations (equation (5)) for real exchange rate

Coefficients Estimates
(p-value)

Variable	Specification 1 (OLS) (1995:06 – 2001:08)	Specification 2 (EGARCH(7, 5)) (1995:06 – 2001:08)	Specification 3 (EGARCH(6, 5) (1995:06 – 2001:08)	Specification 4 (EGARCH(3, 1)) (1995:06 – 1998:07)
EC(-1)	-0.041617	-0.040402	-0.043432	-0.014057
	(0.10)	(0.00)	(0.00)	(0.00)
DUMMY			0.009362	
			(0.00)	
Δlog(TOT)	0.187391			
	(0.01)			
ΔFLOW	-0.502740	0.125576	0.089474	-0.080262
	(0.07)	(0.00)	(0.00)	(0.00)
Δlog(OPEN)	-0.112147	-0.067293	-0.056559	-0.034273
	(0.03)	(0.00)	(0.00)	(0.00)
Δlog(GOV)	0.017466	0.007556	0.012137	0.000553
	(0.04)	(0.00)	(0.00)	(0.00)
Δlog(DCRE)	-0.164652	0.018252	0.030077	0.011302
	(0.03)	(0.00)	(0.00)	(0.00)
Δlog(NEER)	0.591833	0.607370	0.616844	1.505580
	(0.00)	(0.00)	(0.00)	(0.00)
ΔFLOW(-1)		0.104308	0.043656	0.260063
		(0.00)	(0.00)	(0.00)
Δlog(OPEN(-1))		0.014002	0.028187	0.011548
		(0.16)	(0.00)	(0.29)

Δlog(GOV(-1))		-0.007514	-0.009930	0.004312
		(0.00)	(0.00)	(0.00)
Δlog(DCRE(-1))		-0.014223	-0.006580	0.036309
		(0.66)	(0.00)	(0.00)
Δlog(NEER(-1))		-0.031447	-0.010798	0.096798
		(0.00)	(0.03)	(0.00)
MA(1)		0.602067	0.455863	
		(0.00)	(0.00)	
R^2	0.91	0.94	0.94	0.85
Adj. R^2	0.90	0.89	0.90	0.71
Root Mean Sqd. Error	0.017	0.014	0.013	0.011
Mean Absolute Error	0.013	0.010	0.009	0.008
Mean Absolute % Error	0.284	0.215	0.204	0.178
Durbin Watson	0.60	1.700	1.474	0.576
Breusch-Godfrey Stat.	6.02			
Probability (B-G)	0.01			
White Statistic	67.08			
Probability(White)	0.00			
ARCH Statistic	4.84	0.02	0.66	0.125
Probability (ARCH)	0.03	0.90	0.41	0.72

The sign of the error correction term, EC(-1), in the final specifications is crucial. This coefficient reflects the self-correcting dynamic mechanism of the error correction model, and is expected to be negative. If the fundamentals in the last period dictate a lower real exchange rate than that observed, then the real exchange rate will strictly depreciate in the current period. The sign is negative in all the specifications. Stability requires the absolute value of the coefficient to be between zero and one, and this is the case in all specifications.

In all cases the fundamentals that were found to be significant in the long run equilibrium relations (Tables 5 and 6) are also found to be significant in the error correction equations (Tables 7 and 8), except TOT for Russia. In general, the original signs are retained, except for FLOW, OPEN, and GOV for Poland. Thus, the 'temporary' effects of the fundamentals on the short run movements of the real exchange rates are important –as Elbadawi (1994) suggests. NEER and DCRE in the error correction equations account for the effects of nominal devaluation and expansionary macroeconomic policy. Nominal devaluation is statistically significant with a negative impact on the short run movement of the real exchange rate, as expected. The expansionary macroeconomic policy, which is expected to appreciate the real exchange rate, is also found to be significant for both countries.

