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# **Estimation of the Equilibrium Real Exchange Rate in Russia: Trade-Balance Approach**

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## **Abstract**<sup>1</sup>

The paper estimates the equilibrium real exchange rate (ERER) in Russia for 1995-2006 using the partial-equilibrium version of the trade-balance approach. The three-good framework is applied, allowing distinction between the RER for imports and RER for exports. The terms of trade are viewed as exogenous. Russia's export demand is regarded as infinitely price elastic, implying the estimation of export supply function. Russian imports are assumed to be demand determined. The estimation of the trade-volume equations is based on the search of cointegrating relationships. The import elasticities are in line with estimates obtained in other studies. The estimations for the export supply equation confirm "supply elasticity pessimism". The ERER simulations reveal the degree of rouble overvaluation of 25%-40%, depending on the measure of the RER used, before the August 1998 crisis. In 2004-2006, given the surge in oil prices and pro-active exchange rate policy of the Bank of Russia, the rouble appears to be substantially undervalued: by 40-70% on average, depending on the measure of the RER used.

**Keywords:** Equilibrium Real Exchange Rate, Trade Elasticities, Russia

**JEL classification:** C22, E52, F4

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## **1. Introduction**

The issue of assessing the appropriateness of actual exchange rates to their long-run or fundamental values presents an important ingredient of macroeconomic policy analysis for both emerging and developed countries (Williamson, 1985, 1994; Clark et al., 1994; Isard and Faruquee, 1998; Wren-Lewis and Driver, 1998). While some ensured stability of a national currency in nominal and real terms is viewed as desirable, since overly volatile nominal and real exchange rates hamper foreign trade and economic growth (Willet, 1986), substantial and prolonged misalignments are regarded as a certain unpleasant feature of any exchange rate policy (Edwards, 1989; Edwards and Savastano, 1999). On the one hand, overvaluation causes the deterioration of competitiveness and may lead to balance-of-payments crises. The literature on the Early Warning System and crises predictability cites currency overvaluation as one of the best indicators of financial distress (Frankel and Rose, 1996; Sachs, Tornell and Velasco, 1996; Kaminsky, Lizondo and Reinhart, 1998; Berg and Pattillo, 1999; Kaminsky and Reinhart, 1999). On the other hand, undervaluation results in an inefficient allocation of resources. Moreover, undervaluation fuels inflation. Calvo, Reinhart and Végh (1995) show that government policy of real exchange rate targeting allows a more depreciated level of the exchange rate to be attained only temporarily by allowing higher inflation.

The development of exchange rate policy in Russia before the August 1998 crisis is broadly consistent with the general evolution of exchange rates and exchange rates regimes in transition countries (Halpern and Wyplosz, 1997, 1998). During the hyperinflation period, the rouble real exchange rate underwent massive appreciation that may have largely been a catch up from the initial exchange rate collapse, that probably led to the sizeable undervaluation. Beginning July 1995, the Bank of Russia had used an exchange rate band as a key anchor to achieve disinflation. It was a major success: the inflation rate fell from 215% in 1994 to 11% in 1997. The exchange rate was allowed to crawl every day, but at the rate lower than inflation. As a result, the real exchange rate continued to rise after the introduction of the band. Unfortunately, except for Halpern and Wyplosz (1997, 1998), providing estimates of the ERERs in transition economies and indicating a minor overvaluation of the rouble, there was no systematic study of the equilibrium real exchange rate in Russia in the pre-crisis period. On the other hand, given a short history of the market economy in Russia, such estimations would have probably implied a huge margin of error.

Although the 1998 financial turmoil in Russia is mostly viewed as the first generation crisis (Krugman, 1979) with the problems of tight monetary and loose fiscal policies, exacerbated by weak governance and contagion from the Asian crisis, an oil price slump probably precipitated a crunch (Kirsanova and Vines,

2002). The rouble collapsed (more than 2.5 times from its pre-crisis level) when world prices were hitting their twenty-year lows. As a resource-dependent economy, Russia proved to be quite vulnerable to such external shocks.

While the rouble probably overshot its long-run level in the period immediately following the August 1998 crisis, in recent years the country has turned out to fall victim to the Dutch Disease, as the observed steady real rouble appreciation is largely associated with an unprecedented surge in oil prices. The increase in oil prices boosts export revenues, which in turn increases demand for nontraded goods. As a result, prices of nontraded goods rise and the currency appreciates in real terms. The current policy of the Bank of Russia seems to be double-edged. On the one hand, the Bank aims at the stability of the national currency and seeks to avoid the loss of competitiveness of domestic producers by preventing the rouble from substantial real appreciation. In order to address these tasks, the CBR purchased foreign currency at a rising scale: its gross international reserves expanded from \$28 bn in 2000 to \$48 bn in 2002, to \$124.5 bn in 2004 and to \$303.7 bn in 2006. On the other hand, the efforts of the Bank of Russia appear to be in conflict with its primary goal of reducing inflation, since growth of foreign reserves inevitably leads to an increase in monetary base. According to the studies estimating the CBR's monetary rule (Esanov et al., 2004; Vdovichenko and Voronina, 2004) the Bank of Russia tries to balance between targeting the real exchange rate and inflation and stimulating economic growth.

This paper presents the estimations of the equilibrium real exchange rate (ERER) for Russia obtained for the period from Q1:1995 to Q4:2006 using the trade-balance approach originated by Williamson (1985, 1994). As follows from the exposition of the country's past and current exchange rate policy, there is a number of reasons that justify the importance of assessing the currency position relatively to its equilibrium. First, there is still lack of evidence that would shed light on the degree of real rouble overvaluation in the run-up to the August 1998 crisis, which put an end to the exchange rate band as an arrangement of the fixed exchange rate regime in Russia. Second, given the current surge in oil prices and certain pro-active exchange rate management demonstrated by the Bank of Russia, it is worthwhile to get an idea of the degree of misalignment that can be associated with that policy. While the CBR can smooth out the fluctuations of the RER, there is little evidence that very significant undervaluation can stimulate economic growth (Razin and Collins, 1997). On the other hand, according to predictions of Calvo, Reinhart and Végh (1995), an attempt to depreciate the RER beyond its equilibrium level is likely to be accompanied by a mix of higher inflation and rising real interest rates, which may in turn hinder economic growth. Some estimates of the equilibrium RER may be important for the Bank of Russia to deal with its inflation versus the exchange rate dilemma.

The literature on the ERER in Russia is fairly scarce. Apart from the above-mentioned study of Halpern and Wyplosz (1997, 1998), there are several more papers. Halpern and Wyplosz (1997, 1998) use dollar wages as an indicator of the RER and resort to international wage comparisons, applying the panel data estimation technique. The application of the panel data results to Russia reveals some possible minor overvaluation of the rouble in 1997. Following the methodology initially suggested by Edwards (1994), Spatafora and Stavrev (2003), estimate a reduced form equation for the Russian RER. In a long-run cointegrating relationship, including as fundamentals the world price of Russian Urals oil, industrial labor productivity in Russia relative to its trading partners and post-1998-crisis dummy variable, the estimated coefficients have anticipated signs and are statistically significant. Under medium-term world oil prices ranging from \$17/barrel to \$23/barrel, the rouble is reported to be undervalued by about 9-17% in 2002. In addition, Spatafora and Stavrev (2003) attempted to apply the trade-balance approach, but failed to estimate the demand equation for the country's exports and instead used the average export demand elasticities for developing countries reported by Reinhart (1995). Under the assumption of the country's long-run current deficit of 1-3% of GDP and medium-term world oil prices varying from \$17/barrel to \$23/barrel, the rouble overvaluation ranges from 18-25% to 33-40% in 2002.

Sosunov and Zamulin (2004), on the basis of simulation results performed for a small calibrated general equilibrium model, conclude that in 1998-2003, the rise in oil revenues can explain the observed real appreciation but only if the increase in the volume of exports is taken into account. Egert (2005) applies the stock-flow approach (Faruqee, 1995; Alberola, 2003) to estimate the RER reduced form equation in six countries, including Russia, for 1994-2003. For Russia, the long-run cointegrating relationship, which links the real exchange rate to the labor productivity differential between tradables and nontradables sectors and to net foreign assets, is also augmented by oil prices, the country's crude oil production, and the post-1998-crisis dummy variable. In the case of Russia, a search for cointegration produces ambiguous results where the signs and significance of fundamentals depend on the control variables included. Egert reports that overvaluation of about 20% prior to the 1998 crisis was followed by undervaluation of roughly the same magnitude in 1999, while in 2003 the rouble was fairly valued or slightly overvalued.

Although the single reduced-form equation approach is viewed as the most promising methodology for developing countries (Hinkle and Montiel, 1999), there may be certain problems in its implementation. As demonstrated by the results of Egert (2005) for Russia, the estimates of the single reduced-form equation may not be robust with respect to the set of included fundamentals. While the partial-equilibrium version of the trade-balance approach has its own shortcomings, the main of which, according to Wren-Lewis and

Driver (1998) and Ahlers and Hinkle (1999), include large confidence intervals of the estimated trade elasticities and the absence of feedback from the RER to its fundamentals, it is another fairly straightforward method with limited data requirements that can be applied for the estimation of the EREER.

The fact that in using the trade-balance approach Spatafora and Stavrev (2003) failed to specify and estimate a satisfactory export demand equation for Russia can be viewed as expectable since the country's exports are dominated by natural resources, external demand for which does not depend on changes in the RER specified as either the CPI effective RER or the price ratio of nontradables to tradables.

Using the trade-balance approach, this paper applies the three-good framework suggested by Hinkle and Nsengiyumva (1999) for a commodity-exporting developing country. This framework allows a distinction between the two types of the internal real exchange rate – the RER of imports defined as the price ratio of imports to nontradables and the RER of exports defined as the price ratio of exports to nontradables. Moreover, following Ahlers and Hinkle (1999), Russia's export demand is regarded as infinitely price elastic, while export supply is assumed to be finitely price elastic. Such an approach implies the estimation of export supply as a function of the RER of exports and total capacity of the economy. Russian imports are traditionally assumed to be demand determined and dependent on the RER of imports and domestic income. The methodology of Hinkle and Nsengiyumva (1999) and Ahlers and Hinkle (1999) allows the effect of the changes in the terms of trade to be incorporated into the trade-balance approach to the EREER's computations. This novel and important feature for a resource-based economy like Russia is absent in the conventional framework of a single composite good comprised of many differentiated products. The data from Russia's Quarterly National Accounts provide information employed for the construction of import and export price indices as well as a price index of nontradables that is alternatively approximated by the two implicit price deflators: the GDP deflator and deflator for GDP minus exports. The estimation of the trade-volume equations is based on the search of cointegrating relationships, since all variables under investigation prove to be nonstationary, with some ambiguity for the RER of exports. Certain attention is focused on the seasonal properties of the data. The estimation of the trade equations and time series analysis are performed for the period from Q1:1995 to Q1:2005.<sup>2</sup>

Regarding the definition of the internal balance, the paper mostly follows other studies, assuming that actual output adjusted for the cyclical fluctuations represents the equilibrium outcome. Alternatively, the long-run (or equilibrium) path of real GDP is obtained by constructing the Hodrick-Prescott filter. As

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<sup>2</sup> This is the updated version of the paper, in which both the estimates of the trade elasticities and simulations of the EREER are obtained for the period from Q1:2005 to Q1:2005.

regards the definition of the external balance, the paper draws on the intertemporal approach to the current account (Sachs, 1981; Obstfeld and Rogoff, 1995, 1996), and, in particular, views the primary current account equaling the external debt service as a special case satisfying a country's intertemporal budget constraint. Russia's actual external debt together with the actual real effective interest rate paid on the country's debt adjusted for seasonal fluctuations are used to determine the equilibrium primary current account.

The in-sample simulations of the equilibrium real exchange rate for Q1:1995-Q4:2006 are performed using the estimated trade elasticities and the assumption of the equilibrium primary current account. In the first set of simulations, viewed as baseline simulations, all exogenous variables - real GDP, the terms of trade, external debt, and the real effective interest rate - are assumed to equal their historical seasonally adjusted values. Since the results of estimations for export supply equation confirm the conjecture of "elasticity pessimism", the EREER is alternatively derived as the solution of the two models. While in the first model both exports and imports are specified as endogenous, in the second model the export volume is assumed to be exogenously determined. In addition, an evaluation and decomposition of fundamentals driving the EREER in both models are made. In particular, the formulas of fundamentals elasticities of the EREER are derived and evaluated using the estimated trade elasticities as well as the sample values of exogenous and fitted endogenous variables. Moreover, since the paper applies the partial-equilibrium approach to the calculation of the EREER, I perform a sensitivity analysis allowing the examination of different assumptions of the fundamentals, including the terms of trade, domestic output and real interest paid on the country's debt. Instead of making an alternative assumption of Russia's external debt, I consider the "desired reserve accumulation" scenario, where the country's primary current account is used not only to service its debt but also to accumulate foreign reserves according to a specified rule.

The plan of the paper is as follows. Section 2 outlines the methodology, including the three-good framework and version of the trade-balance approach employed in the study. Section 3 discusses the data and the measures of the real exchange rate used in the estimations. Section 4 describes econometric issues which have to be addressed for obtaining Russia's trade elasticity estimates. Section 5 reviews the econometric results of import demand and export supply estimations. The EREER simulations are presented and discussed in Section 6, which also includes the sensitivity analysis. Section 7 concludes.

## 2. Methodology

### 2.1. Trade Balance Approach: Standard Version

The trade balance, or trade-equation, or “elasticities”, approach is one of the methods developed to assess whether exchange rates are broadly in line with economic fundamentals. The analytical basis of the trade balance approach was mostly elaborated by Williamson (1985, 1994) in his work on “Fundamental equilibrium exchange rates” (FEER). According to Williamson’s definition, FEER is a real exchange rate that is simultaneously consistent with internal and external balance over the medium or long term. Internal balance is usually defined as achieving the underlying level of potential output or achieving the level of output consistent with both full employment and a low sustainable rate of inflation (the concept of NAIRU). A broad definition of external balance is an equilibrium position in the current and capital accounts.

This study employs the partial-equilibrium approach based on the estimation of trade equations, while the estimates of the ERER can, in principle, be obtained from simulations of the general-equilibrium macroeconomic models as well. The main idea behind the partial-equilibrium trade-equation approach is that the real exchange rate influences an economy mostly by affecting the primary current account through an expenditure-switching mechanism. Regarding internal balance, the partial-equilibrium framework usually implies that the potential or full employment level of output is determined independently from external balance and the underlying ERER.

Establishing a quantitative relationship between the RER, imports (M), exports (X), and hence the primary current account (S), through the estimation of trade elasticities is the first step of the trade-balance approach. The second step involves the determination of the equilibrium output ( $Y^*$ ) corresponding to internal balance and the equilibrium primary current account ( $S^*$ ) corresponding to external balance, while at the last step, the path of the equilibrium RER is calculated implicitly as equal to the values of the RER which satisfy the following equation:

$$S^*=S(RER, Y^*, \dots) \tag{2.1.1}$$

Ahlers and Hinkle (1999) distinguish between the two versions of the trade-balance approach: a standard version, mostly used for industrial countries, and an alternative one, applied to developing countries in which exports are dominated by primary commodities. The analytical framework used in applying the trade-balance approach to developed countries is usually based on the so-called Mundell-Fleming production structure. In this framework, each country is assumed to produce one composite good



comprised of many differentiated products, which are exported, imported and consumed domestically. Given the complete specialization of both the domestic and foreign economies in producing one composite good (their GDPs), export supply functions can be viewed as perfectly price elastic, while regarding demand, the domestic composite good is an imperfect substitute for the composite goods produced and exported by other countries. Thus, in the trade-balance approach applied to developed countries, export and import volumes are assumed to be demand-determined, while the real exchange rate affects the trade balance through its influence on domestic demand for imports and on external demand for countries' exports.

There are numerous examples of the application of the trade-balance approach to determining the EREER in industrialized countries. It should be noted that suggesting alternative methods of tackling the determination of external balance, the literature introduces close but different concepts of the resulting equilibrium exchange rates, which in turn yield numerous mnemonic definitions. In general, the resulting EREER can be either a normative or a positive construct. The estimate of the EREER has a normative aspect if external balance is determined as some target value of the current account (CA), which is either compatible with some desirable net capital inflows or associated with some optimal policy that has to be pursued to achieve that targeted CA. Introducing the FEER definition of the EREER, Williamson (1985, 1994) stresses that the FEER is inherently a normative concept. The concept of the "desired equilibrium exchange rate" (DEER) employed by the IMF in the partial-equilibrium framework by Bayoumi et al. (1994) and in the general-equilibrium framework by Clark et al. (1994) is quite close to the FEER definition.

The EREER is a positive concept if it is based on some estimations or projections of the actual capital inflows. In the existing literature, it is mostly done through the estimation of medium-term determinants of saving-investment balance. The examples of such methodology are the IMF's application of the FEER concept in its so-called macroeconomic balance approach by Isard and Faruquee (1998) and the "natural equilibrium real exchange rate" (NATREX) of Stein (1994). While Isard and Faruquee (1998) use the partial equilibrium framework, the NATREX of Stein (1994) results in the simulation of the general equilibrium model. The combination of econometric and subjective estimates in determining external balance is used in Wren-Lewis and Driver (1998). The detailed survey of the trade-balance approach as well as other methods of determining the equilibrium exchange rates in both developed and developing countries can be found in Hinkle and Montiel (1999), Driver and Westaway (2003) and Egert (2003).

The notion of the ERER estimated in this paper can be viewed as a rather positive one, since regarding the definition of external balance, it draws on the intertemporal approach to the current account (Sachs, 1981; Obstfeld and Rogoff, 1995, 1996). Subsection 2.3 below describes how the actual level of a country's debt service determines the equilibrium primary current account as one satisfying a country's intertemporal budget constraint.

For those emerging and transition countries whose exports are dominated by differentiated manufactured goods, the version of the trade-balance approach determined by the Mundell-Fleming production structure and applied for developed countries can be adopted as well. For instance, Smidkova et al. (2002) apply the concept of the FEER for determining the real misalignment in five EU pre-accession countries – the Czech Republic, Estonia, Hungary, Poland, and Slovenia. Stein (2005) uses his NATREX model to evaluate the ERERs in the Czech Republic, Hungary, Poland, and Bulgaria.

As already mentioned above, Spatafora and Stavrev (2003) tried to apply the trade-balance approach in its standard version based on the Mundell-Fleming production structure to the estimation of the ERER in Russia. The fact that they failed to specify and estimate a satisfactory export demand equation for Russia can be viewed as expectable. Since about 70-80% of Russia's exports consist of natural resources, mostly oil, gas and metals (see Table 2.1), the structure of the Russian economy does not conform to the standard analytical framework applied to modeling external trade for developed countries. Moreover, quite a different nature of the country's exports and imports precludes us from lumping prices of exported and imported goods together, and a special focus should be on the very definition and measurement of the real exchange rate for Russia.

This study addresses these problems using the version of the trade-balance approach for developing countries whose exports are dominated by undifferentiated products discussed in Ahlers and Hinkle (1999). This alternative version of the trade-balance approach is based on the three-good framework suggested by Hinkle and Nsengiyumva (1999). The three-good framework as well as the approaches to incorporating commodity trade into the trade-balance methodology suggested in the literature for developed countries are discussed in the following subsection. The realization of the second and the third steps of the trade-balance approach in this study is considered in the following two subsections.

## **2.2. Trade Balance Approach: Adding Commodity Trade**

### *The case of developed countries*

Even in some advanced industrial countries, external trade involves not only manufactured differentiated products but also some nontrivial proportion of commodities. For example, in New Zealand and Australia, commodities represent almost 50% of exports. In the late 1970s, after Britain discovered large reserves of oil and began oil production, its real exchange rate experienced significant appreciation. One way to incorporate commodity trade into the trade-balance methodology is proposed by Burda and Wyplosz (1997), who suggest that Britain's primary account can be split into two parts: the non-oil and oil primary current accounts. The authors state: "While the non-oil account normally depends upon Britain's real exchange rate – defined as the relative price of imports to non-oil exports – the oil current account is essentially independent of the country's exchange rate". Thus, non-oil trade can be modeled as demand-determined in line with the standard Mundel-Fleming production structure, while oil trade can be viewed as exogenous.