EGARCH in the final specifications has special significance. The error terms are not only serially correlated, but also have non-constant volatilities that are conditional on the past squared error terms. This means large swings of the real exchange rate in the current period can be at least partly explained by its past volatility. This may happen in spite of the presence of the error correction term in the short run error correction equation for two reasons. First, the strength of the error correction term may not be large enough to fully correct the exchange rate quickly (note that in the estimated error correction equations none of the related coefficients is close to one in absolute value). Second, the 'temporary' changes in the fundamentals and the exogenous variables may be such that they drive the real exchange rate away from the long run equilibrium for a prolonged period.

Figures 1, 2, and 3 present the actual real exchange rate and the short run real exchange rate estimated from the error correction model for Poland and Russia, respectively. They indicate that the estimated error correction equations capture the movements of the real exchange rates in the short run very well.[33]

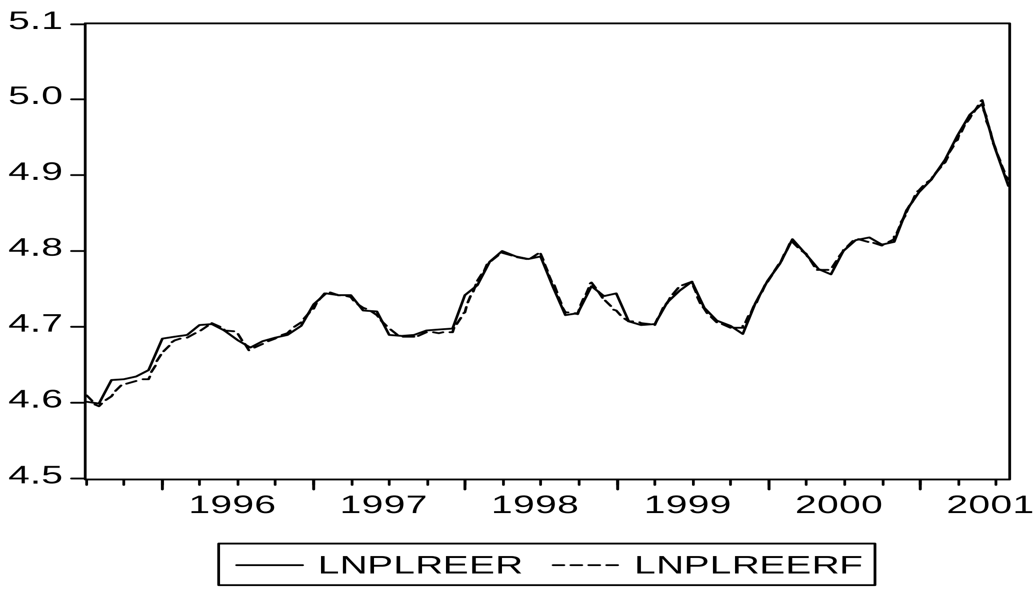

Fig 1. Poland, Actual and Fitted Real Exchange Rates (log), specification 2
* LNPLREER: actual log real exchange rate; LNPLREERF: fitted log real exchange rate

[33] Moreover, although not reported here, the within sample forecast error measures (Root Mean Squared Errors, Mean Absolute Errors, and Mean Absolute Percent Errors) indicate the fitted equations capture the movements of the observed real exchange rates in the short run.

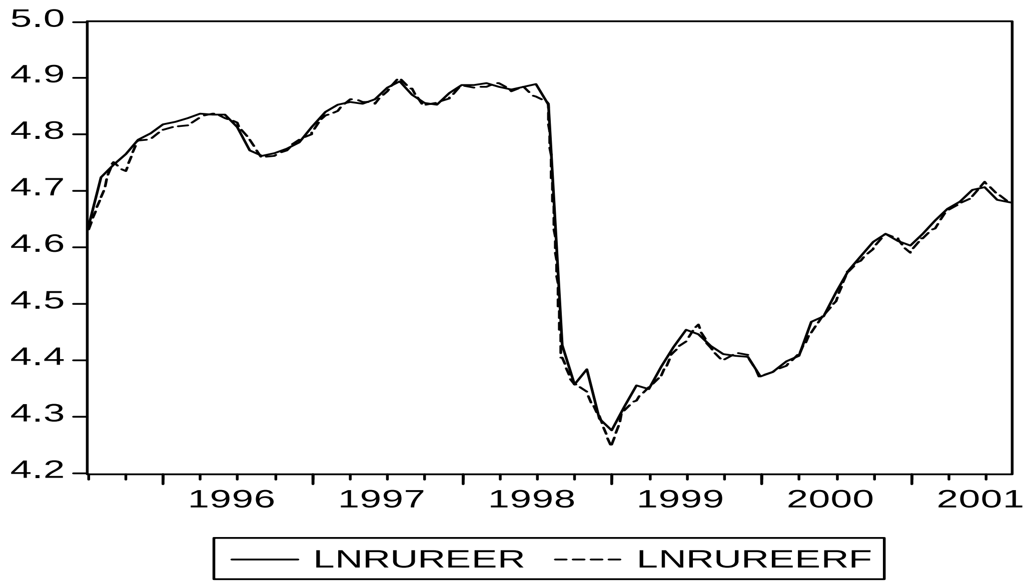

Fig 2. Russia: actual and fitted real exchange rates (log), specification 2
* LNRUREER: actual log real exchange rate; LNRUREERF: fitted log real exchange rate

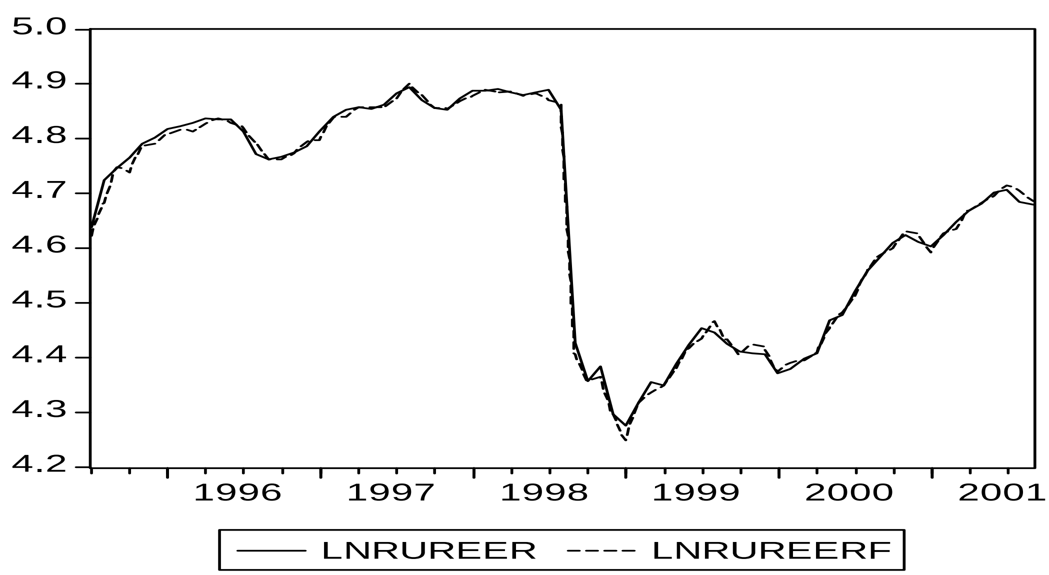

Fig 3. Russia: actual and fitted real exchange rates (log), specification 3
*LNRUREER: actual log real exchange rate; LNRUREERF: fitted log real exchange rate

7. The Effect of Exogenous Shocks

The half-lives of exogenous shocks for both countries are calculated and are presented in Table 9.[34] We consider the coefficient of the error correction term in specification 2, Table 7 for Poland, and in specification 3 and 4, Table 8, for Russia. These are greater than what Baffes, Elbadawi, and O'Connell (1999) calculate for Burkina Faso and Cote d'Ivoire. However, these are clearly consistent with the respective monetary authority's exchange rate policies. In the early years of transition Russia authorities maintained a fairly rigid managed float within a band, but as a result of the onset of the crisis in August 1998 was forced to float the Ruble. During the pre-crisis period the real exchange rate equilibrates mainly via changes in the foreign and domestic price levels, a process that could be quite lengthy. Thus, the half life for the pre-crisis period is much greater than that for the entire sample, as expected. The foreign exchange regime in Poland was a float within a very wide band, then a free float through this period. Thus the real exchange rate then equilibrated via both changes in the nominal exchange rate and changes in foreign and domestic price levels.