Another method representing a hybrid demand and supply determination of total exports is proposed by Wren-Lewis (2004), who incorporates commodity trade into the trade-balance approach to determining the ERER for New Zealand and Australia. He models commodity exports using the decreasing-returns-to scale-production function, while the countries' export of differentiated products is assumed to be traditionally determined by world demand and the ratio of export non-commodity prices to prices of those goods abroad. Using wage equalization between the commodity producing sector and the sector producing differentiated products, Wren-Lewis obtains that a rise in relative commodity prices for a given level of differentiated goods competitiveness will raise total exports by shifting a unique factor of production (labor) into the commodity producing sector.

### *The case of Russia*

In the case of Russia, there are several difficulties in using the methods suggested by Burda and Wyplosz (1997) and Wren-Lewis (2004). First, the application of these methods requires the indices of non-commodity or manufacturing trade prices, which do not appear to be available in Russia. Even the index of manufacturing producer prices, which can be viewed as a bad proxy for the manufacturing trade price index because of the differences in the country's structure of non-commodity exports and production, is available for a very short period – only from 1999. Second, the non-commodity part of Russia's exports is not only small (about 20-30%), but is also quite peculiar. For instance, armaments represent roughly 25% of machinery, which in turn accounts for about 10% of non-commodity exports (see Table 2.1). Selling weapons abroad may be guided by many factors that are not part of economic demand-supply

relationships. So, even Russia's exported non-commodity goods may not be very compatible with differentiated products which constitute the country's imports.

In addition, although methods suggested by Burda and Wyplosz (1997) and Wren-Lewis (2004) allow the incorporation of commodities into the trade-balance approach, they still imply that the real exchange rate, which brings about a particular current account, essentially equals the country's terms of trade.<sup>3</sup> However, for a small open economy with a large proportion of commodities in its exports, like Russia, it is more appropriate to view the terms of trade as exogenously given. Moreover, the methods suggested for developed countries operate with the so-called external real exchange rate, while, as stressed by Edwards (1989) in analyzing developing countries, it is more preferable to use internal real exchange rates defined as the domestic relative price of tradables to nontradables. This definition summarizes incentives that guide resource allocation across the tradable and nontradable sectors.

The initial concept of the internal RER is based on a two-good model, which distinguishes between tradables and nontradables, where tradables themselves are composed of two kinds of goods – exportables and importables. This two-good framework implies little difference between exportables and importables and assumes that their relative prices (i.e. the terms of trade) are constant, so that these goods can be aggregated into a single composite tradable good. However, as pointed out by Hinkle and Nsengiyumva (1999), there are pronounced differences between goods that are exported and imported by developing countries. In addition, the terms of trade tend to fluctuate significantly in developing countries.

The composition of Russia's external trade proved to be a good example that lumping exports and imports into a single category of traded goods can be a meaningless procedure. As can be seen from Table 2.1, Russia's imports are mostly represented by manufacturing goods and food products, while 70-80% of its exports consist of primary commodities, such as oil, gas and metals. Moreover, prices of these commodities are very volatile on world markets.

Given these peculiarities of the Russian economy and seeking to deal with the internal definition of the RER for the calculation of the equilibrium real exchange rate in Russia, this paper employs the alternative version of the trade-balance approach described by Ahlers and Hinkle (1999). This alternative version is

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<sup>3</sup> Or some ratio of the aggregate foreign prices to the home country's aggregate prices measured in a common currency. In fact, introducing non-traded goods, Wren-Lewis (2004) considers also the two other definitions of the RER: the price of output at home relative to that overseas and the price of consumption at home relative to that overseas. These two RERs move with the terms of trade, but also depend on the relative productivity between tradable and nontradable sectors. However, it is the RER equalling the terms of trade that determines a particular trade balance.

based on the three-good framework (Hinkle and Nsengiyumva, 1999), allowing for different internal RERs for imports and exports and for supply determination of total exports.

*Three-good framework: RER for imports and RER for exports*

Hinkle and Nsengiyumva (1999) argue that since exports and imports of developing countries often experience very different price movements, it is more appropriate to use the three-good framework that enables researchers to disaggregate tradables into exportables and importables and to explicitly take into account changes in the terms of trade. In the three-good framework consisting of importables, exportables and nontradables, it is possible to consider two separate internal real exchange rates – the RER for imports (RERM) defined as the relative price of importables to nontradables (RERM) and the RER for exports (RERX) determined as the relative price of exportables to nontradables (RERX):

$$RERM = \frac{P_M}{P_N} \quad (2.2.1)$$

$$RERX = \frac{P_X}{P_N} \quad (2.2.2)$$

where  $P_M$  is the domestic price of importables,  $P_X$  is the domestic price of exportables and  $P_N$  is the price of nontradables. For a small open economy, the foreign currency prices of imports ( $P_M^*$ ) and exports ( $P_X^*$ ) are assumed to be exogenous variables. If the Law of One Price holds for exportables and importables while trade taxes are ignored, the respective definitions of the RERs for imports and exports can be written as follows:

$$RERM = \frac{E * P_M^*}{P_N} \quad (2.2.3)$$

$$RERX = \frac{E * P_X^*}{P_N} \quad (2.2.4)$$

where E is the nominal exchange rate. The RER for exports is related to the RER for imports through the terms of trade ratio:

$$RERX = \frac{E * P_X^*}{E * P_M^*} * \frac{E * P_M^*}{P_N} = \lambda * RERM \quad (2.2.5)$$

where  $\lambda$  denotes the exogenously given terms of trade (in foreign or domestic currency):

$$\lambda = \frac{P_X^*}{P_M^*} = \frac{P_X}{P_M} \quad (2.2.6)$$

For an economy like Russia's, whose exports are dominated by primary resources, which on world markets are perfect substitutes for the same commodities produced by other countries, the concept of external competitiveness appears to be quite irrelevant. If all the three goods, exportables, importables and nontradables, are assumed to be produced and consumed domestically, the RER for imports and the RER for exports are indicators of the internal price competitiveness of importables and exportables in consumption and production relative to nontradables. The RERM and RERX measure the incentives guiding resource allocation between domestic sectors producing importables and nontradables and exportables and nontradables respectively.

In the case of Russia and for the purpose of the study, the general three-good framework can be simplified: it is assumed that the home country consumes but does not produce importables, while exportables are produced but not consumed domestically (see, e.g., De Gregorio and Wolf, 1994). Then the RER of imports and RER of exports reflect the two sides of internal price competition: RERX can be viewed as a measure of internal price competitiveness of the exporting sector relative to the sector producing nontradable goods, where resource allocation is subject to competition between these two sectors, while the RERM can be used to reveal the degree of the internal price competitiveness of domestic goods relative to imports in consumption.

The fact that there is no longer a single internal RER can be viewed as a disadvantage of the three-good framework. However, as suggested by Hinkle and Nsengiyumva (1999), in the case of a developing country which exports a narrow range of undifferentiated primary products but imports a wide range of items, the RER for imports may be used as a single indicator of the internal real exchange rate. This study follows this suggestion and uses the RERM in the simulations of the equilibrium real exchange rate in Russia.

#### *Three-good framework: application to the trade-balance approach*

The three-goods framework allows not only the definition of a separate RER for imports and exports, but also the application of the alternative version of the trade-balance approach, which is more appropriate for countries whose exports are dominated by primary commodities. While in the trade-balance approach for developed countries the export supply functions are assumed to be perfectly elastic, and hence exports are modeled as demand-determined similarly to imports (with foreign real income instead of domestic income), Ahlers and Hinkle (1999) stress that for a small open developing economy that accounts for a tiny fraction of the world trade, it is more reasonable to consider export demand as being infinitely price

elastic but to allow for a finite elasticity of export supply. Such an approach implies the estimation of the export supply function, which can be specified in the following form:

$$\ln X = \varepsilon_X \ln RERX + \eta_X \ln Y + f(Z_X) \quad (2.2.7)$$

where  $X$  is the volume of goods and services exports,  $RERX$  is the real exchange rate for exports,  $Y$  is the potential or actual real output, which proxies the capacity of the economy,  $Z_X$  is the vector of predetermined or exogenous variables. The elasticities of export supply with respect to the RER for exports ( $\varepsilon_X$ ) and output ( $\eta_X$ ) are expected to be positive:  $\varepsilon_X > 0, \eta_X > 0$ .

As in the case of developed countries, imports can be modeled as demand-determined, assuming that the import supply function is perfectly elastic:

$$\ln M = \varepsilon_M \ln RERM + \eta_M \ln Y + f(Z_M) \quad (2.2.8)$$

where  $M$  is the volume of import of goods and services,  $RERM$  is the real exchange rate for imports,  $Y$  is domestic real income,  $Z_M$  is the vector of predetermined or exogenous variables. The elasticity of import demand with respect to the RER for imports ( $\varepsilon_M$ ) is expected to be negative, while the income elasticity of import demand ( $\eta_M$ ) is expected to be positive:  $\varepsilon_M < 0, \eta_M > 0$ .

The following deliberately simple model can be considered to justify the particular specification of the export supply and import demand equations, (2.2.7) and (2.2.8), and demonstrate relationships between the ERER and its fundamentals. A home country is assumed to produce exportable and nontradable goods, while the latter are imperfect substitutes for imports in consumption. Since exports ( $X$ ) are substitutes for nontradables ( $Y_N$ ) in production, the relationship between those two goods can be expressed as a transformation function describing the economy's production possibilities frontier (PPF). The PPF summarizes maximal combinations of exports and nontradables that an economy can produce, given its resource constraints. In order to have the PPF bowed-out, the production function of exports and/or nontradables is assumed to be subject to decreasing returns to scale.

To further simplify the representation, production of both exports and nontradables is assumed to require only labor, which is inelastically supplied at  $L$ . Total supply ( $L$ ) is fixed and determines the capacity of the economy:

$$X = a_X L_X^\alpha \quad (2.2.9)$$

$$Y_N = a_N L_N^\beta \quad (2.2.10)$$

$$L_X + L_N = L \quad (2.2.11)$$

where  $0 < \alpha < 1$ ,  $0 < \beta \leq 1$ <sup>4</sup> and  $a_X$  and  $a_N$  are the parameters of labor productivity in the two sectors. The decreasing returns to scale of the production functions can be viewed as corresponding to zero capital mobility across sectors and internationally.

Profit maximization along with wage equalization across sectors and the resource constraint (2.2.11) imply that the marginal rate of transformation, measured by the slope of the PPF, equals the relative price of exports to nontradables, i.e. to the RER for exports. That means that the supply of exports and nontradables can be expressed as functions of the RER for exports, the total capacity of the economy and the productivity differential between the sectors:

$$X = X\left(\frac{P_X}{P_N}, L, \frac{a_X}{a_N}\right) \quad (2.2.12)$$

$$Y_N = Y\left(\frac{P_X}{P_N}, L, \frac{a_X}{a_N}\right) \quad (2.2.13)$$

where the partial derivatives of functions  $X(\cdot)$  and  $Y(\cdot)$  with respect to the RER for exports, the capacity of the economy and the productivity differential between the sectors are such that  $X_1 > 0$ ,  $X_2 > 0$ ,  $X_3 > 0$  and  $Y_1 < 0$ ,  $Y_2 > 0$ ,  $Y_3 < 0$ .

The consumption side of the economy where imports are imperfect substitutes for nontradables can be described by some utility function:

$$U = U(C_N, C_M) \quad (2.2.14)$$

which is maximized subject to the consumer's budget constraint. From the first order condition of the maximization problem it follows that the marginal rate of substitution between imports and nontradables

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<sup>4</sup> Both  $\alpha$  and  $\beta$  are assumed to be less than unity in order not to have a fixed proportion of labour going to the production of exports. Since the nontradables sector is probably more labour intensive than the exportables sector, it can be assumed that  $\alpha < \beta$ .



equals the relative prices of imports and nontradables, i.e. the RER for imports. Assuming no savings and hence the zero current account, and the equilibrium in the market of nontradables ( $C_N=Y_N$ ), we obtain that demand for imports equals supply of exports times the terms of trade ( $\lambda$ ):

$$M\left(\frac{P_M}{P_N}, Y_N\right) = \lambda * X \quad (2.2.15)$$

Substituting (2.2.12) and (2.2.13) into expression (2.2.15), which equates exports and imports, we can solve for either the RER for exports or the RER for imports (since they are connected through the terms of trade ratio (2.2.5)). For example, the RER for exports can be determined from the following equation:

$$M\left(\frac{P_X}{P_N} * \frac{1}{\lambda}, Y\left(\frac{P_X}{P_N}, L, \frac{a_X}{a_N}\right)\right) = \lambda * X\left(\frac{P_X}{P_N}, L, \frac{a_X}{a_N}\right) \quad (2.2.16)$$

From (2.2.16) it follows that the real exchange rate for exports is a function of the terms of trade ( $\lambda$ ), the capacity of the economy ( $L$ ) and the productivity differential between the sectors producing exported and nontradable goods ( $a_X/a_N$ ) and the parameters of utility and production functions:

$$\frac{P_X}{P_N} = P\left(\lambda, L, \frac{a_X}{a_N}, \dots\right) \quad (2.2.17)$$

Expressions (2.2.12) and (2.2.15) give rise to the traditional functional forms of the export supply and import demand equations:

$$X = X\left(\frac{P_X}{P_N}, Y, Z_X\right) \quad (2.2.18)$$

$$C_M = M\left(\frac{P_M}{P_N}, Y, Z_M\right) \quad (2.2.19)$$

where  $Y$  is real output or income in the economy, which can proxy the economy's capacity ( $L$ ), given that all resources are utilized in production (2.2.11), and  $Z_M$  and  $Z_X$  are vectors of exogenous variables.

Assuming the constancy of elasticities of export supply and import demand, expressions (2.2.18) and (2.2.19) can be rewritten in the standard double-logarithmic form of equations (2.2.7) and (2.2.8). There are numerous empirical studies employing these standard specifications.<sup>5</sup>

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<sup>5</sup> For example, the results of the estimation of price and income elasticities of import demand in specification (2.2.8) are reported by Goldstein and Khan (1985), Reinhart (1995), Senhadji (1997), Meacci and Turner (2001), Chinn (2005) and all papers on the trade-balance approach to determination of the EER cited in Sections 2.1. The estimations of the import demand function for Russia are presented in the work of Dynnikova (2001), Belomestnova (2002) and Spatafora and Stavrev (2003). The estimates of the export supply function in specification (2.2.7) can be

World demand, as a traditional fundamental of the ERER, has turned out to be missing as a result of the assumption of infinite price elasticity of export demand and estimation of the export supply function. This can be viewed as a certain disadvantage of the version of the trade-balance approach suggested by Ahlers and Hinkle (1999). On the other hand, world demand can still be regarded as affecting the country's RER through its impact on exogenously given export prices.

#### *Balassa-Samuelson effect*

The simple static model presented above is close to that of De Gregorio and Wolf (1994), who first examined the joint effect of productivity differentials and terms of trade movements on the RER. As follows from the exposition of the model (see (2.2.12) and (2.2.16)), vectors of exogenous variables ( $Z_M$  and  $Z_M$ ) in the trade equations may include the productivity differential between the tradables and nontradables sectors. Thus, the Balassa-Samuelson effect can, in principle, be incorporated into the trade-balance approach to the determination of the ERER. So far, studies employing the trade-balance approach seem to have overlooked that possibility, while there is extensive literature originated by Balassa (1964) and Samuelson (1964), testing the proposition that faster productivity growth in the tradables sector raises the relative price of nontradable goods and that economies with a higher productivity in tradables will be characterized by a more appreciated RER. One reason why the productivity differentials appear to be neglected by the trade-balance literature as possible fundamentals for the ERER, may be somewhat mixed evidence of the Balassa-Samuelson effect in the studies for both developed and developing countries (Froot and Rogoff, 1995; Edwards and Savastano, 1999).

In order to test the Balassa-Samuelson effect, one needs to proxy for sectoral productivity, while national statistics are normally not broken down into the tradables and nontradables sectors. It is quite common to use manufacturing and services as proxies for sectors producing respectively tradable and nontradable goods. Moreover, most studies employ labour productivity rather than total factor productivity suggested by the theory. While certain efforts have to be made to choose the appropriate variables approximating sectoral productivity in Russia, this paper attempts a rather oversimplified approach and uses the time trend as a proxy for productivity gains in the exportables sector. In particular, the two specifications of the export supply equations are estimated: the basic specification (2.2.7a), including only the RER for exports and output, and the alternative one (2.2.7b) where the time trend is added:

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found in Goldstein and Khan (1978), Bond (1987), Khan and Knight (1988), Kinal and Lahiri (1993), Cerra and Vaez-Zadeh (1999).

$$\ln X = \varepsilon_x \ln RERX + \eta_x \ln Y \quad (2.2.7a)$$

$$\ln X = \varepsilon_x \ln RERX + \eta_x \ln Y + \delta t \quad (2.2.7b)$$

However, while a number of studies (Spatafora and Stavrev, 2003; Egert, 2005) tend to support the link between the ERER and productivity in Russia, the scope for the Balassa-Samuelson effect may, in principle, be quite limited in a resource-based economy. In any case, the examination of the Balassa-Samuelson effect as a possible explanation for the real appreciation in Russia in general and in the framework of the trade-balance approach, deserves closer attention, and can therefore be left for further research.

### 2.3. Defining External Balance

Regarding the definition of internal balance, the paper mostly follows some other studies, applying the partial equilibrium version of the trade-balance approach, and assumes that actual output adjusted for the cyclical fluctuations represents the equilibrium outcome. Alternatively, the long-run (or equilibrium) path of real GDP is obtained by constructing the Hodrick-Prescott filter.

In the previous subsection 2.2, foreign financial assets are ignored for the simplicity of exposition. However, in the real world, the international exchange of assets plays a significant role in shaping countries' current accounts and ERERs. In order to define external balance for the computations of the ERER in Russia, the paper assumes the presence of foreign assets in the form of the country's total external debt ( $B_t$ ), the sum of public and private external debt. The other positions of Russia's capital account are ignored since they tend to be too volatile. The right approach would be to look at changes in the country's net total external debt, but, unfortunately, only data on Russia's debt to other countries are published, while data on Russia's loans to other countries are not available.

The definition of external balance in the paper is based on the intertemporal approach to the current account. With development of this approach in works of Sachs (1981) and Obstfeld and Rogoff (1995, 1996), the external balance of a particular country is viewed as identifying the path of the equilibrium current account (CA) that is such that the present value of future CA surpluses equals a country's current net foreign asset position. This formulation can be derived from the economy's intertemporal budget constraint, which results from the consolidation of the budget constraints of the private and public sectors. According to the economy's intertemporal budget constraint, the change in the country's net foreign asset

position, which in this paper corresponds to the change in the country's total external debt ( $B_t$ ), is given by:

$$B_t - B_{t-1} = r_t * B_{t-1} + Y_t - C_t - G_t \quad (2.3.1)$$

where  $r_t$  is the real interest rate,  $Y_t$  is real income, received by the private sector,  $C_t$  is private consumption and  $G_t$  is government consumption (investment is ignored). The country's primary current account is defined by

$$S_t = Y_t - C_t - G_t \quad (2.3.2)$$

Then the intertemporal budget constraint of the economy can be rewritten as follows:

$$B_t - B_{t-1} = r_t * B_{t-1} + S_t \quad (2.3.3)$$

Using the forward iteration, for example, for  $t+1$  and  $t+2$ , (2.3.3) can be written in the following form:

$$B_{t-1} = \frac{S_t}{(1+r_t)} + \frac{S_{t+1}}{(1+r_t)(1+r_{t+1})} + \frac{S_{t+2}}{(1+r_t)(1+r_{t+1})(1+r_{t+2})} + \frac{B_{t+2}}{(1+r_t)(1+r_{t+1})(1+r_{t+2})} \quad (2.3.4)$$

The interest discount factor between periods  $t$  and  $t+i$  can be defined as follows:

$$R_{t,t+i} = \frac{1}{\prod_{j=t}^i (1+r_j)} \quad (2.3.5)$$

Using (2.3.5), further forward iterations of (2.3.4) leads to

$$B_{t-1} = \sum_{i=0}^n R_{t,t+i} S_{t+i} + R_{t,t+n} B_{t+n} \quad (2.3.6)$$

As  $n$  goes to infinity, one would expect that households and the government would have to repay their debt. This requirement is known as the transversality condition, which is usually written as follows:

$$\lim_{n \rightarrow \infty} R_{t,t+n} B_{t+n} \leq 0 \quad (2.3.7)$$

Since it is reasonable to assume that in “the end” no wealth is wasted, the inequality of (2.3.7) can be replaced by an equality and the infinite-horizon equivalent of (2.3.6) is given by

$$B_{t-1} = \sum_{i=0}^{\infty} R_{t,t+i} S_{t+i} \quad (2.3.8)$$

which says that the present value of future primary current accounts is equal to the country’s today’s external debt. There may be different paths of the primary current account ( $S_t$ ) satisfying the country’s intertemporal budget constraint (2.3.8), given the today’s level of the country’s external debt ( $B_{t-1}$ ) and the path of the real interest rate ( $r_t$ ). One path of  $S_t$  satisfying (2.3.8) is such that each period the primary current account equals the debt service:

$$S_t = r_t * B_{t-1} \quad (2.3.9)$$

This condition is applied in the paper for definition of the equilibrium primary current account corresponding to external balance, which is in turn used for the computations of the ERER. The external debt and real effective interest rate are assumed to equal their actual historical values adjusted for the cyclical fluctuations. As already mentioned, the absence of information on Russia’s loans to other countries precludes the definition of  $B_{t-1}$  as net total external debt, that would be the correct way to define the equilibrium condition.<sup>6</sup>

In fact, (2.3.9) means the balanced current account. This condition is close to that of Spatafora and Stavrev (2003), who, trying to apply the trade-balance approach to Russia, consider other transition and resource-based non-transition emerging economies as a benchmark for Russia and assume that the country’s current account will tend to a long-run deficit of 1-3% of GDP. On the other hand, condition (2.3.9) is obtained on quite different grounds.

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<sup>6</sup> However, since the right hand side of equation (2.3.9) equals the net interest payments on net external debt, which are available, the equilibrium primary current account can be determined using (2.3.9) even without separate information on net total external debt and the interest rate.

## 2.4. Simple Model of Current Account Determining EREER

After estimating the elasticities of the export supply and import demand functions, (2.2.7) and (2.2.8), and determining the condition for equilibrium primary current account (2.3.9), the final step in the version of the trade-balance approach applied in the paper is the solution for the EREER. Export supply and import demand equations (2.2.7) and (2.2.8) are specified and estimated in real terms. Since foreign debt data are usually available in foreign currency, we can use the terms of trade ( $\lambda$ , see (2.2.5)) to write down the primary current account in terms of import prices in foreign currency (assuming that the Law of One Price holds for exports and imports):

$$S_t = \lambda_t * X_t - M_t \quad (2.4.1)$$

Using the estimates of constant elasticities of the trade equations and the condition of the equilibrium primary current account (2.3.9), the equilibrium real exchange rate for imports,  $ERER_t = q_t$ , can be solved from the following equation:

$$\bar{X} \lambda_t^{\varepsilon_X + 1} q_t^{\varepsilon_X} Y_t^{\eta_X} - \bar{M} q_t^{\varepsilon_M} Y_t^{\eta_M} - r_t B_{t-1} = 0 \quad (2.4.2a)$$

where the terms of trade ( $\lambda_t$ ), real output ( $Y_t$ ), the real interest rate ( $r_t$ ) and the country's external debt in terms of import prices ( $B_t$ ) are assumed to equal either their actual historical values adjusted for cyclical fluctuations or some specified medium-term values. In equation (2.4.2a), the real interest rate and real external debt are obtained by deflating the nominal values by foreign currency import prices, which are assumed to be exogenously given and independent from the country's nominal and real exchange rates. Although one can suggest that it is possible alternatively to derive the EREER from the equation specified in terms of ratios to GDP, in fact for data used it does not seem to be a very suitable approach for two reasons. First, as can be seen from Section 3, while the price index of nontradables, used in the definition of the RERM and RERX, is alternatively approximated by the two implicit price deflators - the GDP deflator and the deflator for GDP minus exports, the latter deflator is viewed as a more correct proxy for nontradable prices. Therefore in order to derive the EREER defined using the deflator for GDP minus exports from an equation like (2.4.2a) specified in terms of ratios to GDP, one needs to employ the share of nontradables sector in GDP, which is not exactly known. Second, while the external debt data are available only in foreign currency, in the intertemporal economy's budget constraint (2.3.1), and hence in the condition of equilibrium primary current account (2.3.9) it is assumed that the economy pays interest on its debt inherited by the end of period  $t-1$  between periods  $t-1$  and  $t$ . Therefore, one needs to introduce

the nominal exchange rate changes between those two periods to work with the ratios of GDP in an equation like (2.4.2a). This is not desirable, as the nominal exchange rate consistent with the ERER is generally unknown.

In equation (2.4.2a), referred below as model A, both exports and imports are specified as endogenous variables affected by changes in the RER. However, this model can be criticized on the grounds of the so-called “export-supply pessimism” (for discussion, see Ghei and Pritchett , 1999), which states that if exports are concentrated in a few products, changes in relative prices of exports to those of domestically produced and consumed goods will induce a very low supply response, and domestic producers will not change their output significantly. Changes in the RER will not affect export volumes if these changes do not alter the relative profitability of the factors in producing exports versus, for example, nontradables. This can be the case if the natural resources sector, which dominates the country’s exports, constitutes an “enclave” and does not compete with the other domestic sectors for the factors of production (Sachs and Warner, 1995; Spatafora and Warner, 1999). In addition, export volumes of natural resources can be irresponsive to fluctuations of the RER, especially in the short term, because of difficulties involved in changes in resources availability.

For Russia, whose exports are dominated by primary commodities, mostly oil and gas, these concerns of “export-supply pessimism” may be quite valid. Therefore, alternatively to model A (2.4.2a), the paper also derives the ERER for imports ( $q_t$ ) as the solution of the model where the export volume ( $X_t$ ) is assumed to be an exogenous variable (model B):

$$X_t \lambda_t - \bar{M} q_t^{\varepsilon_M} Y_t^{\eta_M} - r_t B_{t-1} = 0 \quad (2.4.2b)$$

The solution of model B, the ERER= $q_t^B$ , is calculated using the actual historical data for the volume of exports ( $X_t$ ), the terms of trade ( $\lambda_t$ ), real output ( $Y_t$ ), the real interest rate ( $r_t$ ) and the country’s external debt in terms of import prices ( $B_t$ ).

Using the specifications of the trade equations it is possible to obtain the formulas for the elasticities of the ERER with respect to its fundamentals in model A and model B. The left-hand sides of equations (2.4.2a) and (2.4.2b) represent the current account as the functions of the vectors of variables ( $q_t, \lambda_t, Y_t, r_t, B_t$ ) and ( $q_t, \lambda_t, Y_t, r_t, B_t, X_t$ ) respectively:

$$F(q_t, \lambda_t, Y_t, r_t, B_t) = \bar{X} \lambda_t^{\varepsilon_X+1} q_t^{\varepsilon_X} Y_t^{\eta_X} - \bar{M} q_t^{\varepsilon_M} Y_t^{\eta_M} - r_t B_{t-1} = 0 \quad (2.4.3a)$$

$$F(q_t, \lambda_t, Y_t, r_t, B_t, X_t) = X_t \lambda_t - \bar{M} q_t^{\varepsilon_M} Y_t^{\eta_M} - r_t B_{t-1} = 0 \quad (2.4.3b)$$

The application of the theorem of implicit differentiation to (2.4.3a) yields the following formulas of the ERER's elasticities with respect to its fundamentals in model A:

$$\frac{\partial q_t^A}{\partial \lambda_t} \frac{\lambda_t}{q_t^A} = - \frac{(\varepsilon_X + 1) X_t}{(\varepsilon_X X_t - \varepsilon_M M_t)} < 0 \quad (2.4.4a)$$

$$\frac{\partial q_t^A}{\partial Y_t} \frac{Y_t}{q_t^A} = - \frac{(\eta_X X_t - \eta_M M_t)}{(\varepsilon_X X_t - \varepsilon_M M_t)} \quad (2.4.5a)$$

$$\frac{\partial q_t^A}{\partial r_t} \frac{r_t}{q_t^A} = \frac{\partial q_t^A}{\partial B_t} \frac{B_t}{q_t^A} = \frac{r_t B_{t-1}}{(\varepsilon_X X_t - \varepsilon_M M_t)} > 0 \quad (2.4.6a)$$

As can be expected, formulas (2.4.4a) and (2.4.6a) show that, other things being equal, improvement in the terms of trade unambiguously causes equilibrium real appreciation, while an increase in the real interest rate or in the level of external debt inevitably leads to equilibrium real depreciation. At the same time, it can be seen from (2.4.5a) that in general case the effect of output (income) on the equilibrium RER is ambiguous and depends on the particular values of the output (income) elasticities of export supply and import demand functions as well as on the initial trade balance. If the estimates of elasticities of exports and imports functions are such that  $\eta_X > \eta_M$ , model A predicts that higher output improves the current account and respectively causes an equilibrium real appreciation as long as the trade balance in real terms is in surplus or in a small deficit (such that still  $\eta_X X_t > \eta_M M_t$ ).

Applying the theorem of implicit differentiation to (2.4.2b), the formulas for the ERER's elasticities with respect to its fundamentals in model B are obtained as follows:

$$\frac{\partial q_t^B}{\partial \lambda_t} \frac{\lambda_t}{q_t^B} = \frac{\partial q_t^B}{\partial X_t} \frac{X_t}{q_t^B} = \frac{X_t \lambda_t}{\varepsilon_M M_t} < 0 \quad (2.4.4b)$$

$$\frac{\partial q_t^B}{\partial Y_t} \frac{Y_t}{q_t^B} = - \frac{\eta_M}{\varepsilon_M} > 0 \quad (2.4.5b)$$



$$\frac{\partial q_t^B}{\partial r_t} \frac{r_t}{q_t^B} = \frac{\partial q_t^B}{\partial B_t} \frac{B_t}{q_t^B} = -\frac{r_t B_{t-1}}{\varepsilon_M M_t} > 0 \quad (2.4.6b)$$

As regards the impact of changes in the terms of trade, the real interest rate and external debt (measured in foreign currency import prices) on the ERER, the predictions of model B are close to those of model A. However, unlike model A, the income or output elasticity of the ERER is always positive in model B, i.e. a rise in real output always weakens the current account and causes real depreciation. Regarding the impact of changes in output (income) on the equilibrium real exchange rate, the prediction of Model A can be viewed as more realistic.

### 3. Data and Measures of Real Exchange Rate in Russia

As discussed in Section 2, the paper distinguishes between the two versions of the internal RER – RER for imports (RERM) and that for exports (RERX). The data on trade volumes, the activity variable and price deflators employed for the construction of various measures of the RER are taken from Russia's Quarterly National Accounts (QNA). The consistent information on GDP and its main components at current and constant rouble prices in the Russian QNA is available beginning 1995. The largest sample of the Russian QNA data used for the ERER simulations covers 48 quarters from Q1:1995: through Q4:2006, while the estimates of the trade elasticities are obtained for the period from Q1:1995 to Q1:2005 (41 quarters). The base period for the constant-price series is 1995:Q1. The series of total export and import of goods and services at constant prices are used as indicators of trade volumes, while GDP at constant prices is used as an activity variable.

The implicit deflators for GDP components available from the QNA allow the construction of measures of real exchange rates of exports (RERX) and imports (RERM) suggested by Hinkle and Nsengiyumva (1999) and discussed in Section 2 (see (2.2.1) and (2.2.2)). The price index of nontradables is alternatively approximated by the two implicit price deflators: the deflator for GDP and the deflator for GDP minus exports. While the deflator for GDP ( $P_Y$ ) in fact represents the aggregate price, including the prices of exported goods with some weights, the implicit deflator for GDP minus exports ( $P_{YX}$ ) can be viewed as a proxy for the price index of domestically produced and domestically consumed goods.<sup>7</sup> The combination

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<sup>7</sup> In principle, as shown in Hinkle and Nsengiyumva (1999), the exact measure of domestic goods prices requires information on imported intermediates used in the production of exports. These data are not available in Russia's QNA, but given the nature of Russian exports, the share of imported intermediate inputs used in the production of exported goods is assumed to be negligible.

of the import deflator ( $P_M$ ) with the two candidates for the price index of nontraded goods can produce the two measures of the RER for imports:

$$RERM_Y = \frac{P_M}{P_Y} \quad (3.1) \quad \text{and} \quad RERM_{YX} = \frac{P_M}{P_{YX}} \quad (3.2)$$

In the same way, the RER for exports is computed using the export deflator ( $P_X$ ):

$$RERX_Y = \frac{P_X}{P_Y} \quad (3.3) \quad \text{and} \quad RERX_{YX} = \frac{P_X}{P_{YX}} \quad (3.4)$$

Since the trade-volume equations (2.2.7) and (2.2.8) are specified in logarithms,  $m_t$ ,  $x_t$  and  $y_t$  denote respectively the logs of real imports, exports and GDP, while  $pmpy_t$ ,  $pmpyx_t$  equal the logs of the RER for imports defined in (3.1) and (3.2) and  $pXPY_t$ ,  $pXPYX_t$  correspond to the logs of the RER for exports defined in (3.3) and (3.4).

The RER for both imports and exports sharply rose in the period from the beginning of 1995 to the August 1998 crisis<sup>8</sup>, collapsed as a result of the crisis and has been appreciably recovering ever since. In Figure 3.1, the movements in the RER of imports and that of exports are depicted using two alternative measures of the nontradable goods price index – the implicit deflator for GDP and the deflator for GDP minus exports.<sup>9</sup> At the end of 2006, both measures of the RERM already overshoot their pre-crisis levels by about 80%, while the RER of exports is still about 5% below its peak of 1998:Q2. This observation confirms the fact that Russia's imported and exported goods are of very different nature and that mixing these goods in one RER indicator may be misleading. Another feature following from the definition of the price indices is that both the RERM and RERX constructed using the deflator for GDP minus exports fluctuate more widely than their respective counterparts based on the implicit GDP deflator. Since the deflator for GDP ( $P_Y$ ) is a weighted average of the prices of domestic nontradable goods and exported goods, it can be written as follows:

$$P_Y = P_{YX}^\tau * P_X^{1-\tau}, \quad (3.5)$$

<sup>8</sup> Most of this period, beginning from July 1995, saw a fixed exchange rate regime: initially in the form of a horizontal band and, from June 1996, in the form of a crawling band. More on the arrangements of the fixed exchange rate regime and its collapse in Russia in August 1998 can be found, e.g., in Ivanova and Wyplosz (2003).

<sup>9</sup> The time series of Figure 3.1 are seasonally adjusted. The issues of seasonality and nonstationarity of the time series are discussed in Section 4.

where  $\tau$  is the share of value added of the nontradables sector in GDP, the indicators of the real exchange rate of imports and exports based on the deflator for GDP are a “shrunk” version of these indicators constructed using the deflator for GDP minus exports:

$$RERM_Y = \frac{P_M}{P_Y} = \frac{P_M}{P_{YX}^\tau * P_X^{1-\tau}} = RERM_{YX}^\tau * \lambda^{\tau-1} \quad (3.6)$$

$$RERX_Y = \frac{P_X}{P_Y} = \frac{P_X}{P_{YX}^\tau * P_X^{1-\tau}} = RERX_{YX}^\tau \quad (3.7)$$

where  $\lambda$  is the terms of trade defined in (2.2.6).

The RERM seems to be close to the two traditional proxies for the internal RER: the CPI-based and PPI-based real effective exchange rates (REER). Figure 3.2 compares movements in the RER of imports with the CPI-based and PPI-based REERs. The CPI-based REER comes from the IMF’s International Financial Statistics (IFS). The PPI-based REER is constructed as a weighted average of the PPI-based RERs against the US and Germany (the latter is a proxy for Europe), with equal weights of 0.5. It can be seen that while the general trend is quite similar for both the traditional measures and the RER of imports, the former had not yet risen enough to reach their pre-crisis levels by Q1 2005. By definition of the price indices used in the construction of the different measures of the RER, the traditional indicators (CPI- and PPI-based REERs) show much less fluctuations than the two measures of the RER of imports. For instance, the CPI (P) includes prices of both tradable and nontradable goods:

$$P = P_N^\gamma * P_T^{1-\gamma} = P_{YX}^\gamma * P_M^{1-\gamma} \quad (3.8)$$

where  $\gamma$  is the share of nontradable goods in the consumer basket and none of exportable goods are assumed to be domestically purchased. Then using the Law of One Price, expression (3.8) for the CPI, and assuming that all goods (and services) making up the foreign consumer baskets are imported into Russia, the CPI-based REER can be written as follows:

$$REER = \frac{E * P^*_M}{P} = \frac{P_M}{P} = RERM_{YX}^\gamma = RERM_Y^{\gamma/\tau} * \lambda^{\gamma*(1-\tau)} \quad (3.9)$$

However, in practice the baskets of goods and services purchased by foreign consumers and used for the construction of foreign CPIs include many items that are not imported into Russia. The same is true for the Producer Price Indices. Moreover, the Russian CPI comprises many traded, in particular, imported goods.

That is why in order to measure the internal RER it is more preferable to use indicators based on the price indices of tradable and nontradable goods, of course, if such indices are available. As stressed in Section 2.2, the real exchange rate for imports, RERM, constructed using the price index of domestic nontradable goods, reflects the internal competitiveness of domestic goods in consumption. Since the RERM and RERX are connected through the terms of trade ratio, one of these indicators, in particular the RERM, can be used to analyze the consequences of changes in relative prices for a country's current account as shown in Section 2.4

#### **4. Econometric Issues**

The raw quarterly data of Russia's National Accounts are seasonally unadjusted. In principle, seasonally unadjusted data is viewed as preferable for carrying out econometric analysis, since the procedures of seasonal adjustment are believed to cause the problem of serial correlation in estimations and eliminate economically meaningful information from the series. However, when seasonally unadjusted series are suspected to be nonstationary, in addition to testing for the conventional nonstationarity (at zero frequency), it is advisable to check for seasonal units roots (at semiannual and annual frequencies in the case of quarterly data), because when the latter are present the simple non-seasonal first differencing will not render the series stationary. As expressed by Osborn (1993) "the presence of all seasonal units roots implies that no two quarters are cointegrated with unit coefficients" and the series in "a specific quarter  $q$  ( $q=1,2,3,4$ ) is influenced only by quarter  $q$  shocks".

The series of  $m_t$ ,  $x_t$  and  $y_t$  are shown in Figures 4.1-4.3 for the sample of the trade-equation estimations (Q1:1995-Q1:2005). It can be seen from the figures that the series of  $m_t$ ,  $x_t$  and  $y_t$  may have a random-walk nature, implying that a unit root at the zero frequency can be found. In addition, it is clear from the figures that all the three series have a strong seasonal pattern: the seasonal pattern of  $x_t$  appears to change over the sample period, while  $m_t$  and  $y_t$  demonstrate a more constant seasonality. These observations provide preliminary evidence that some seasonal unit roots can be present in the series, especially in  $x_t$ . On the other hand, the seasonality in  $m_t$  and  $y_t$  may turn out to be of deterministic rather than stochastic nature, and can therefore be corrected at least to some extent by introducing the seasonal quarterly dummies.

Since the alternative measures of the RERM and RERX are constructed using the implicit deflators of quarterly seasonally unadjusted data, their series may contain some seasonal unit roots too. Figures 4.4-4.5 show the dynamics of  $pm\dot{p}y_t$ ,  $pm\dot{p}yx_t$  and  $px\dot{p}y_t$ ,  $px\dot{p}yx_t$  for Q1:1995-Q1:2005. The seasonal pattern exhibited by the RER's measures is less pronounced than that in the series of real GDP and trade volumes but is still quite evident in the figures.