Table 9
Speed of automatic adjustment to correct 50% of exogenous shock

Country	Required no. of years
Poland, Spec. 2, Table 7, entire period	1.32
Russia, Spec. 3, Table 8, entire period	1.30
Russia, Spec. 4, Table 8, pre-crisis period	4.11

[34] Given the coefficients, the speed of automatic adjustments from exogenous shocks is

$$(1-\alpha) = (1-|\beta|)^T,$$

where α is the percentage correction, β is the estimated coefficient of EC(-1), and T is the required number of periods to correct the shock. See Baffes, Elbadai and O'Connell (1990), p. 442.

8. The Long Run Equilibrium Real Exchange Rates and Misalignments

Calculating the long run equilibrium real exchange rates require the permanent values of the macro fundamentals. In many applications the trend component of a non-stationary time series is taken as the permanent value. However, in some cases what may appear to be a 'trend', may in fact be the accumulation of changes that are autocorrelated, having a mean value. To overcome this limitation, Beveridge and Nelson (1981) provide an alternative method for decomposing a time series into permanent and transitory or cyclical components using ARIMA models. The advantage of this method is that at least part of the short run changes in any economic variable can be attributed to changes in the equilibrium values. Cuddington and Winters (1987) suggest an improvement that reduces the computational cost of the decomposition method, and their approach is utilized in order to decompose the time series of the macroeconomic fundamentals into permanent and transitory components.

The estimates of the long run equilibrium real exchange rates (e^{eq}) are then obtained by substituting the values of the permanent components into the estimated cointegrating equations (specification 2 from Table 3 for Poland, and specification 2 from Table 4 for Russia). The misalignments then are calculated as

$$M = \log(e) - \log(e^{eq}), \quad (7)$$

where e^{eq} is the long run equilibrium real exchange rate, e is the actual real exchange rate, and M > 0 implies a currency overvaluation.

In Figure 4 the real exchange rate misalignments for both countries are plotted. Note that in Russia there was a strong under-valuation of the currency in the very early years, followed by a prolonged overvaluation in the pre-crisis period due to excessive net capital inflows and high rates of inflation. It is also found that just around the time of the crisis, the speculative pressure in the foreign exchange market and depletion of reserves led to a sudden devaluation and undervaluation of the Ruble. At the beginning of August the overvaluation was about 21%. When the Ruble floated there was a sharp decline resulting in a 21% undervaluation. The average overvaluation of the Ruble of 10% in the pre-crisis period was 150% higher than the average undervaluation of 4% in the post-crisis period.

In Poland there were several changes in the foreign exchange regime to increase the flexibility of the exchange rate during the mid-1990s. First, the band around central parity was widened from 0.5% to 2% in March 1995. Then there was a revaluation of 6% at the end of 1995 and a widening of the band to 7% in May 1996, 10% in February 1998 and 15% in March 1999. Finally in April 2000 a full float was introduced.[35] As the band widened the greater flexibility of the nominal exchange rate appeared to reduce the degree of misalignment. The greatest misalignment was in 1995 just prior to the revaluation, and in late 1999 just prior to the introduction of the free float. While our methodology is quite different our results for Poland also corroborate the claims of Dufrenot and Egert (2005) and Lommatzsch and Tober (2005) that the real appreciations in transition economies were equilibrating movements with macrofundamentals and productivity gains being important determinants of those movements.

If we take movements in the real zloty exchange rate, which could more readily equilibrate via both nominal exchange rate changes and foreign and domestic price level changes as a benchmark, the maximum overvaluation of the Ruble, 21%, was 250% higher than the maximum overvaluation of the zloty, 6%. The maximum undervaluation of the Ruble, 21%, was more than 100% higher than the maximum undervaluation of the zloty, 10%. We see that if the nominal rate is fixed or heavily managed, as in Russia at that time, without proper foresight and stabilization programs, then significant misalignments are likely outcomes. Further, if the

[35] See Orlowski (2000) for additional details.

nominal rate is fixed, a positive inflation differential with respect to the foreign countries will appreciate the currency. In addition, higher domestic inflation, if brought about by an increase in demand, implies a higher rate of interest, which, in turn, increases net capital inflows. This increases the rate of inflation and overvalues the currency further. However, nearing 2001, the real exchange rate for Russia is found to be approaching the equilibrium values.