The formal test for seasonal as well as non-seasonal integration, the so-called HEGY test, was developed by Hylleberg, Engle, Granger and Yoo (1990). For variable  $X_t$  the basic auxiliary regression of the HEGY test (before the augmentation by the deterministic terms and the lagged dependent variable) is the following:

$$X_{4t} = \pi_1 X_{1t-1} + \pi_2 X_{2t-1} + \pi_3 X_{3t-2} + \pi_4 X_{3t-1} \quad (4.1)$$

where

$$\begin{aligned} X_{1t} &= (1 + B + B^2 + B^3)X_t \\ X_{2t} &= -(1 - B + B^2 - B^3)X_t \\ X_{3t} &= -(1 - B^2)X_t \\ X_{4t} &= (1 - B^4)X_t \end{aligned} \quad (4.2)$$

and B is the backward operator.

HEGY (1990) demonstrated that the seasonal difference operator,  $(1 - B^4)$ , can be factorized to reveal all possible roots (+1, -1, +i, -i) in a seasonal process. The root +1 occurs at the zero frequency and corresponds to the long-run behavior of the series. The root -1 occurs at the semiannual frequency, while the two complex roots occur simultaneously and interpreted as lying at the annual frequency. HEGY (1990) proposed t-statistics for  $\pi_1$ ,  $\pi_2$ ,  $\pi_3$  and  $\pi_4$  in (4.1) as well as the F-statistic for  $\pi_3$  and  $\pi_4$  jointly denoted  $F_{34}$ . If the null hypothesis that  $\pi_1=0$  is not rejected, it implies the presence of a non-seasonal unit root. If the null hypothesis that  $\pi_2=0$  is not rejected, it can be concluded that there is a unit root at the semiannual frequency. Finally, if  $\pi_3=\pi_4=0$  is not rejected, there is an annual unit root. Ghysels et al. (1994) extended the HEGY test by proposing an F-statistic for the presence of unit roots at all the seasonal frequencies simultaneously,  $F_{234}$  and an F-statistic for the presence of all unit roots simultaneously, including the zero frequency,  $F_{1234}$ .

The results of the HEGY tests are presented in Table 4.1. First of all, all series under consideration, as expected, appear to have non-seasonal unit roots, although in the case of zero deterministic terms the

measures of the RER of exports prove to be stationary at 5%, but not at the 1% level of significance. This is an interesting finding that can be viewed as a kind of manifestation of the Dutch Disease phenomenon in Russia: an increase in export prices corresponds to an almost proportionate increase in the price index of nontraded goods expressed in the same currency. The results of the traditional ADF tests for unit roots are similar to those of the HEGY tests for a non-seasonal unit root. Since Ghysels et al. (1994) demonstrated that the asymptotic equivalence between the t-statistic for  $\pi_t$  and the ADF t-statistic found in HEGY (1990) is also valid for the finite samples, the results of the ADF tests for seasonal unadjusted series are not reported.

As far as the seasonal nonstationarity is concerned, the results of Table 4.1 show that the null hypothesis of semiannual unit roots cannot be rejected for all series. However, where the seasonal dummies are included, the presence of the annual unit roots can be rejected for all series except for real exports,  $x_t$  and the two measures of the RER for exports. The same also appears to be true for the null hypothesis concerning all seasonal unit roots. Summarizing, it can be concluded that there is a clear indication of the seasonal integration of the series of real exports, while the evidence of the presence of the seasonal unit roots in all other series is ambiguous.

The presence of some or all seasonal unit roots have certain implications for the estimation strategy. Abeysinghe (1994) showed that the use of seasonal dummies for removing the nonstationary stochastic seasonality is likely to produce spurious regressions. In terms of the Engle-Granger methodology (1987), HEGY (1990) and Engle et al. (1993) suggested and discussed the concept and tests for seasonal cointegration, implying that the right specification of the ECM should include the error terms for deviations from cointegrating relations for all frequencies if such relationships are found. However, Lee and Siklos (1995) stressed that the Johansen ML test for cointegration at the zero frequency proves to be still correct in the case of the right VAR-representation in line with the validity of the traditional ADF tests demonstrated by Ghysels et al. (1994)

While the search for seasonal cointegration for the trade-volume equations, can, in principle, be carried out, the final goal of this study is not the modeling of seasonal fluctuations in the trade-volumes per se but the computation of the ERER, which is the medium-run and long-run concept by definition. Thus, cointegration at non-zero frequencies is not considered here. The alternative approach to dealing with the nonstationary stochastic seasonality is to use seasonally adjusted series. On the other hand, it is known that in some cases cointegrating relationships can be found for raw seasonally unadjusted data, but not for seasonal adjusted series (see, e.g., Bohl, 2000). That is why the trade equations have been estimated using

both raw and adjusted data. The census II method developed and used by the Census of the US Department of Commerce was used for producing the seasonally adjusted series.

The results of the ADF tests (Dickey and Fuller, 1979) for unit root for the seasonal adjusted series reported in Table 4.2 are generally in line with the findings on non-seasonal integration of the HEGY test. The seasonally adjusted series of real imports, GDP and the RERM defined using the implicit deflator for GDP, are likely to be generated by a pure random walk processes. The series of real exports appears to be characterized not only as a random walk with drift but, according to the F-test, may also contain a linear trend. However, there is some possibility that for the particular period of estimation the seasonally adjusted series of the RERXs and the RERM defined using the implicit deflator for GDP minus exports can be viewed as stationary. On the one hand, the hypothesis that the RER is stationary in developing countries has not received much support in the literature (Edwards and Savastano, 1999). On the other hand, there is no study examining the time series properties of the RER for exports, especially in resource-based economies. Following most of the studies on the estimation of trade equations, it is assumed that the two alternative measures of both the RER for imports and RER for exports are nonstationary, while this issue certainly deserved more attention, especially as a larger sample for the Russian data is available.

Since all variables under consideration are viewed as nonstationary, the appropriate estimation technique is search for cointegration and estimation of the long-run trade elasticities as the coefficients of the cointegrating vectors. The presence of cointegrating relationships is tested by applying Johansen's Maximum-likelihood methodology (Johansen, 1988, 1991) and the residual-based test developed by Engle and Granger (1987) and Phillips and Ouliaris (1990). These residual-based tests for cointegration are applied to the OLS estimates of the long-run relationships (2.2.7) and (2.2.8). The OLS estimates of a cointegrating vector are known to be superconsistent, however, in a finite sample where some of the regressors are not exogenous, the OLS estimates can be substantially biased (see, for example Hayashi, 2000). In addition, the residuals of the OLS regressions can be serially correlated, which precludes the use of the OLS t-statistics to make an inference of the significance of coefficients of the cointegrating vector. In order to remedy these shortcomings of the OLS estimator of the cointegrating vector, "static" OLS (SOLS), Stock and Watson (1993) suggested the dynamic ordinary least square (DOLS) estimator, which incorporates lags and leads of the regressors in the first differences as well as the lagged changes of the dependent variable and thus accounts for the endogeneity of the regressors and for serial correlation in the residuals. For example, for the import equation with the RERM defined by (3.1), the DOLS regressions have the following forms:

$$m_t = \alpha_0 + \varepsilon_M pmpy_t + \eta_M y_t + \sum_{j=-k_1}^{k_2} \gamma_j \Delta pmpy_{t-j} + \sum_{j=-l_1}^{l_2} \delta_j \Delta y_{t-j} + \sum_{j=1}^m \lambda_j \Delta m_{t-j} + \varepsilon_t \quad (4.3)$$

where  $k_1$  and  $l_1$  denote leads and  $k_2$ ,  $l_2$  and  $m$  respectively denote lags. Since the SOLS estimates can be potentially biased the presence of cointegration is also checked by performing the residual-based tests applied to the residuals of the long-run relationship derived using the DOLS estimates in equations, like (4.3).

In addition to the DOLS, the long-run trade elasticities are estimated by the Johansen procedure (Johansen, 1988, 1991), which involves the ML estimation of the Vector Error Correction Model (VECM). The Johansen procedure is based on the full-system estimation that can help to eliminate the simultaneity bias and raise efficiency relative to the single-equation methods. For a general  $p \times 1$  vector  $Y_t$  of stochastic variables, the VECM has the following form:

$$\Delta Y_t = \zeta_1 \Delta Y_{t-1} + \zeta_2 \Delta Y_{t-2} + \dots + \zeta_{k-1} \Delta Y_{t-k+1} + \zeta_0 Y_{t-1} + \mu + \Psi D_t + \varepsilon_t \quad (4.4)$$

where  $\zeta_0 = -BA'$ ,  $D_t$  are deterministic variables, such as centered seasonal dummies.

$\zeta_0 Y_t$  is interpreted as a long-run equilibrium relationship between the variables in the system, and the  $p$ -vector  $A' Y_t$  is a vector of disequilibrium deviations from the equilibrium relationship. Each period  $Y_t$  is corrected by proportions in matrix B of these deviations. If the disturbances move the time series from the long-run relationship, the series will return to the long-run relationship over time following the VECM. The hypothesis of reduced rank,  $r$ , of the long-run matrix  $\zeta_0$  is used to formulate the hypothesis of cointegration. In the absence of cointegration  $r=0$ . For testing the number of cointegrating vectors, the  $\lambda_{max}$  statistic and  $\lambda_{trace}$  statistic are employed. The  $\lambda_{max}$  statistic tests the null hypothesis of  $r=s$  cointegrating vectors against the alternative that  $r=s+1$ . The  $\lambda_{max}$  statistic is

$$\lambda_{max} = -T \ln(1 - \lambda_{s+1}) \quad (4.5)$$

where  $T$  is the size of the sample,  $\lambda_1 > \lambda_2 > \dots > \lambda_p$  are the eigenvalues,  $p$  is the full rank and  $s$  is the hypothesized number of cointegrating vectors. The  $\lambda_{trace}$  statistic tests the null hypothesis of  $r=s$  cointegrating vectors against the alternative that  $r \geq s+1$ . The  $\lambda_{trace}$  statistic is



$$\lambda_{trace} = -T \sum_{i=s+1}^p \ln(1 - \lambda_i) \quad (4.6)$$

Cheung and Lai (1993) indicate that the  $\lambda_{trace}$  statistic is more robust to skewness and excess kurtosis than the  $\lambda_{max}$  statistic is.

The Johansen procedure allows testing restricted forms of the deterministic components. This is important since the appropriate critical values  $\lambda_{max}$  and  $\lambda_{trace}$  statistics vary depending on assumptions made about the deterministic components, such as the constant term and trend in the VECM and cointegrating vectors, and on how these assumptions are related to the true data generating process. In particular, for the series under investigation, the three alternative models are considered. The first model assumes no linear trend in the data because each series under investigation can be characterized by a pure random process, and therefore the intercept in the VECM is restricted to the long-run cointegrating vector. The second model allows for the linear trends in the data, since some of the time series can be characterized by a random walk with drift, so that the intercept is present in the VECM. The third model allows for the linear trends in the data and in the cointegrating vector, while there is no trend in the VAR. That third model is checked for the export volume equation, where the linear trend is used as a proxy for the increasing productivity gains in the trade sector. Under the assumption of  $s$  cointegrating vectors, the first (restricted) model is tested against the second (unrestricted) one using the following LR statistic:

$$-T \sum_{i=s+1}^p [\ln(1 - \lambda_i^*) - \ln(1 - \lambda_i)] \quad (4.7)$$

Under the null hypothesis that the intercept can be restricted to the cointegrating vector, (4.7) has a  $\chi^2$  distribution with  $(p-s)$  degrees of freedom. In turn, under the assumption of  $s$  cointegrating vectors, the third (restricted) model is tested against the second (unrestricted) model using the following LR statistic:

$$-T \sum_{i=1}^p [\ln(1 - \lambda_i^*) - \ln(1 - \lambda_i)], \quad (4.8)$$

Under the null hypothesis that there is a linear trend in the data but there is no trend in the cointegrating vectors, (4.8) has a  $\chi^2$  distribution with  $s$  degrees of freedom.  $\lambda_1 > \lambda_2 > \dots > \lambda_p$  and  $\lambda_1^* > \lambda_2^* > \dots > \lambda_p^*$  are eigenvalues corresponding to the unrestricted and restricted model respectively.  $T$  is the number of observations,  $p$  is the number of variables in the system.

Since the size of the sample used for the estimation of Russia's trade elasticity is rather small, while the critical values of  $\lambda_{max}$  and  $\lambda_{trace}$  statistics tabulated by Osterwald-Lenum (1992) are valid only asymptotically, the small sample correction factor of the critical values suggested by Cheung and Lai (1993) is applied:

$$CF = 0.1 + 0.9 * \frac{T}{(T - p * k)} \quad (4.9)$$

where  $T$  is the number of observations,  $p$  is the number of variables in the system and  $k$  is the order of the VAR. The order of the VAR is determined using the Akaike and Schwarz information criteria as well as the likelihood ratio test suggested by Sims (1980):

$$LR = (T - c) \log \left| \hat{\Omega}(k) \right| - \log \left| \hat{\Omega}(k + 1) \right|, \quad (4.10)$$

where  $\hat{\Omega}(k)$  is a residual variance-covariance matrix of  $k$ th-order VAR,  $T$  is the number of observations,  $c = I + p(k+1)$ , and  $p$  is the number of elements in the vector of the time series. Under the null hypothesis that generating VAR has order  $k$ , LR statistic is approximately distributed as  $\chi^2$  with  $p^2$  degrees of freedom. The alternative hypothesis is that the order of the VAR is  $k+1$ .

## 5. Trade Equations: Estimation Results

### 5.1. Demand for Imports

The results of the tests for cointegration and estimations of the cointegration relations for import demand equation (2.2.8) performed using the raw seasonal unadjusted data are presented in Table 5.1.1. Equation (2.2.8) is estimated in its most standard form where the import volume depends on changes in the relative prices of imports (RERM) and the country's real income (real GDP). Table 5.1.2 shows the same kind of results obtained for the seasonal adjusted series. Both alternative measures of the RER for imports (RERM) are used. The upper parts of Table 5.1.1 and Table 5.1.2 report the estimation results performed for the RERM defined as the ratio of import prices to the GDP deflator (RERM<sub>Y</sub>, see 3.1), while the lower parts of the tables show the results for the RERM defined as the ratio of import prices to the deflator for GDP minus exports (RERM<sub>YX</sub>, see 3.2). For seasonal unadjusted series, the long-run relationship between the volume of imports, real GDP and the RERM is detected by the Johansen ML and residual-based tests for cointegration with the 5% and 1% level of significance for both alternative measures of the RERM. On the other hand, for seasonally adjusted series, there is more evidence of the presence of the

cointegration relationship for the second alternative measure of the RERM,  $RERM_{YX}$ , while for  $RERM_Y$  the null hypothesis of no cointegration of the Johansen test can be rejected only with 10% of significance only for  $\lambda_{trace}$  statistic. This result can be viewed as expectable given the fact that  $RERM_{YX}$  is closer than  $RERM_Y$  to the theoretical definition of the internal real exchange rate suggested by Hinkle and Nsengiyumva (1999). Moreover, for both the seasonally unadjusted and adjusted series, the estimates of coefficients of the cointegrating vectors obtained for  $RERM_{YX}$  have lower standard errors than the ones obtained for  $RERM_Y$ .

The absolute values of the estimated long-run elasticities of imports with respect to the real exchange rate are higher for  $RERM_Y$  as a measure of the RERM than for  $RERM_{YX}$ . This result can be viewed as expectable, given that  $RERM_Y$  is a “shrunk” version of  $RERM_{YX}$  (see (3.6)). For the former, the price elasticity of imports is about  $-0.7$ , while for the latter it is around  $-0.5$ . The income elasticity of imports is between 1.3 and 1.5.

The values of the estimated import elasticities are generally in line with the estimates obtained in other empirical studies for both developed and developing countries. For example, Meacci and Turner (2001) report that the average price elasticity of import demand for the OECD countries equals  $-0.69$  and the average income elasticity equals 1.49. According to Reinhart (1995) and Senhadji (1997), the average price elasticity of import demand for developing countries is  $-0.51$  and  $-0.88$  respectively. The estimates of the price elasticity of import demand obtained for Russia in other studies are  $-0.5$  (Dynnikova, 2001),  $-0.69$  (Belomestnova, 2002) and  $-0.74$  (Spatafora and Stavrev, 2003), while these authors used different measures of the variables under investigation and different periods of estimation compared with those of the current study.<sup>10</sup>

The DOLS estimates of the cointegrating vectors are generally close to the estimates obtained by the Johansen ML procedure. The fact that the leads and lags of real GDP and the real exchange rate appear to be significant in the DOLS regression implies that those variables may indeed be endogenous with respect to the estimated system.

Apart from the estimation of the long-run relationship, the Johansen methodology allows estimation of all short-run dynamics of the VECM. The adjustment coefficients in the import equations of the VECM are,

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<sup>10</sup> At the time when the previous studies on the import demand functions in Russia were performed, the consistent QNA in both current and constant prices was not available, so the authors had to use some proxy for the index of import prices.

as expected, negative for both the alternative definitions of the RERM and for both the seasonally unadjusted and adjusted series. However, when the sample of estimation includes the year 1995, the adjustment coefficient in the import equation is statistically significant only for seasonally unadjusted data, while for seasonally adjusted data, the absolute value of the adjustment coefficients is much lower. Experiments with the sample of estimation reveal that starting Q1 1996 the absolute value of the adjustment coefficient in the import equation substantially increases and the coefficient becomes statistically significant at 1%.

This finding may have two explanations. First, the trade liberalization was possibly still under way in 1995, although its major steps appear to have been taken in 1993-1994. Second, the year 1995 saw a change in the exchange rate regime: in July 1995 the Bank of Russia abandoned the floating exchange rate regime introducing a narrow horizontal band for daily rouble fluctuations. The operation of these two factors may have caused a structural break in the import demand function in 1995. That is why the dynamics of the smoothed seasonally adjusted series of imports may not respond to deviations from the long-run equilibrium until 1995 is excluded from the period of estimation. As the sample starts from 1996, the estimate of the adjustment terms appears to be quite high with almost all of the adjustment made in one quarter. Figure 5.1 presents the impulse-response functions for the import demand equation of the VECM estimated with the serial adjusted series for  $RERM_{YX}$  as the measures of the real exchange rate. The impulse-response functions for  $RERM_Y$  have a similar shape and are not presented for the sake of space. The shapes of the impulse response functions indicate that the dynamic responses of the variables conform to the theoretical predictions.

## **5.2. Supply of Exports**

The results of the tests for cointegration and estimation of the cointegration relations for export supply are presented in Table 5.2.1 for raw seasonally unadjusted data and in Table 5.2.2 for seasonally adjusted series. Both alternative measures of the RER of exports ( $RERX$ ) are used. The upper parts of Table 5.2.1 and Table 5.2.2 report the estimation results performed for the  $RERX$  defined as the ratio of export prices to the GDP deflator ( $RERX_Y$ , see (3.3)), while the lower parts of the tables show the results for the  $RERX$  defined as the ratio of export prices to the deflator for GDP minus exports ( $RERX_{YX}$ , see (3.4)). As suggested in Section 2, the two specifications of the export supply function (2.2.7) are estimated. The first basic specification (2.2.7a) includes only the RER of exports and real GDP as the explanatory variables for export volumes. In the second specification (2.2.7b), the time trend is added as a proxy for possible increasing productivity gains in the trade sector.

First it should be said that the second specification of the long-run relationship for export volume, including the time trend, appear to be rejected by the data for both the seasonally unadjusted and adjusted series. Although the time trend looks significant in the SOLS regressions, these SOLS estimates are likely to be biased because of the regressors' endogeneity, and their standard errors may be incorrect because of the serial correlations in the errors. The presence of the simultaneity problem is confirmed by the significance of the leads and lags of real GDP and the RERX in the DOLS regressions, so the SOLS estimates for the export supply function can probably be viewed as unreliable. The DOLS and the Johansen ML estimates of the time trend are insignificant for both alternative measures of the RERX and for both raw and seasonally adjusted series. Moreover, according to tests based on LR statistics (4.7) and (4.8) of the Johansen methodology, the hypothesis about the presence of the linear trend in the data is confirmed, but its absence in the cointegrating vectors cannot be rejected. Therefore the rest of the discussion will be focused on results for the first basic specification (2.2.7a).

It can be seen from Table 5.2.1 and Table 5.2.2 that while for the raw data the evidence of the presence of the cointegrating relationships is ambiguous, for the seasonally adjusted series it can be viewed as rather weak. For the raw data, the Johansen test rejects no cointegration with the 1% level of significance for both alternative definitions of the RERX, but, according to the residual-based test for the residuals derived from the DOLS estimates of equation (2.2.7a), the absence of cointegration can be rejected (with the 5% level of significance) only for  $RERX_{YX}$  as a measure of the real exchange rate of exports. On the other hand, for the seasonally adjusted series, the residual-based tests do not allow rejection of no cointegration even at 10% for both alternative measures of the RERX. The results of the Johansen test for seasonally adjusted series reject no cointegration at 10% according to both  $\lambda_{max}$  and  $\lambda_{trace}$  statistics for  $RERX_Y$  as a measure of the RER of exports and only according to  $\lambda_{max}$  statistics for  $RERX_{YX}$ .

Despite the fact that both the DOLS and the Johansen estimates of the real exchange rate of exports are found to be highly significant, the absolute value of price elasticity of export supply appeared to be very low: 0.10-0.12 for the RERX defined as the ratio of export prices to the deflator of GDP ( $RERX_Y$ ) and 0.07-0.09 for the RERX defined as the ratio of export prices to the deflator of GDP minus exports ( $RERX_{YX}$ ).<sup>11</sup> The elasticity of export supply with respect to the capacity variable (real GDP) turned out to be quite high: between 1.7 and 1.8.

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<sup>11</sup> Again, as in the case of import demand equation, the estimations of export supply performed with the measure of the RER constructed using the GDP deflator as a proxy for prices of nontraded goods produce a bit higher absolute values of price elasticities compared with the same estimations where prices of nontraded goods are approximated by the deflator of GDP minus exports. The reason behind such difference in the estimates is a higher volatility of  $RERX_{YX}$  compared to  $RERX_Y$ .

Since the RERX is viewed as a measure of internal price competitiveness of exports in production relative to nontradable goods, the low elasticity of export supply with respect to the RERX means that competition for resource allocation between the sectors producing these two categories of goods is weak in Russia. In other words, the assumption made in the literature (see, for example, Sachs and Warner, 1995; Spatafora and Warner, 1999) that the oil-producing sector in oil-exporting countries can be modeled as an “enclave” seems to be correct for Russia, since oil and gas constitute the major part of the country’s exports. Such low estimates of the price elasticity of export supply are in line with the so-called “elasticity pessimism” and in particular “export supply pessimism” stressed in the literature (for the discussion see Ghei and Pritchett (1999)), which states that if exports of developing countries are concentrated in a small number of products, changes in relative prices will induce a very low domestic supply response and domestic producers will not change their output significantly. The estimates of export price elasticities of supply obtained for the aggregated Russian data resemble the estimates of export price elasticities of supply reported by Bond (1987) for developing countries for minerals as a separate product group: about 0.09. Bond (1987) excluded oil-exporting countries from his study, but minerals (ferrous and non-ferrous metals) are the second largest group of Russia’s exports.

Another confirmation of “export supply pessimism” is provided by the fact that the adjustment coefficient in the export equation in the VECM estimated by the Johansen ML methodology is not very statistically significant, although it is of the correct negative sign. This means that dynamics of export volumes are not very responsive to disequilibrium deviations and most of the adjustment is made through the other variables: in particular, through the relative prices, since the adjustment coefficients of the RERX is highly statistically significant. Figure 5.2 presents the impulse-response functions for the export supply equation of the VECM estimated with the serial adjusted series for  $RERX_Y$  as the measures of the real exchange rate. For  $RERX_{YX}$  the impulse-response functions are of a similar shape and not presented for the sake of space. The shapes of the impulse response functions indicate that the dynamic responses of the variables generally correspond to the theoretical predictions.

### **5.3. Choice of Elasticities Estimates and Measure of RER for ERER Simulations**

Although there is more evidence for the presence of a long-run relationship between trade flows, real GDP, and the real exchange rate for the raw unadjusted data than there is for the same seasonally adjusted series (especially for export supply equation), the ERER is a long-run concept by definition, as already stressed in Sections 2 and 4, and, hence it will be reasonable to calculate the estimates of the ERER using the seasonally adjusted data and calibrate models A and B by the estimates of elasticities obtained for the

seasonally adjusted series. Furthermore, the results of Tables 5.1.1-5.2.2 show that the elasticities estimated using the raw and seasonally adjusted data are quite close for both the import and export equations. Thereby, while evidence for the presence of the cointegrating vector obtained for the seasonally adjusted series probably cannot be viewed as totally convincing, more indications of the presence of long-run relationships between the raw data under investigation can, in principle, be viewed as providing a firmer basis for using this concept in calculating the ERER.

As regards the two alternative measures of the nontradable goods price index used in constructing the RER for imports and exports, the implicit GDP deflator, and the implicit deflator for GDP minus exports, the results of the regressions do not definitely show the superiority of one method of measuring the real exchange rate over the other. In theory, the deflator for GDP minus exports reflects the nontradable goods price index more accurately, and hence the indices of the RER constructed using this deflator are more correct measures of the internal price competitiveness of domestic goods. Indeed, as discussed in Section 5.1, the results obtained for the import demand equation for both seasonally unadjusted and seasonally adjusted series are consistent with this theoretical consideration. Conversely, for the export supply equation, the measure of the RER constructed using the deflator for GDP minus exports prove to be more preferable than that constructed using the GDP deflator only in the regressions run with the raw data (see Section 5.2). In addition, comparisons of the error sums of squares of the regressions estimated with the two alternative measures of the nontradable goods price index for the seasonally adjusted series reveal that for the export equation,  $RERX_Y$  provides a better fit than  $RERX_{YX}$  for both the Johansen and DOLS estimates, while for the import equation,  $RERM_Y$  provides a better fit than  $RERM_{YX}$  only for the DOLS estimator. Therefore in the absence of clear superiority of either of the indices of nontraded goods prices, the simulations of the ERER will be performed using both alternative measures of the RERM. Since the RERX and RERM are connected through the terms of trade ratio, which is exogenous, only the terms  $RERM_Y$  and  $RERM_{YX}$  will be used below in order to distinguish between the two alternative measures of the RER.

It is also difficult to establish the supremacy of elasticities obtained using the Johansen or DOLS estimators. Figures 5.3.1-5.3.3 show the actual seasonally adjusted real exports, imports, and PCA and their fitted counterparts obtained with the use of the Johansen and DOLS estimates of the long-run price and income elasticities for  $RERM_Y$ . For  $RERM_{YX}$ , the same graphs are not presented for the sake of space. The fitted values of trade volumes obtained using the Johansen and DOLS estimators are very close for both alternative measures of the RER.

While estimated long-run imports and exports generally approximate the dynamics of their actual seasonally adjusted counterparts reasonably well, their long-run equations predict the persistent overvaluation of imports since 1999:Q2 and undervaluation of exports in the period from 1998:Q2 to 2000:Q2. As a result, the estimated long-run PCA appears to be consistently lower than its actual values in the period from 1998:Q2 to 2001:Q1.

Since for both export and import equations and for both measures of the RER, the values of elasticities obtained using the Johansen and DOLS estimators are very close to each other, and there is no clear dominance of any of these estimates, the trade elasticities with the highest absolute values of the real exchange rate elasticities are used in the simulations of the EREs: for  $RERM_Y \varepsilon_M = -0.74$ ,  $\eta_M = 1.246$  (DOLS),  $\varepsilon_X = 0.117$ ,  $\eta_X = 1.716$  (Johansen) and for  $RERM_{YX} \varepsilon_M = -0.464$ ,  $\eta_M = 1.441$  (Johansen, estimation period starts from Q1 1996),  $\varepsilon_X = 0.086$ ,  $\eta_X = 1.752$  (Johansen). These elasticities are also summarized in Table 5.3.

## 6. Simulations of ERE

This section starts with the description of the stylized facts of ERE fundamentals consistent with the version of the trade-balance approach that this paper applies to Russia. Then the section presents the in-sample simulations of the equilibrium real exchange rate using the trade elasticities estimated in Section 5 and the assumption of the equilibrium primary current account discussed in Section 2.3 (see (2.3.9)). In the first set of simulations, viewed as baseline simulations, all exogenous variables - real GDP, the terms of trade, external debt and real effective interest rate - are assumed to equal their actual seasonally adjusted values. As follows from Section 6.1, the ERE's fundamentals in Russia, especially the country's terms of trade, remain rather volatile even if adjusted for seasonal fluctuations. Therefore the baseline simulations can be viewed as exercises answering the question what would happen to the country's ERE if the medium-term values of its fundamentals had equaled their actual historical values.

The ERE is defined as the solution of model A (equation (2.4.2a)), where both exports and imports are specified as endogenous. In addition, since the results of section 5.2 for export supply equation confirm the conjecture of "elasticity pessimism", the ERE is also derived as the solution of model B (equation (2.4.2b)), where exports are assumed to be exogenous. Next, I make an evaluation and decomposition of fundamentals driving the ERE in models A and B. In particular, the formulas for the ERE elasticities with respect to its fundamentals derived in Section 2.4 are evaluated using the estimated trade elasticities as well as the sample values of exogenous and fitted endogenous variables. Moreover, the ERE is simulated under the alternative assumptions of the fundamentals' dynamics. Finally, instead of just



making an alternative assumption of Russia's external debt, I consider the "desired reserve accumulation" scenario, where the country's primary current account is used not only to service its debt but also to accumulate foreign reserves according to a specified rule. Most computations of the EREER under different assumptions about the fundamentals and external balance are performed for the two alternative measures of the real exchange rate used in the estimations of the trade elasticities.

## **6.1 Dynamics of EREER Fundamentals in Russia**

### *Terms of trade / world oil prices*

Among the factors suggested as fundamentals by the trade-balance approach to the determination of the equilibrium real exchange rate (ERER), the terms of trade (TOT) is the first one catching the eye. It can be seen from Figure 6.1.1 that the RERM and TOT indeed show similar trends throughout the period under study. The dynamics of the terms of trade follow world oil price movements very closely, since oil and gas constitute the bulk of the country's exports (see Figure 6.1.2). The simple correlation coefficient between world oil prices and the terms of trade is 0.98. This implies that most variation in Russia's terms of trade corresponds to changes in world oil prices, and the country appears to be quite vulnerable to such external shocks. For instance, the severe crisis of August 1998, which triggered a more-than-50% real rouble depreciation, broke out amid an oil price slump, when world prices were hitting their twenty-year lows. Conversely, real rouble appreciation seen in recent years is largely associated with an unprecedented surge in oil prices.

Real appreciation of a domestic currency due to an increase in world oil prices is usually viewed as the so-called spending effect of the Dutch Disease phenomenon. An increase in oil prices raises export revenues, which in turn increases demand for nontraded goods. As a result, prices of nontraded goods rise and the currency appreciates in real terms. The second feature of the Dutch Disease is the resource allocation effect. Higher export commodity prices imply higher marginal labor productivity in the exporting sector, and, accordingly, higher demand for labor in the sector. This causes wages in the exporting sector to increase, encouraging labor to move to the oil sector from other industries, and, if wages are equalized across sectors, it leads to an overall wage increase in the economy. This hurts producers of non-oil traded goods, as they become less competitive.<sup>12</sup>

The importance of world oil prices as the determinants of the Russian EREER was documented by several empirical and theoretical studies. In particular, Spatafora and Stavrev (2003) and Egert (2005), using the

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<sup>12</sup> The investigation of the symptoms of the Dutch Disease in Russia as well as the discussion of their implication for the country's long-term growth can be found in Volchkova (2005).

single-equation approach, and Sosunov and Zamulin (2004), in the framework of a small calibrated model, found that the Dutch Disease was a possible driving force of RER movements in Russia. There are numerous studies confirming the significance of the TOT as one of the fundamentals of the EREER for both oil-exporting and non-oil exporting countries.<sup>13</sup>

### *External debt*

The country's external debt is another fundamental determining the EREER under the trade-balance approach outlined in Section 2. The evolution of Russia's total external debt and external public debt is shown in Figure 6.1.3. At the beginning of transition, all Russia's external debt was represented by the \$90 bn foreign debt of the former Soviet Union (FSU) inherited by the Russian government.<sup>14</sup> Due to the repayment and partial writing off of the London Club loans (\$11 bn in Q3 2000) and early repayment of the Paris Club loans (\$23.3 in Q3 2006), the debt of the FSU was significantly reduced, and at the end of 2006 totaled \$9.8 bn (about 20% of Russia's total external public debt).

New foreign borrowing rapidly boosted the Russian government's debt, which peaked at about \$52 bn in 1998. In 1998 alone, the new foreign public debt grew by \$20 bn. As the crisis unfolded, declining tax revenues and rising yields on domestic short-term government bills (GKOs) precipitously worsened domestic debt servicing. In mid-July 1998, the Russian government, in a vain attempt to alleviate the burden of forthcoming repayments of domestic debt, converted a portion of GKOs into foreign currency-denominated Eurobonds with longer maturities. Wyplosz and Yudaeva (1998) recognize the GKO swap as a gross mistake and provide estimates of its cost. By the end of 1998, the country's total Eurobond obligations rose to one third of the new Russian public debt (as of end-2006 their share in Russia's external public debt increased to 51%). Moreover, in July 1998, trying to defend the doomed fixed exchange rate regime and replenish its drained international reserves, the Russian government arranged a large emergency loan from the IMF and the World Bank, of which \$5.6 bn was disbursed almost immediately. As discussed in detail in Ivanova and Wyplosz (2003), all these measures were ineffective, with Russia's external debt inevitably soaring.

The share of the private sector in the country's external debt attained 25% only at the end of 2001, but from that moment on, due to increasing oil export revenues and improved creditworthiness of Russian

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<sup>13</sup> One example of the studies for oil-exporting countries is Koranchelian (2005), who applies the single-equation approach to EREER estimation in Algeria.

<sup>14</sup> Since the FSU's foreign debt was mostly of medium- and short-term maturity, Russia started debt restructuring negotiations with the London and Paris Clubs of creditors in 1991-1992. The restructuring, which has continued since 1992, has markedly improved the maturity structure of Russia's external public debt. The majority of the FSU debt was rescheduled under a deal with the London Club on December 1997.

firms, private borrowing rapidly expanded and as of end-2006 amounted to \$261 bn, or 84% of Russia's total external debt.

#### *Real interest rate*

Along with the level of the country's debt, the average real interest rate paid on Russia's foreign debt determines the country's external budget constraint, which, under the condition of the equilibrium primary current account (2.3.9), allows the definition of the equilibrium real exchange rate. Figure 6.1.4 presents the real effective seasonally adjusted interest rate paid on Russia's total external debt per annum. The nominal interest rate paid on foreign debt is converted into real interest rate using foreign currency import prices. The first local maximum of the real interest rate (10%) corresponded to the peak of external debt and occurred in Q2 1998. In 1999 through 2002, the real interest rate paid on Russia's external debt ranged from 7% to 9%, but from 2003, probably because of the rapidly growing share of private debt, it started to increase sharply, peaking at an unprecedented 20% at end-2006.

#### *Domestic economic growth*

In the version of the trade-balance approach applied in this study, changes in domestic real output are the only internal factor determining the evolution of the ERER. The dynamics of seasonally adjusted series of GDP at constant prices are presented in Figure 6.1.5. The beginning of the period under investigation saw a shrinkage of output that had continued from the start of transition. The tentative recovery of 1997 was interrupted by an abrupt, 9%, decline in 1998. The sharp real rouble depreciation unlocked economic growth, and in 1999 and 2000 output rose by 12% and 8% respectively. The booming world oil prices along with sound fiscal and monetary policies and some progress in structural reforms are believed to be major factors behind sustained economic growth of 2001-2006. However, there have so far been no studies estimating the contribution of each of the above factors to Russia's economic growth. Overall, the Russian economy has expanded almost 80% since the end of 1998.

## **6.2. Baseline Simulations of ERER**

The baseline values of the ERERs consistent with models A and B are computed as the solutions of equations (2.4.2a) and (2.4.2b). All exogenous variables in equations (2.4.2a)-(2.4.2b) are set to equal their actual seasonally adjusted values. Figure 6.2.1 shows the paths of the ERER computed for model A ( $ERER_A$ ) and model B ( $ERER_B$ ) along with the actual RER defined as the ratio of import prices to the GDP deflator. Figure 6.2.3 displays the actual RER and ERERs simulated according to models A and B determined as the ratio of import prices to the deflator for GDP minus exports.

The first observation is that except for the August 1998 crisis and a few quarters following the crisis, both model A and model B predict rather close paths of the ERES according to both alternative measures of the real exchange rate. Second, the dynamics of the simulated ERES very closely resemble those of the country's terms of trade (see Figure 6.1.2). Indeed, volatile world oil prices and hence Russia's terms of trade, underwent substantial changes over the sample period. Moreover, the estimated trade elasticities along with the fitted (or actual) values of trade volumes imply fairly high terms of trade elasticities of the ERES in both models. Those elasticities are not constant but vary over the sample. In particular, formulas (2.4.4a) and (2.4.4b), evaluated at maximum and minimum values of the fitted trade volumes using the estimated trade elasticities for  $RERM_Y$ , yield the following results:

$$\frac{\partial q_t^A}{\partial \lambda_t} \frac{\lambda_t}{q_t^A} \in [-2.84, -1.45] \quad (6.2.2a)$$

$$\frac{\partial q_t^B}{\partial \lambda_t} \frac{\lambda_t}{q_t^B} \in [-1.43, -0.73] \quad (6.2.2b)$$

According to both models, in the first two years of the sample, 1995-1996, the ERES remains stable, but in Q1 1997 through Q2 1998, the deterioration of the country's terms of trade accompanied by the expansion in external debt, causes some ERES depreciation in both models. However, while according to model A, in Q3 1998, i.e. the period including the August 1998 crisis,  $ERES_A$  depreciates sharply (down 23% for  $RER=RERM_Y$  and down 40% for  $RER=RERM_{YX}$ ), model B already predicts some recovery of  $ERES_B$  in that period. There are two reasons behind such difference in the solutions of the two models for the crisis period. First, in the estimated export supply equation, the decline in output (real GDP) causes export volumes to decrease in Q3:1998 (down 8%), while according to official statistics, the actual raw and seasonally adjusted real exports even increased a bit in that quarter. Second, the two models differ as regards the prediction of the effect of changes in real output on the ERES. As shown in Section 2.4, in general case, the effect of real output on the equilibrium RER in model A is ambiguous and depends on the particular values of the income (output) elasticities of export supply and import demand functions as well as on the initial trade balance (see (2.4.5a)). However, since the estimated output elasticity of exports has proved to be higher than the estimated income elasticity of imports, i.e.  $\eta_X > \eta_M$  (see Table 5.1.1-5.3), in model A, a decline in real GDP unambiguously weakens the current account and, accordingly, causes real rouble depreciation, all other things being equal. In particular, formula (2.4.5a) of the output elasticity of the ERES in model A, evaluated at sample values using the estimated trade elasticities, produces the following:

$$\frac{\partial q_t^A}{\partial Y_t} \frac{Y_t}{q_t^A} \in [-2.1, -0.5] \quad (6.2.3a)$$

On the contrary, in model B, the income or output elasticity of the ERER is always positive and with the estimated trade elasticities equals the following:

$$\frac{\partial q_t^B}{\partial Y_t} \frac{Y_t}{q_t^B} = 1.68 \quad (6.2.3a)$$

Since the year 1998 saw a decline in output, while the actual export volumes remained stable, model B forecasts a less depreciated ERER than model A does for the crisis and the period immediately following the crisis. However, as mentioned in Section 2, the predictions of Model A on the impact of output on the real exchange rate should be regarded as more realistic and hence the ERER is more likely to depreciate considerably in the wake of the August 1998 crisis, in line with the simulations of model A.