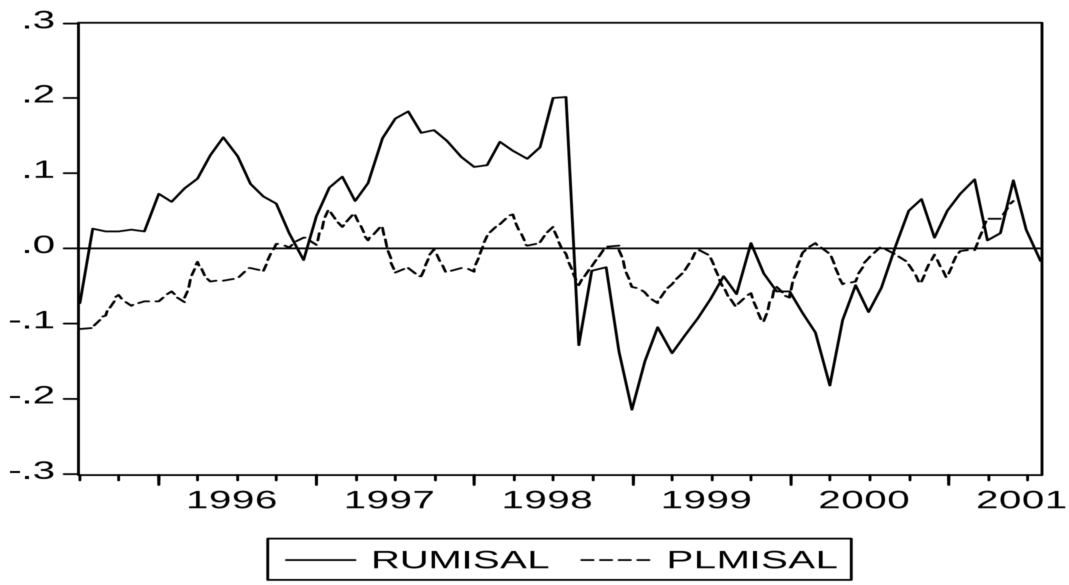

Fig 4. Poland and Russia: real exchange rate misalignments
Misalignment, $M = \boldsymbol{log(e)\text{-}\ log(e^{eq})}$

RUMISAL: misalignment for Russia; PLMISAL: misalignment for Poland

These results corroborate the claim by Chapman and Mulino (2000) and Kharas, Pinto and Ulatov (2001) that the Russian crisis has features in common with first generation crisis models: the overvalued currency and the government's inability to manage the fiscal deficit were inconsistent, which ultimately led to the abandonment of the exchange rate regime itself. Finally, it is found that the average misalignment in Russia for the entire period is 8.8%, 150% greater than the average misalignment in Poland, 3.6%, which, with a more flexible nominal exchange rate, experienced no currency crisis at all.

9. Out of Sample Forecasting

Finally, can the movements of the macroeconomic fundamentals and the exogenous variables predict the movements of the real exchange rate in the post crisis periods in Russia? To answer this, two out of sample forecasts for the post-crisis period, based on the error correction equation specified for the pre-crisis periods (specification 4 of Table 8), are performed. First, the real exchange rates are forecast for the post crisis periods with the known values of the exogenous variables and lagged values of the real exchange rate -- a one period ahead static forecast. And second, the forecasts are performed with the lagged values of the real exchange rate from the forecast of the real exchange rate in the previous period and with the known values of the exogenous variables -- a one period ahead dynamic forecast.