From Q1 1999 on, with the recovery of oil prices, the ERER starts appreciating sharply, according to both models, and the gap between  $ERER_A$  and  $ERER_B$  narrows by mid-2000. In the Q3 2000 – Q1 2002 period, the cumulative depreciation of both  $ERER_A$  (-20% - for  $RER=RERM_Y$ ) and  $ERER_B$  (-15% – for  $RER=RERM_Y$ ) corresponds to the decline in world oil prices and commensurate deterioration in Russia's terms of trade (-17%). In the same manner, the upward trend of the ERER in the last five years of the sample is almost entirely associated with the surge in oil prices as confirmed by the results of Section 6.3. At the same time, for the last two years of the sample, model A predicts a bit larger appreciation of the ERER than model B does.<sup>15</sup> At the end of 2006 slight depreciation of the ERER reflects some decline in the world oil prices and accordingly in Russia's terms of trade.

Not surprisingly, the ERER constructed using the deflator for GDP minus exports fluctuates more widely than the ERER determined using the GDP deflator (see Section 3.1). This fact is confirmed by Figures 6.2.2 and 6.2.4, which present the ERER indicator of real rouble misalignment for  $RERM_Y$  and  $RERM_{YX}$  respectively derived from both model A and model B. If the ERER values are higher than the actual real

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<sup>15</sup> In the Q1 2002 –Q4 2006 period  $ERER_A$  increases by 111% and  $ERER_B$  – by 92% for the RER defined as the ratio of import prices to the GDP deflator and  $ERER_A$  increases by 181% and the  $ERER_B$  by 144% for the RER defined as the ratio of import prices to the deflator for GDP minus exports.

exchange rates and the indicator of misalignment is positive, the rouble can be viewed as undervalued. On the other hand, the negative values of the indicator signal that the currency may be overvalued.

According to both models and both measures of the RER, the actual real exchange rate appears to be undervalued in the first two years of the sample (1995-1996), while the signs of real overvaluation are observed from mid-1997 to Q3:1998 in model A and to Q2:1998 in model B. This evidence coincides with the findings of other studies (see Halpern and Wyplosz, 1997, 1998), Egert (2005)), which showed that the rouble was probably overvalued before the financial crisis of August 1998. Both models predict the largest degree of overvaluation just before the crisis, in Q2:1998 (-25% for  $RERM_Y$  and -40% for  $RERM_{YX}$ ). A variety of studies (Calvo and Végh, 1998; Kaminsky and Leiderman, 1998) documented that in many countries, the exchange-rate-based inflation stabilization policy, such as that pursued by the CBR from July 1995 to August 1998, ended up in a massive cumulative real exchange rate appreciation and a balance-of-payments crisis. The Russian pre-crisis experience is consistent with a general tendency for the real exchange rate to be overvalued during the year preceding financial crises, as stressed in Dornbusch et al. (1995). Kaminsky and Reinhart (1999) reported that in their sample of crisis episodes the real exchange rate showed an overvaluation of about 20% relative to a tranquil time in periods preceding the currency crash.

In the numerous studies of the 1990s on the predictability of crises, the real exchange rate is cited among the main fundamentals whose weakness increases the probability of the crisis, and the currency overvaluation is mentioned as one of the best indicators for financial turmoil (see Frankel and Rose, 1996, Sachs, Tornell and Velasco, 1996; Kaminsky, Lizondo and Reinhart, 1998; Berg and Pattillo, 1999; Kaminsky and Reinhart, 1999). More recently, Asici, Ivanova and Wyplosz (2005) found that countries are more likely to abandon, both voluntarily and involuntarily, the fixed exchange rate regimes if the exchange rate is overvalued. Unfortunately, except for Halpern and Wyplosz (1997, 1998), providing estimates of the ERERs in transition economies and indicating a minor overvaluation of the rouble, there was no systematic study of the equilibrium real exchange rate in Russia in the pre-crisis period, although, on the other hand, such a short history of a market economy in Russia probably made it extremely difficult to draw accurate conclusions on the rouble's equilibrium at that time.

While the Russian financial distress of August 1998 clearly falls within the so-called first generations of crises with tight monetary and loose fiscal policy (described by Krugman, 1979), aggravated by the problems of poor debt management, weak governance, both public and private, and contagion from the

Asian crisis, the adverse terms of trade shock probably precipitated a crunch.<sup>16</sup> However, already at the end of 1998, even before the oil price recovery, the massive nominal rouble depreciation (more than 2.5 times from the pre-crisis level) appears to have provided grounds for currency undervaluation, as the pace of actual RER appreciation fell behind that of the ERER. Such a reverse in the Russian RER and its signs of misalignment after the crisis can be seen as quite typical from the international perspective, as, for instance, Goldfajn and Valdes (1999) found that in their sample, 86% of large real appreciations gave place to devaluations. In addition, Asici, Ivanova and Wyplosz (2005) applying a sample selection model to the set of developed and developing countries, demonstrated that for countries exiting from fixed exchange rate regimes, the pre-exit large degree of overvaluation is associated with large nominal depreciations in post-exit periods.

It is interesting that for the sample under investigation (Q1:1995-Q4:2006) and according to the assumption of the equilibrium primary current account, the peak of real rouble undervaluation (65% for  $RERM_Y$  and 110% for  $RERM_{YX}$ ) is observed during the year 2000, which, on the one hand, saw the country's terms of trade significantly improve, while, on the other hand, the nominal rouble exchange rate probably overshot its long-run level in the period after the crisis of August 1998. In addition, the government policy of containing the state-regulated prices of natural monopolies (electricity and railroad tariffs) may have contributed to the high real rouble undervaluation in 2000.

From mid-2001, the degree of the real rouble misalignment starts to decrease, and by the end of 2003 the undervaluation reaches about 30% for  $RERM_Y$  and 50% for  $RERM_{YX}$ , but beginning 2004 the gap between the actual and equilibrium RER increases again, and by Q1 2006 it equals 52% for  $RERM_Y$  and 97% for  $RERM_{YX}$ . At the end of 2006, due to some decline in world oil prices, the degree of real rouble misalignment slightly decreased: in Q4:2006 it equals 36% for  $RERM_Y$  and 69% for  $RERM_{YX}$ . The main factor for real rouble undervaluation in the last five years of the sample is the combination of the external oil price shocks and the policy of the Bank of Russia, choosing between the RER and inflation.<sup>17</sup>

Supporting the stability of the rouble and seeking to prevent it from substantial real appreciation, the CBR has to purchase foreign currency to build up international reserves at a rising scale: its gross international reserves rose by \$ 47.6 bn in 2004, by \$57.7 bn in 2005 and by \$121.5 bn in 2006.<sup>18</sup> However, as stressed

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<sup>16</sup> See e.g. Kirsanova and Vines (2002).

<sup>17</sup> The analysis of monetary policy rules applied by the CBR, especially in recent years, can be found in studies of Esanov et al (2004), Vdovichenko and Voronina (2004).

<sup>18</sup> Operating from 2004, the Stabilization Fund of the Russian Ministry of Finance is the second instrument that enables the monetary and fiscal authorities to sterilize the inflow of excess export revenues. If prices of Russia's Urals oil blend rise above the so-called base price (\$20 per barrel in 2004-2005 and \$27 per barrel in 2006), extra

in Calvo, Reinhart and Végh (1995), a more depreciated level of the RER can be attained only temporarily as a result of government efforts to avoid the loss of competitiveness.

Moreover, the predictions of their model to Russia imply that this can only be achieved by allowing higher inflation. This conclusion is supported by the experience of other countries, which adopted a policy of real exchange rate targeting in various years. These findings may be important for the Bank of Russia to address the inflation versus exchange rate dilemma.

### **6.3. Sensitivity Analysis**

This subsection presents the decomposition of the trade-balance approach fundamentals driving the ERES in Russia. After examining the behavior of the ERES simulated with the exogenous variables equaling their actual seasonal adjusted values, it is worthwhile to look at what happens to the equilibrium real exchange rate under the alternative assumptions of the fundamentals. Since, as showed in the previous subsection, the predictions of Model B regarding the impact of real GDP on the equilibrium real exchange rate are less realistic than those of model A, the simulations of the ERES discussed below are obtained only as solutions of model A.

#### *Terms of trade*

As world oil prices, and hence Russia's terms of trade, are very volatile, it is reasonable to perform the ERES simulation with the terms of trade fixed at their medium-run level. Given the uncertainty about this variable, the country's long-run terms of trade are assumed to equal their sample average of 1.15, which in turn corresponds to a sample average world oil price of \$29 per barrel. Figure 6.3.1 depicts the path of the ERES defined as the ratio of import prices to the GDP deflator calculated with the medium-run terms of trade, while all other exogenous variables equal their actual seasonally adjusted values. For comparison, Figure 6.3.1 also shows the baseline ERES and the actual RER. The same kind of simulations for the RER determined as the ratio of import prices to the deflator for GDP minus exports are presented in Figure 6.3.3. The ERES simulated with the terms of trade fixed at their sample average exhibits a fairly low variability compared with the baseline ERES simulated with all exogenous variables equaling their actual seasonally adjusted values. That confirms the observation that most changes in Russia's ERES are caused by variations in the country's terms of trade.

The ERES simulated with the medium-run terms of trade corresponding to an oil price of \$29 per barrel appears to be more appreciated than the actual RER for almost the entire sample period (see also Figures

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revenues from exports of oil and oil products and the extraction tax go to the Stabilization Fund. At the end of 2006, the Fund stood at \$ 89.13 bn.



6.3.2 and 6.3.4 showing the degree of real misalignment), and, in particular, for the period preceding the 1998 crisis. In other words, the rouble could have been viewed as fairly valued before the August 1998 crisis only if oil prices had not dropped below \$23-24 per barrel, while in reality oil prices slumped to \$11-14 per barrel in 1998. On the other hand, similar to the baseline scenario, at the medium-run oil price, the rouble appears to be heavily undervalued in real terms right after the crisis and remained significantly undervalued in 2000-2001 despite the recovery of commodity prices in that period.

At the same time, contrary to the baseline simulations, for the medium-run oil price of \$29 per barrel, the degree of real misalignment gradually declines beginning end-1999. For the RER defined as the ratio of import prices to the GDP deflator, at a medium-run oil price of \$29 per barrel, the implied degree of real misalignment in 2002 (39-44%) is quite close to the results obtained by Spatofoa and Stavrev (2003), who reported an undervaluation of about 33-40% at a long-run oil price of \$23 per barrel for the same period. Given the medium-run oil price of \$29 per barrel, the rouble can be viewed as fairly valued in 2005 and even overvalued in 2006.

#### *Domestic growth*

The simplest method of obtaining the long-run path of real GDP is to construct its Hodrick-Prescott (HP) trend. As can be seen from Figure 6.1.5, actual output appears to be rather close to its HP trend for the entire sample period except for the first year of the sample and the year after the 1998 crisis. Therefore the assumptions of the higher and lower output growth in the post-crisis period are regarded as the two alternative scenarios of real GDP dynamics. According to both alternative scenarios, real GDP is assumed to follow its HP trend till end-1998. Beginning Q1 1999, real GDP is assumed to increase by 2% quarterly (8.2% annually) under the higher growth scenario and only by 0.5% quarterly (2% annually) under the lower growth scenario (see Figure 6.1.5). The average quarterly growth of actual seasonally adjusted output amounts to 1.8% in the period from Q1:1999 through Q4:2006.

Figure 6.3.5 shows the paths of the EREs simulated according to the faster and slower growth scenarios as well as the baseline ERE and actual RER defined as the ratio of import prices to the GDP deflator. The degree of real rouble misalignment computed on the basis of the baseline and alternative assumptions is presented in Figure 6.3.6. As expected, the baseline ERE and EREs simulated with the alternative assumptions about output growth are almost identical for the pre-crisis period. But, since in Q3 1998 actual seasonally adjusted output declined by almost 6%, while the HP trend of real GDP increased by 0.6%, the rouble, according to the simulations using the HP trend of real GDP, turns out to be 10% less overvalued than in the baseline simulations. In the post-crisis period, the difference between the baseline

ERER and ERERs simulated using the alternative assumptions about the output growth, gradually increases over time, peaking at the end of the sample period. By Q4:2006, the rouble appears to be undervalued by 47% under the faster growth scenario, by 4% under the slower growth scenario, and by 36% according to the baseline simulations.<sup>19</sup>

#### *Real interest rate*

As discussed in Section 6.1 and shown in Figure 6.1.4, there are two periods of a remarkable increase in the real effective interest rate paid on Russia's total external debt during the sample period. The first period is observed before the August 1998 crisis, while the second one, in 2003-2006, when the real interest rate rose to a stunning 20% per annum, is more surprising and may be associated with the rapid growth in the private sector's external debt seen from end-2002. If the last four years are excluded from the sample, the average real effective interest rate paid on the country's external debt amounts to 7.4% per annum. If the increase in the real interest rate in 2003-2006 is viewed as temporary, it is reasonable to simulate the ERER with the real effective interest rate set to equal this average value.

Figure 6.3.7 shows the results of simulations for the RER defined as the ratio of import prices to the GDP deflator. The respective real misalignment is presented in Figure 6.3.8. For the RER defined as the ratio of import prices to the GDP deflator, compared with the baseline simulation, the rouble appears to be less overvalued, by about 5-8% in Q1 1998-Q3 1998, and more undervalued, by 2-12% in 2003-2006. For the RER defined as the ratio of import prices to the deflator for GDP minus exports these differences are larger and amount to 8-13% and 3-20% respectively. In general, the long-run RER appears to be moderately responsive to changes in the real interest rate on the country's external debt.

#### *"Desired reserve accumulation" scenario*

Instead of considering a different scenario for Russia's external debt, I assume that the country's primary current account is used not only to service its debt but also to accumulate foreign reserves.

In particular, the Bank of Russia is assumed to build up its gross international reserves (GIR) in such a way that each quarter they cover the country's short-term external debt (STED) plus 50% of the country's broad money, M2.

A similar measure of reserve adequacy for emerging market economies was proposed by Wijnholds and Kapteyn (2001), who, in turn, combine the two indicators of the short-term vulnerability considered in the

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<sup>19</sup> For the RER determined as the ratio of import prices to the deflator of GDP minus exports, the degrees of rouble misalignment by the end of sample period (Q4:2006) equal 83% under the faster growth scenario and 28% under the slower growth scenario (69% in the baseline simulations).

literature on Early Warning Systems and crises predictability (see e.g. Kaminsky, Lizondo and Reinhart, 1997; Calvo, 1998): the ratio of reserves to short-term external debt and the ratio of reserves to broad money supply. Stressing that for emerging economies the full coverage of short-term external debt would be a prudent measure against the possible external drain<sup>20</sup>, Wijnholds and Kapteyn (2001) also took into account the potential of capital outflow stemming from residents (internal drain). Wijnholds and Kapteyn (2001) admitted that it is difficult to ascertain how much of a country's broad money could be mobilized against reserves to finance capital flight. De Gregoria et al. (1999) argued that "if residents are inclined to flee in response to developing financial difficulties, the whole money supply (M1 or even wider aggregates) has to be covered by foreign reserves to prevent the collapse of the exchange rate regime and financial system". Wijnholds and Kapteyn (2001) viewed this as too extreme and instead assumed that for countries with a managed float or fixed regime the fraction of domestic money to be covered by reserves could be between 10% and 20%. The fractions suggested by Wijnholds and Kapteyn (2001) are somewhat arbitrary and may be too low, as, for instance, in Russia, the ratio of GIR to M2 amounted to 27% (see Figure 6.3.10) in the run-up to the 1998 crisis. Therefore, instead of 20%, I use the fraction of 50%, which is certainly arbitrary too. In addition, there are other two caveats regarding the approach. First, the monetary aggregate (M2) measured in terms of the domestic currency (roubles) is converted into dollars using the actual nominal exchange rate, while the ERES probably implies some equilibrium nominal exchange rate that differs from the actual one. Second, in reality, especially in periods of high oil prices, the causality may run in the opposite way: in order to prevent substantial rouble appreciation, the Bank of Russia builds up its reserves, accordingly, increasing the monetary base.

Nevertheless, this approach allows some rationale for the rule of reserve accumulation. The dynamics of the "desired" reserves, which would be accumulated according to the suggested rule, are presented in Figure 6.3.11 along with those of actual GIR. The level of the "desired" reserves is assumed to be unchanged in quarters when both STED and M2 declined, and to equal the actual GIR for the period before Q3:1994. As can be seen from Figure 6.3.11, the "desired" reserves exceed the actual GIR, before Q1:2005, when they both reached about \$137 bn, while in the last two years of the sample the actual GIR surpasses the "desired" level: as of end-2006 the "desired" reserves equal \$248 bn versus \$303.7 bn of the actual GIR.

The ERES simulated under that "desired reserve accumulation" scenario along with the baseline ERES and actual RER defined as the ratio of import prices to the GDP deflator are shown in Figure 6.3.12. The

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<sup>20</sup> In Russia, the share of short-term external debt covered by GIR decreased from more than 100% at the end of 1997 to 60% in Q2:1998. In the post-crisis period, the full coverage of STED was restored by the end of 2000, with reserves covering more than 500% of STED at the end of 2006 (see Figure 6.3.9).

degree of real misalignment is presented in Figure 6.3.13. As expected, the ERER in the “desired reserve accumulation” scenario is more depreciated than the ERER in the baseline simulations for the entire sample period. In particular, under the “desired reserve accumulation” scenario, the rouble appears to be overvalued not only in the last year before the 1998 crisis but already from end-1995.<sup>21</sup> Moreover, according to the “desired reserve accumulation” scenario, the rouble can be roughly viewed as fairly valued from Q2:2003 to Q1:2004. Nevertheless, at the end of the sample period, which saw high oil prices, the rouble appears to be undervalued even under the assumption of reserves accumulation. In 2004-2006, the average degree of misalignment is about 17% for the RER defined as the ratio of import prices to the GDP deflator and 37% for the RER determined as the ratio of import prices to the deflator of GDP minus exports. This observation may prove that the considerable capital flight from Russia, which is ignored as too volatile by the baseline and “desired reserve accumulation” scenarios, may have helped to prevent the actual rouble from a more substantial real appreciation in recent years. In 2000-2003, capital flight ranged from \$1.9 in 2003 to \$24.8 bn in 2000, amounting to \$8.4 bn in 2004. On the other hand, the significant capital inflow in 2006 (\$41.7 bn) may have contributed to the actual RER appreciation.

## **7. Conclusion**

This paper presents the estimations of the equilibrium real exchange rate (ERER) in Russia obtained for the period from Q1:1995 to Q4:2006 using the partial-equilibrium version of the trade-balance approach. The paper applies the three-good framework suggested by the literature for a commodity-exporting developing country. This framework allows a distinction between the two types of the internal real exchange rate – the RER for imports defined as the price ratio of imports to nontradables and the RER for exports defined as the price ratio of exports to nontradables. Russia’s export demand is regarded as infinitely price elastic, while export supply is assumed to be finitely price elastic. Such an approach implies the estimation of export supply as a function of the RER for exports and the total capacity of the economy. Russian imports are traditionally assumed to be demand determined and dependent on the RER for imports and domestic income. This methodology allows the effect of changes in the terms of trade to be incorporated into the trade-balance approach to the ERER’s computations.

Data from Russia’s Quarterly National Accounts provide information employed for the construction of import and export price indices as well as a price index of nontradables that is alternatively approximated by the two implicit price deflators: the GDP deflator and deflator for GDP minus exports. The estimation

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<sup>21</sup> The largest degree of overvaluation falls on Q3:1998 (down 37% for the RER defined as the ratio of import prices to the GDP deflator and down 64% for the RER determined as the ratio of import prices to the deflator for GDP minus exports).

of the trade-volume equations is based on the search of cointegrating relationships, since all variables under investigation prove to be nonstationary, with some ambiguity for the RER for exports.