The results are presented in Figure 5 and Table 10. The standard measures of forecast errors indicate that the static forecasts do reasonably well. This suggests that the error correction equation specified for the pre-crisis period may be generalizable. However, the dynamic forecasts yield much less satisfactory results. The predicted path entirely misses the movements of the real exchange rate, indicating that the values of the macroeconomic fundamentals in the pre-crisis period are not able to explain the movements of the real exchange rate in the post-crisis period, demonstrating the severity of the crisis and the strength of speculative factors not included in the model. The misalignment calculated on the basis of macro fundamentals, quite severe prior to August 1998 (Figure 4), may be seen as a precondition for the crisis, but we are not able to predict the crisis *per se*.

Table 10
Russia: performance results, one period ahead out of sample forecasts

Type of Forecast	Root Mean Squared Error	Mean Absolute Error	Mean Absolute Percent Error
Static	0.125	0.041	0.930
Dynamic	1.362	1.340	29.700

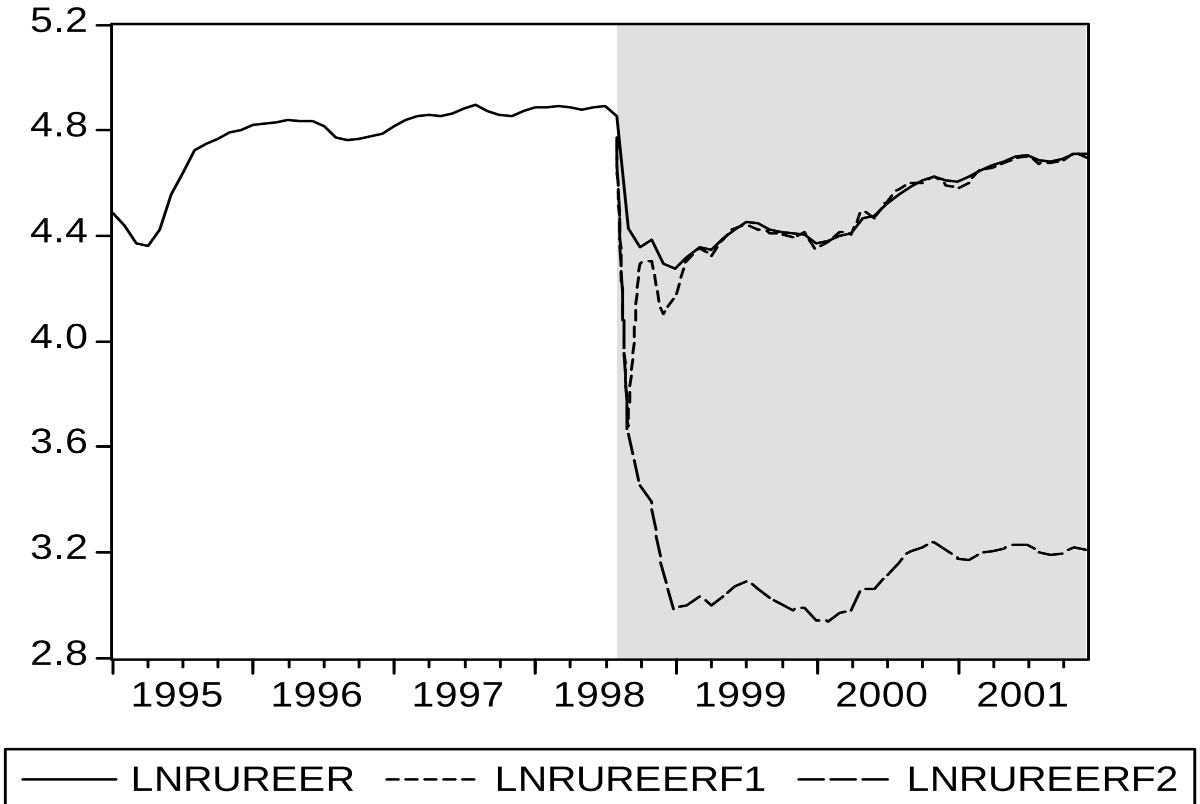

Fig 5. Russia, out of sample forecasting for the post crisis period; specification 4

* LNRUREER is the Actual Log Real Exchange Rate
LNRUREERF1 is the 'Static Forecast', one period ahead
LNRUREERF2 is the 'Dynamic Forecast', one period ahead

10. Conclusion

Long run equilibrium real exchange rates, the short run movements of the real exchange rates, and the corresponding misalignments have been estimated for Poland and Russia. The results explain short run and long run movements of the real exchange rates quite well in light of the exchange rate and macroeconomic stabilization policies adopted by the respective governments. The results confirm the suggestions by Brada (1998) and Drabek and Brada (1998) that due to liberalized capital account policies, the transition economies, in general, had large capital inflows in the early transition period that resulted in high rates of inflation and overvalued real exchange rates. The results also confirm the claim by Halpern and Wyplosz (1997), Balazs (2002), de Broeck and Slok (2001) that productivity growth in the traded goods sector appreciated the real exchange rates in the transition economies. The response to exogenous shocks in each country clearly indicates that the more flexible exchange rate regime in Poland allowed the zloty to return to equilibrium much more quickly than the Ruble did in the less flexible exchange rate regime in the pre-crisis period in Russia. The calculations of misalignments for Poland indicate that as the nominal exchange rate regime became more flexible, real misalignment decreased. For Russia the misalignment results suggest that significant overvaluation of the ruble, nominal exchange rate rigidity, and mistaken macroeconomic policies in the pre-crisis period are the source of the currency crisis in Russia. Moreover, there were incipient pressures to devalue the ruble around the time of the crisis. Finally, the dynamic out of sample forecasts of the real exchange rate for the post-crisis period indicate that macroeconomic fundamentals and other short run variables in the pre-crisis period may not explain the movements of the real exchange rate in the post-crisis period for Russia.

Appendix

For both countries data on the real effective exchange rate are from International Financial Statistics (IFS). Terms of trade, TOT, is the ratio of the price of exports to the price of imports. For Poland, the terms of trade data for import and export prices were obtained from International Financial Statistics (IFS). For Russia, however, data on export prices and import prices were not available. Therefore, a proxy employing available data was constructed:

$$PTOT = (EX/FGDP)/(IM/GDP),$$

where EX is real exports, GDP is nominal GDP, IM is nominal imports, and FGDP is the sum of the real GDP's of the top five major export recipients. The rationale for this is that for given tastes and preferences, in equilibrium, the volumes of export and import are determined by the terms of trade, GDP of the home country, and GDP's of the export recipients. The relationship between terms of trade and PTOT depends on the relative strengths of the income effect and substitution effect on exports and imports. An increase in the terms of trade increases domestic purchasing power and the domestic demand for goods in general, some of which are imports. This increase in imports reflects an income effect. In addition, consumers shift from the consumption of exportables and non-traded goods to the consumption of imports. Producers increase the production of exportables and decrease the production of non-tradables. Generally the income effect and the substitution effect in consumption dominate the substitution effect in production and we expect a negative relationship between the terms of trade and PTOT. Further the value of PTOT remains more or less stable with respect to changes in GDP and FGDP. This is due to the fact that imports are a positive function of GDP, and hence, the import shares (EX/FGDP & IM/GDP) do not change significantly with respect to changes in the respective GDP's. For regression purposes, the negative of logarithm of PTOT was considered.

To construct FGDP, major import partners were found from Europa World Year Book, (2003).[36] The five major importers for Russia are Germany, USA, Italy, France, and Finland. For both countries data on GDP was obtained from IFS. Data on the CPI, exports and imports for both countries were obtained from IFS.

To construct the FLOW variable the data on net capital inflow was taken from Institute for Economic Research – Halle (IERH) for Poland. However, reliable data on net capital inflow could not be obtained for Russia. Hence, following Elbadawi (1994), net capital inflow for Russia is taken to be equal to the difference between import and export. The variable, OPEN represents a country's *openness* to trade. For the construction of the GOV variable, data for government expenditure for both countries were taken from IFS.[37] Data for NEER was obtained from IFS. Finally, the DCRE variable is constructed from data on domestic credit for both countries from IERH.

[36] However if for any major importer adequate data on either nominal GDP and/or CPI (for converting nominal GDP to real GDP) could not be obtained then the next major importer was utilized.

[37] Monthly observations for GDP for Russia, import and export for both countries, and government expenditure for Poland, are interpolated from quarterly data.

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