The values of the estimated import elasticities appear to be generally in line with estimates obtained in other empirical studies for both developed and developing countries. The long-run elasticities of imports with respect to the real exchange rate are estimated at between  $-0.7$  and  $-0.5$ , depending on the measure of the RER for imports used. The results of estimations for the export supply equation confirm the conjecture of “supply elasticity pessimism”, as the long-run price elasticity of export supply appears to be very low:  $0.07-0.12$ , depending on the used measure of the RER for exports. The specification of the export supply equation including the time trend as a proxy for a possible increase in productivity differentials between the exportable and nontradable goods sector, appears to be rejected by the estimation results. Since certain efforts have to be made to choose the appropriate variables approximating sectoral productivity in the country, the examination of the Balassa-Samuelson effect as a possible explanation for the real appreciation in Russia, in particular, using the trade-balance approach, can be the subject of further research.

Regarding the definition of internal balance, the paper mostly follows other studies, assuming that actual output adjusted for the cyclical fluctuations represents the equilibrium outcome. The definition of external balance in the paper is based on the intertemporal approach to the current account, and, in particular, views the primary current accounts equaling the external debt service as a special case satisfying a country’s intertemporal budget constraint. Russia’s actual external debt together with the actual real effective interest rate paid on the country’s debt adjusted for seasonal fluctuations are used to determine the equilibrium primary current account.

The in-sample simulations of the equilibrium real exchange rate for Q1:1995-Q4:2006 are performed using the estimated trade elasticities and the assumption of the equilibrium primary current account. The results of the ERER’s calculations show the importance of choosing the measure of the country’s real exchange rate. In the baseline simulations, using the actual historical values of the exogenous variables, the rouble proves to be significantly undervalued at the beginning of the sample (about 50-70%, depending on the measure of the ERER used), but the degree of undervaluation rapidly declines and some signs of overvaluation were already observed in mid-1997. The largest degree of overvaluation is seen in the run-up to the August 1998 crisis (about 25% or 40%, depending on the measure of the RER used), which is followed by undervaluation of the same size in 1999. The peak of undervaluation (about 65% or 110%, depending on the measure of the RER used) is reached in 2000, when the country’s terms of trade

significantly improved, the nominal rouble overshot its long-run level in the post-crisis period and the government regulated natural monopolies' prices.

In recent years, the country has turned out to fall victim to the Dutch Disease, while the Bank of Russia seeks to prevent the rouble from nominal and real appreciation by building up reserves at an increasing scale. In 2006, the average degree of the rouble real undervaluation equals 45% or 85%, depending on the measure of the RER used. There is little evidence in the literature that a very significant undervaluation can stimulate economic growth. Moreover, there is a consensus that undervaluation fuels future inflation when government policy of targeting the real exchange rate allows a more depreciated level of the exchange rate to be attained only temporarily.

The Russia's ERER appears to be very responsive to changes in the country's terms of trade. The terms of trade elasticities of the ERER are estimated in the range from  $-2.8$  to  $-0.7$ . The sensitivity analysis performed with the alternative assumptions of the ERER's fundamentals reveals that the rouble could have been viewed as fairly valued before the August 1998 crisis only if the oil price had not decreased below \$23-24 per barrel. In addition, assuming that the medium-run oil price equals the sample average of \$29 per barrel, the rouble can be viewed as fairly valued in 2005 and even overvalued in 2006. Under the "desired reserve accumulation" scenario, the rouble appears to be still undervalued (17% or 37%, depending on the measure of the RER used) in the last three years of the sample period. This finding may highlight the importance of capital flight from Russia in shaping the country's actual real exchange rate.

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**Table 2.1. Structure of Russia's exports and imports (\$ bn, %)**

Tariff code	Total	1995		1997		1999		2001		2004											
		Exports		Imports		Exports		Imports		Exports		Imports									
		\$ bn	% of total	\$ bn	% of total	\$ bn	% of total	\$ bn	% of total	\$ bn	% of total	\$ bn	% of total								
	<b>Total</b>	<b>78.2</b>	<b>100</b>	<b>46.7</b>	<b>100</b>	<b>85.1</b>	<b>100</b>	<b>53.1</b>	<b>100</b>	<b>72.9</b>	<b>100</b>	<b>30.3</b>	<b>100</b>	<b>100.0</b>	<b>100</b>	<b>41.9</b>	<b>100</b>	<b>181.6</b>	<b>100</b>	<b>57.8</b>	<b>100</b>
1-24	Food products and agricultural raw materials, less textile	1.4	3.3	13.1	28.2	1.6	1.9	13.3	25.1	1.0	1.3	8.1	26.7	1.9	1.9	9.2	22	3.3	1.8	10.4	17.9
25-27	<b>Mineral products and electricity</b>	<b>33.3</b>	<b>42.0</b>	<b>3.0</b>	<b>6.4</b>	<b>41.1</b>	<b>48.4</b>	<b>3.1</b>	<b>5.8</b>	<b>32.7</b>	<b>44.9</b>	<b>1.2</b>	<b>4.0</b>	<b>54.7</b>	<b>54.7</b>	<b>1.7</b>	<b>4.1</b>	<b>104.9</b>	<b>57.8</b>	<b>0.6</b>	<b>1</b>
27	of which: Crude oil	13.3	17.0			14.3	16.9			14.2	19.4			24.6	24.6			58.3	32.1		
27	Petroleum products	5.0	6.4			7.2	8.5			5.4	7.5			9.4	9.4			19.3	10.6		
27	Natural gas	12.1	15.5			16.4	19.3			11.4	15.6			19.2	19.2			21.9	12.0		
28-40	Chemical products, rubber	7.8	9.9	5.1	10.9	7.1	8.3	7.6	14.4	6.2	8.5	4.9	16.0	7.5	7.5	7.6	18.2	12.0	6.6	10.2	17.6
41-43	Raw hide, peltry-wear, and articles thereof	0.3	0.4	0.1	0.4	0.4	0.5	0.2	0.3	0.2	0.3	0.1	0.3	0.2	0.2	0.2	0.5	0.4	0.2	0.2	0.4
44-49	Timber, wood pulp, paper products	4.4	5.6	1.1	2.4	3.6	4.2	1.9	3.6	3.7	5.1	1.1	3.6	4.4	4.4	1.7	4	7.0	3.9	2.3	4
50-67	Textiles and textile articles, footwear	1.1	1.5	2.7	5.5	0.9	1.1	2.4	4.5	0.8	1.1	1.6	5.2	0.8	0.8	2.3	5.5	1.0	0.6	2.1	3.7
71-83	<b>Metals, precious stones and articles thereof</b>	<b>20.9</b>	<b>26.1</b>	<b>4.0</b>	<b>8.4</b>	<b>20.4</b>	<b>24.0</b>	<b>3.8</b>	<b>7.1</b>	<b>19.0</b>	<b>26.1</b>	<b>2.2</b>	<b>7.3</b>	<b>18.8</b>	<b>18.8</b>	<b>3.1</b>	<b>7.4</b>	<b>36.8</b>	<b>20.2</b>	<b>3.2</b>	<b>5.5</b>
84-90	<b>Machinery and transport equipment</b>	<b>8.0</b>	<b>9.9</b>	<b>15.7</b>	<b>33.7</b>	<b>9.2</b>	<b>10.7</b>	<b>18.7</b>	<b>35.3</b>	<b>8.0</b>	<b>10.9</b>	<b>10.0</b>	<b>33.3</b>	<b>10.5</b>	<b>10.5</b>	<b>14.2</b>	<b>34</b>	<b>14.2</b>	<b>7.8</b>	<b>26.4</b>	<b>45.7</b>
	of which: armaments	2.4	3.1			2.2	2.6			n.a				n.a				n.a			
68-70, 91-97	Other products	1.0	1.3	1.9	4.1	0.8	0.9	2.1	3.9	1.3	1.8	1.1	3.6	1.2	1.2	1.8	4.3	2.1	1.1	2.5	4.2
93	of which: arms and ammunitions	0.6	0.8			0.4	0.5			n.a				n.a				n.a			

Source: Customs statistics, VNIKI (All-Russia Market Research Institute).

**Table 4.1. Tests for non-seasonal and seasonal integration (HEGY), Q1:1995-Q1:2005**

Time series	Auxiliary regression		$t_1$	$t_2$	$t_3$	$t_4$	$F_{34}$	$F_{234}$	$F_{1234}$
	D <sup>a</sup>	k	$\pi_1$	$\pi_2$	$\pi_3$	$\pi_4$	$\pi_3 \cap \pi_4$		
$m_t$	-	1,2	0.90	-1.20	-1.45	-1.71	2.80	<b>2.41</b>	2.03
	I	1,2	-0.41	-1.18	-1.44	-1.70	2.76	<b>2.36</b>	1.79
	I, SD	1	-0.63	-2.58	-1.29	-3.65 <sup>b</sup>	7.59 <sup>b</sup>	7.81 <sup>b</sup>	6.32 <sup>b</sup>
	I, TR	1	-2.31	-1.28	-1.51	-1.60	2.48	<b>2.16</b>	3.36
	I, SD, TR	1	-1.64	-2.34	-1.56	-3.05 <sup>b</sup>	6.16	6.10 <sup>b</sup>	6.80 <sup>b</sup>
$x_t$	-	1	2.61	-1.43	-1.08	-0.91	0.99	<b>1.35</b>	2.84 <sup>b</sup>
	I	1	1.51	-1.30	-1.12	-0.81	0.96	<b>1.21</b>	1.62
	I, SD	-	2.97	-1.77	-1.48	-1.38	2.22	<b>2.83</b>	6.12 <sup>b</sup>
	I, TR	1,3	-2.66	-0.98	-1.27	-1.20	1.53	<b>1.43</b>	2.88
	I, SD, TR	-	-1.39	-1.84	-1.59	-1.20	2.14	<b>2.87</b>	2.63
$y_t$	-	1,2	1.61	-1.34	-0.10	-0.29	0.05	<b>0.64</b>	1.15
	I	1,2	0.10	-1.31	-0.10	-0.28	0.04	<b>0.62</b>	0.47
	I, SD	-	0.17	-2.68	-1.94	-4.45 <sup>b</sup>	16.03 <sup>b</sup>	48.48 <sup>b</sup>	45.36 <sup>b</sup>
	I, TR	1,4	-2.23	-0.94	0.02	-0.16	0.01	<b>0.30</b>	1.59
	I, SD, TR	-	-2.19	-2.38	-2.37	-3.94 <sup>b</sup>	15.23 <sup>b</sup>	36.19 <sup>b</sup>	33.01 <sup>b</sup>
$pmpy_t$	-	1,2	-0.84	-1.54	-0.21	-3.46 <sup>b</sup>	6.15 <sup>b</sup>	4.88 <sup>b</sup>	3.82 <sup>b</sup>
	I	1,2	-0.99	-1.50	-0.28	-3.44 <sup>b</sup>	6.03 <sup>b</sup>	4.76 <sup>b</sup>	3.81 <sup>b</sup>
	I, SD	1	-1.68	-1.94	-0.62	-4.09 <sup>b</sup>	8.64 <sup>b</sup>	8.03 <sup>b</sup>	8.51 <sup>b</sup>
	I, TR	1,2	-1.36	-1.53	-0.25	-3.24 <sup>b</sup>	5.34 <sup>b</sup>	4.33 <sup>b</sup>	3.80
	I, SD, TR	1	-2.02	-1.81	-0.79	-3.66 <sup>b</sup>	7.21 <sup>b</sup>	6.57 <sup>b</sup>	8.22 <sup>b</sup>
$pmpyx_t$	-	1	-1.93	-1.47	-0.91	-4.04 <sup>b</sup>	8.67 <sup>b</sup>	6.80 <sup>b</sup>	7.52 <sup>b</sup>
	I	1	-1.98	-1.45	-0.91	-4.00 <sup>b</sup>	8.54 <sup>b</sup>	6.69 <sup>b</sup>	7.45 <sup>b</sup>
	I, SD	1	-1.70	-1.81	-0.84	-3.57 <sup>b</sup>	6.78 <sup>b</sup>	6.30 <sup>b</sup>	7.13 <sup>b</sup>
	I, TR	1	-2.18	-1.34	-1.09	-3.60 <sup>b</sup>	7.31 <sup>b</sup>	5.64 <sup>b</sup>	7.03 <sup>b</sup>
	I, SD, TR	1	-1.89	-1.71	-0.98	-3.23 <sup>b</sup>	5.84	<b>5.38</b>	6.74 <sup>b</sup>
$pXPY_t$	-	4	-2.49 <sup>b</sup>	-1.50	-1.43	-2.58 <sup>b</sup>	4.32 <sup>b</sup>	3.74 <sup>b</sup>	6.18 <sup>b</sup>
	I	4	-2.46	-1.48	-1.41	-2.55	4.22	3.65 <sup>b</sup>	5.93 <sup>b</sup>
	I, SD	4	-2.22	-2.20	-1.56	-2.44 <sup>b</sup>	4.18	<b>4.68</b>	6.84 <sup>b</sup>
	I, TR	4	-2.29	-1.44	-1.41	-2.48 <sup>b</sup>	4.06 <sup>b</sup>	3.50 <sup>b</sup>	5.30 <sup>b</sup>
	I, SD, TR	4	-2.07	-2.15	-1.54	-2.37 <sup>b</sup>	4.00	<b>4.49</b>	6.19
$pXPYX_t$	-	4	-2.39 <sup>b</sup>	-1.43	-1.24	-2.66 <sup>b</sup>	4.28 <sup>b</sup>	3.69 <sup>b</sup>	5.95 <sup>b</sup>
	I	4	-2.35	-1.41	-1.22	-2.62 <sup>b</sup>	4.15 <sup>b</sup>	3.58 <sup>b</sup>	5.70 <sup>b</sup>
	I, SD	4	-2.15	-2.02	-1.33	-2.46 <sup>b</sup>	3.87	<b>4.24</b>	6.25 <sup>b</sup>
	I, TR	4	-2.20	-1.37	-1.23	-2.55 <sup>b</sup>	3.98 <sup>b</sup>	3.98 <sup>b</sup>	5.13 <sup>b</sup>
	I, SD, TR	4	-2.01	-1.98	-1.32	-2.38 <sup>b</sup>	3.70	<b>4.06</b>	5.67

<sup>a</sup> Deterministic part: I=intercept, SD=seasonal dummies, TR=trend.  $\pi_1$  (zero frequency),  $\pi_2$  (biannual frequency),  $\pi_3$  (annual frequency),  $\pi_4$  (annual frequency).

<sup>b</sup> A unit root can be rejected at the 5% significance level. Critical values are from Hylleberg et al. (1990) and Ghysels et al. (1994) for T=48.

**Table 4.2. ADF test for unit root, seasonally adjusted data, Q1:1995-Q1:2005**

Time series	Deterministic part <sup>a</sup>	Augmentation: k	ADF t-statistic	H0: deterministic part=0 F-statistic
<i>msa<sub>t</sub></i>	-	1,4	0.80	
	I	1,4	-0.55	0.47
	I, TR	1,4	-1.83	1.94
<i>xsa<sub>t</sub></i>	-			
	I	1,2	1.55	8.82***
	I, TR	2	-2.06	7.64**
<i>ysa<sub>t</sub></i>	-	1	1.52	
	I	1	0.30	1.16
	I, TR	1	-2.4	3.74
<i>pmpysa<sub>t</sub></i>	-	1,4	-1.91	
	I	1,4	-2.05	2.13
	I, TR	1,4	-2.45	2.46
<i>pmpyxa<sub>t</sub></i>	-	1,4	-1.97**	
	I	1,4	-2.01	2.05
	I, TR	1,4	-2.26	2.18
<i>pxpysa<sub>t</sub></i>	-	1,4	-2.32**	
	I	1,4	-2.29	2.63
	I, TR	1,4	-2.14	1.75
<i>pxpyxa<sub>t</sub></i>	-	1,4	-2.31**	
	I	1,4	-2.27	2.58
	I, TR	1,4	-2.14	1.76

<sup>a</sup> Deterministic part: I=intercept, TR=trend.

\*\* and \*\*\* denote significant statistics at 5% and 1%. Critical values are from Fuller (1976) and Dickey and Fuller (1979).

**Table 5.1.1. Lon-run elasticities: demand for imports, seasonally unadjusted data ( $m_t$ )**

	SOLS	SOLS	DOLS	Johansen ML	Johansen ML			
$\ln(RERM_t)=pmpy_t$	-0.745*** (0.045)	-0.756*** (0.044)	-0.732*** (0.034)	-0.460*** (0.053)	-0.579*** (0.034)			
$y_t$	1.055*** (0.082)	1.098*** (0.074)	1.27*** (0.064)	1.666*** (0.100)	1.486*** (0.065)			
Constant	-2.119** (1.048)	-2.683*** (0.956)	-4.882*** (0.822)	-9.915*** (1.288)	-7.661			
Residual-based t-statistic <sup>a</sup>	-4.32**	-4.76***						
$\lambda_{trace}$ -statistic <sup>b</sup>				50.40**	49.91***			
$\lambda_{max}$ -statistic <sup>b</sup>				38.60***	35.47***			
Adjustment coefficient ( $m_t$ )				-0.878*** (0.211)	-1.676*** (0.299)			
Order of VECM (k-1)\ DOLS (a ; b ; c) <sup>c</sup>			(-3;-1;0,+1)	2	2			
Period adjusting end points	1995.1: 2005.1	1996.1: 2005.1	1996.1: 2004.4	1995.4: 2005.1	1996.1: 2005.1			
Number of observations	41	37	36	38	37			
$cor(pmpy_t, y_t)$	-0.54			No trend	Trend in the data			
$\ln(RERM_t)=pmpyx_t$	-0.522*** (0.034)	-0.526*** (0.033)	-0.445*** (0.026)	-0.424*** (0.015)	-0.476*** (0.016)			
$y_t$	1.199*** (0.082)	1.249*** (0.075)	1.514*** (0.071)	1.497*** (0.041)	1.40*** (0.040)			
Constant	-3.953*** (1.056)	-4.606*** (0.958)	-8.013*** (0.914)	-7.780	-6.528			
Residual-based t-statistic <sup>a</sup>	-4.55**	-9.47***						
$\lambda_{trace}$ -statistic <sup>b</sup>				45.60**	57.07***			
$\lambda_{max}$ -statistic <sup>b</sup>				31.74**	43.89			
Adjustment coefficient ( $m_t$ )				-1.379* (0.796)	-1.659*** (0.430)			
Order of VECM (k-1)\ DOLS (a ; b ; c) <sup>c</sup>			(-2,-3,-4;+3;- 1,+1)	3	1, SD			
Period adjusting end points	1995.1: 2005.1	1996.1: 2005.1	1996.3: 2004.2	1996.1: 2005.1	1996.1: 2005.1			
Number of observations	41	37	33	37	37			
$cor(pmpyx_t, y_t)$	-0.46			Trend in the data	Trend in the data			
<i>Adjusted critical values<sup>b</sup>:</i>	<i>No trend, T=38, k=3</i>		<i>Trend, T=37, k=3</i>		<i>Trend, T=37, k=4</i>		<i>Trend, T=37, k=2</i>	
	$\lambda_{trace}$	$\lambda_{max}$	$\lambda_{trace}$	$\lambda_{max}$	$\lambda_{trace}$	$\lambda_{max}$	$\lambda_{trace}$	$\lambda_{max}$
90 percent	40.94	25.29	34.53	23.98	38.36	26.64	31.46	21.84
95 percent	44.66	28.14	38.27	27.04	42.50	30.03	34.85	24.62
99 percent	52.54	34.30	45.96	32.90	51.05	36.54	41.86	29.97

\*, \*\* and \*\*\* denote significant statistics at 10%, 5% and 1%. <sup>a</sup> Critical values are from Phillips and Ouliaris (1990) and Enders (2004). <sup>b</sup> Critical values are from Osterwald-Lenum (1992) adjusted using the small sample correction factor suggested by Cheung and Lai (1993).

<sup>c</sup> (a ; b ; c) – lags of changes in the dependent variable and leads and lags of changes in the right hand side variables in the DOLS, where “a” stands for  $\Delta m_t$ , “b” stands for  $\Delta RERM_t$  and “c” stands for  $\Delta y_t$ .



**Table 5.1.2. Lon-run elasticities: demand for imports, seasonally adjusted data ( $msa_t$ )**

	SOLS	SOLS	DOLS	Johansen ML	Johansen ML
$\ln(RERM_t)=pmpysa_t$	-0.685*** (0.035)	-0.707*** (0.030)	-0.740*** (0.034)	-0.658*** (0.044)	-0.698*** (0.041)
$ysa_t$	1.19*** (0.068)	1.208*** (0.057)	1.246*** (0.066)	1.33*** (0.087)	1.313*** (0.076)
Constant	-3.849*** (0.869)	-4.096*** (0.727)	-4.575*** (0.842)	-5.631*** (1.109)	-5.445
Residual-based t-statistic <sup>a</sup>	-4.27**	-4.37***			
$\lambda_{trace}$ -statistic <sup>b</sup>				40.52*	34.56*
$\lambda_{max}$ -statistic <sup>b</sup>				22.34	21.33
Adjustment coefficient ( $m_t$ )				-0.275 (0.32)	-0.987*** (0.343)
Order of VECM\ DOLS (a ; b ; c) <sup>c</sup>			(-2; -1,+1;-)	1	1
Period adjusting end points	1995.1: 2005.1	1996.1: 2005.1	1995.4: 2004.4	1995.3: 2005.1	1996.1: 2005.1
Number of observations	41	37	37	39	37
$cor(pmpysa_t, ysa_t)$	-0.58			No trend in the data	Trend in the data
$\ln(RERM_t)=pmpyxsat$	-0.48*** (0.022)	-0.492*** (0.018)	-0.419*** (0.022)	-0.453*** (0.017)	-0.464*** (0.015)
$ysa_t$	1.346*** (0.057)	1.374*** (0.044)	1.533*** (0.059)	1.431*** (0.04)	1.441*** (0.036)
Constant	-5.843*** (0.735)	-6.207*** (0.571)	-8.230*** (0.754)	6.925*** (0.575)	7.075
Residual-based t-statistic <sup>a</sup>	-5.35***	-5.84***			
$\lambda_{trace}$ -statistic <sup>b</sup>				55.42***	49.99***
$\lambda_{max}$ -statistic <sup>b</sup>				38.65***	39.17***
Adjustment coefficient ( $m_t$ )				-0.267 (0.407)	-1.135*** (0.431)
Order of VECM\ DOLS (a ; b ; c) <sup>c</sup>			(-; 0; -2,0,+2)	1	1
Period adjusting end points	1995.1: 2005.1	1996.1: 2005.1	1995.4: 2004.3	1995.3: 2005.1	1996.1: 2005.1
Number of observations	41	37	37	39	37
$cor(pmpyxsat, ysa_t)$	-0.49			No trend in the data	Trend in the data
<i>Adjusted critical values<sup>b</sup></i>	<i>No trend in the data, T=39</i>		<i>Trend in the data, T=37</i>		
		$\lambda_{trace}$	$\lambda_{max}$	$\lambda_{trace}$	$\lambda_{max}$
90 percent		37.24	23.01	31.46	21.84
95 percent		40.62	25.60	34.85	24.62
99 percent		47.79	31.20	41.86	29.97

\*, \*\* and \*\*\* denote significant statistics at 10%, 5% and 1%. <sup>a</sup> Critical values are from Phillips and Ouliaris (1990) and Enders (2004). <sup>b</sup> Critical values are from Osterwald-Lenum (1992) adjusted using the small sample correction factor suggested by Cheung and Lai (1993).

<sup>c</sup> (a ; b ; c) – lags of changes in the dependent variable and leads and lags of changes in the right hand side variables in the DOLS, where “a” stands for  $\Delta m_t$ , “b” stands for  $\Delta RERM_t$  and “c” stands for  $\Delta y_t$ .

**Table 5.2.1. Lon-run elasticities: supply of exports, seasonally unadjusted data ( $x_t$ )**

	SOLS	SOLS	DOLS	DOLS	Johansen ML	Johansen ML
$\ln(RERX_t)=pxpy_t$	-0.011 (0.099)	-0.066 (0.064)	0.123*** (0.033)	0.134*** (0.041)	0.095*** (0.019)	0.091*** (0.021)
$y_t$	1.40*** (0.129)	0.55*** (0.139)	1.80*** (0.044)	1.883*** (0.191)	1.68*** (0.027)	1.65*** (0.097)
Constant	-6.156*** (1.654)	4.422** (1.755)	-11.3*** (0.560)	-12.36*** (2.405)	-9.855	-9.357
Time trend		0.013*** (0.002)		-0.001 (0.002)		0.001 (0.001)
Residual-based t-statistic <sup>a</sup>	-3.22	-3.89*	-3.05	-3.45		
$\lambda_{trace}$ -statistic <sup>b</sup>					52.15***	54.08
$\lambda_{max}$ -statistic <sup>b</sup>					39.10***	39.26**
Adjustment coefficient ( $m_t$ )					-0.326 (0.398)	-0.364 (0.411)
Order of VECM\ DOLS (a ; b ; c) <sup>c</sup>			(-3,-2;-2,-1,0,+1; -1,0,+1)			3, SD
Period adjusting end points	1995.1: 2005.1		1996.1: 2004.4		1996.1: 2005.1	
Number of observations	41		36		37	
$cor(pxpy_t, y_t)$	-0.06				Trend in the data	
$\ln(RERX_t)=pxpyx_t$	-0.001 (0.065)	-0.043 (0.042)	0.074*** (0.020)	0.058*** (0.025)	0.072*** (0.014)	0.066*** (0.015)
$y_t$	1.40*** (0.129)	0.55*** (0.140)	1.75*** (0.043)	1.56*** (0.180)	1.72*** (0.031)	1.64*** (0.102)
Constant	-6.146*** (1.661)	4.472** (1.762)	-10.7*** (0.558)	-8.26** (2.267)	-10.312	-9.358
Time trend		0.013*** (0.002)		0.002 (0.002)		0.001 (0.001)
Residual-based t-statistic <sup>a</sup>	-3.21	-3.88*	-4.34**			
$\lambda_{trace}$ -statistic <sup>b</sup>					53.24***	55.69
$\lambda_{max}$ -statistic <sup>b</sup>					40.54***	41.05**
Adjustment coefficient ( $m_t$ )					-0.356 (0.355)	-0.423 (0.377)
Order of VECM\ DOLS (a ; b ; c) <sup>c</sup>			(-3,-2;-1,+1,+2; 0,+1)			3, SD
Period adjusting end points	1995.1: 2005.1		1996.1: 2004.4		1996.1: 2005.1	1996.1: 2005.1
Number of observations	41		36		37	
$cor(pxpyx_t, y_t)$	-0.11				Trend in the data	
Adjusted critical values <sup>b</sup> :	Trend in the data, T=37		Trend in the data and in the CE, T=37			
	$\lambda_{trace}$	$\lambda_{max}$	$\lambda_{trace}$	$\lambda_{max}$		
90 percent	38.36	26.64	55.93	33.09		
95 percent	42.50	30.03	60.77	36.57		
99 percent	51.05	36.54	69.38	43.45		

\*, \*\* and \*\*\* denote significant statistics at 10%, 5% and 1%. <sup>a</sup> Critical values are from Phillips and Ouliaris (1990) and Enders (2004). <sup>b</sup> Critical values are from Osterwald-Lenum (1992) adjusted using the small sample correction factor suggested by Cheung and Lai (1993).

<sup>c</sup> (a ; b ; c) – lags of changes in the dependent variable and leads and lags of changes in the right hand side variables in the DOLS, where “a” stands for  $\Delta x_t$ , “b” stands for  $\Delta RERX_t$  and “c” stands for  $\Delta y_t$ .

**Table 5.2.2. Lon-run elasticities: supply of exports, seasonally adjusted data ( $xsa_t$ )**

	SOLS	SOLS	DOLS	DOLS	Johansen ML	Johansen ML
$\ln(RERX_t)=pxpy_{sa_t}$	0.098* (0.054)	0.037 (0.033)	0.113*** (0.027)	0.089** (0.032)	0.117*** (0.034)	0.107*** (0.037)
$ysa_t$	1.62*** (0.076)	0.82*** (0.106)	1.696*** (0.036)	1.50*** (0.151)	1.716*** (0.049)	1.633*** (0.162)
Constant	-9.038*** (0.979)	1.02 (1.332)	-10.013*** (0.462)	-7.545*** (1.900)	-10.266	-9.231
Time trend		0.01*** (0.001)		0.003 (0.002)		0.001 (0.002)
Residual-based t-statistic <sup>a</sup>	-2.97	-3.81	-3.01	-2.85		
$\lambda_{trace}$ -statistic <sup>b</sup>					34.98*	38.99
$\lambda_{max}$ -statistic <sup>b</sup>					25.35*	25.56
Adjustment coefficient ( $m_t$ )					-0.327 (0.227)	-0.385 (0.238)
Order of VECM\ DOLS (a ; b ; c) <sup>c</sup>			(-; -1,0,+1;-)			2
Period adjusting end points	1995.1: 2005.1		1995.3: 2004.4		1995.4: 2005.1	
Number of observations	41		38		38	
$cor(pxpsay_t, ysa_t)$	-0.06				Trend in the data	
$\ln(RERX_t)=pxpy_{xsa_t}$	0.066* (0.035)	0.023 (0.022)	0.074*** (0.018)	0.055** (0.021)	0.086*** (0.025)	0.076*** (0.026)
$ysa_t$	1.627*** (0.076)	0.823*** (0.107)	1.711*** (0.037)	1.474*** (0.149)	1.752*** (0.056)	1.626*** (0.170)
Constant	-9.134*** (0.981)	0.977 (1.345)	-10.2*** (0.470)	-7.224 (1.871)	10.727	9.143
Time trend		0.01*** (0.001)		0.003 (0.002)		0.001 (0.002)
Residual-based t-statistic <sup>a</sup>	-2.98	-3.82	-3.01	-3.12		
$\lambda_{trace}$ -statistic <sup>b</sup>					33.00	36.97
$\lambda_{max}$ -statistic <sup>b</sup>					24.32*	24.75
Adjustment coefficient ( $m_t$ )					-0.338 (0.209)	-0.418 (0.226)
Order of VECM\ DOLS (a ; b ; c) <sup>c</sup>			(-; -1,0,+1;-)			2
Period adjusting end points	1995.1: 2005.1		1995.3: 2004.4		1995.4: 2005.1	
Number of observations	41		38		38	
$cor(pxpy_{xsa_t}, ysa_t)$	-0.11				Trend in the data	
Adjusted critical values <sup>b</sup> :	Trend in the data, T=38		Trend in the data and in the CE, T=38			
	$\lambda_{trace}$	$\lambda_{max}$	$\lambda_{trace}$	$\lambda_{max}$		
90 percent	34.27	23.8	49.97	29.56		
95 percent	37.97	26.83	54.29	32.67		
99 percent	45.61	32.65	61.98	38.81		

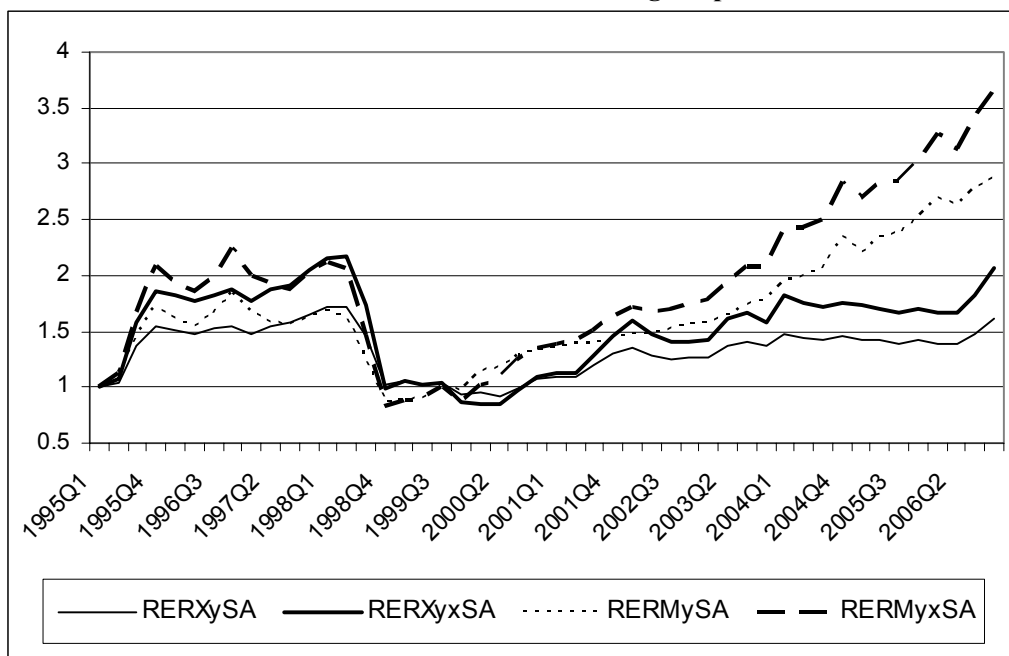
\*, \*\* and \*\*\* denote significant statistics at 10%, 5% and 1%. <sup>a</sup>Critical values are from Phillips and Ouliaris (1990) and Enders (2004). <sup>b</sup>Critical values are from Osterwald-Lenum (1992) adjusted using the small sample correction factor suggested by Cheung and Lai (1993).

<sup>c</sup> (a ; b ; c) – lags of changes in the dependent variable and leads and lags of changes in the right hand side variables in the DOLS, where “a” stands for  $\Delta x_t$ , “b” stands for  $\Delta RERX_t$  and “c” stands for  $\Delta y_t$ .

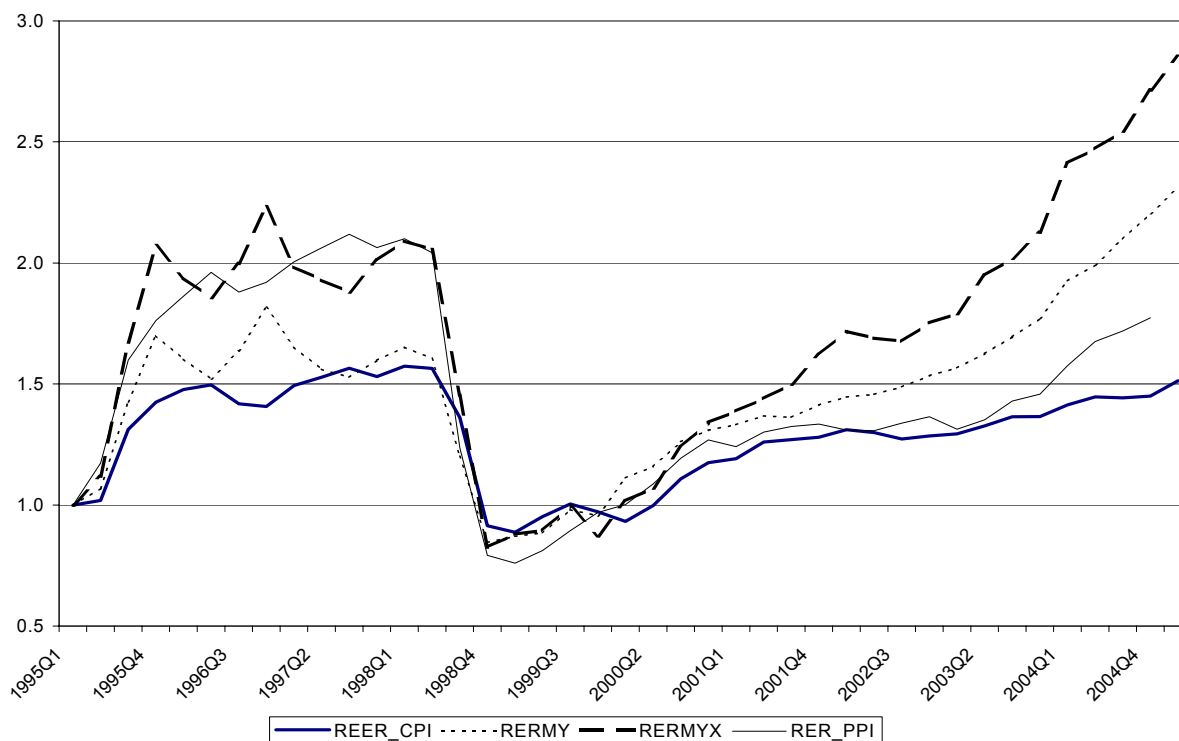
**Table 5.3. Long-run trade elasticities used in ERES simulations**

	Method	Price elasticity ( $\varepsilon$ )	Income (output) elasticity ( $\eta$ )
		$RER=RERM_Y$	
Imports	DOLS	-0.74	1.246
Exports	Johansen	0.117	1.716
		$RER=RERM_{YX}$	
Imports	Johansen (Q1 1996)	-0.464	1.441
Exports	Johansen	0.086	1.752

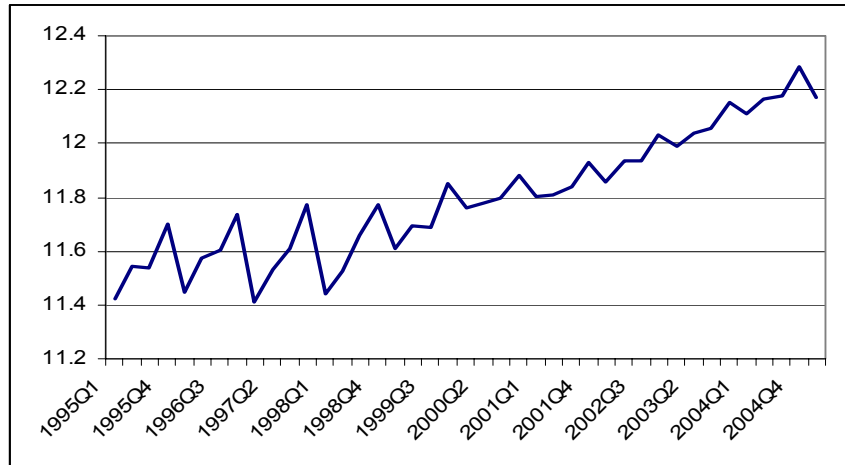
**Figure 3.1 RER for imports ( $RERM_Y$ ,  $RERM_{YX}$ ) and RER for exports ( $RERX_Y$  and  $RERX_{YX}$ ) measured with two alternative nontradable good price indices, SA**



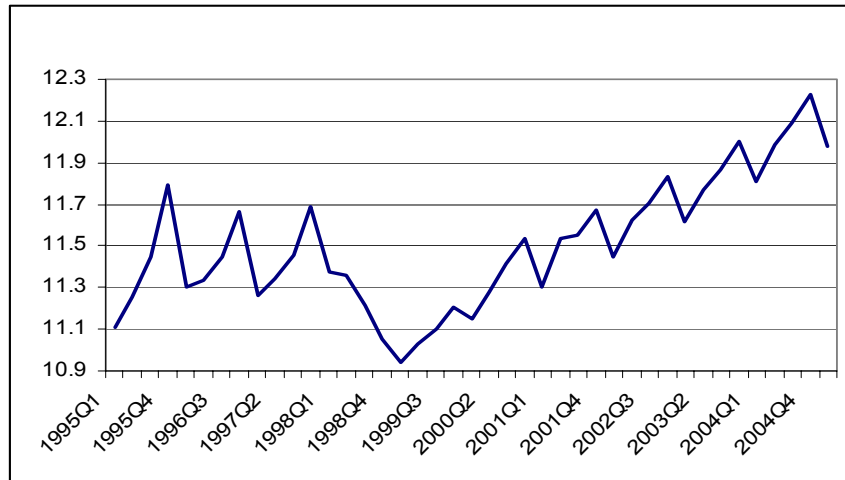
**Figure 3.2 CPI-based and PPI based REER and RER for imports ( $RERM_Y$  and  $RERM_{YX}$ , SA)**



**Figure 4.1. Log of exports (constant roubles, Q1:1995):  $x_t$**



**Figure 4.2. Log of imports (constant roubles, Q1:1995):  $m_t$**



**Figure 4.3. Log of GDP (constant roubles, Q1:1995):  $y_t$**

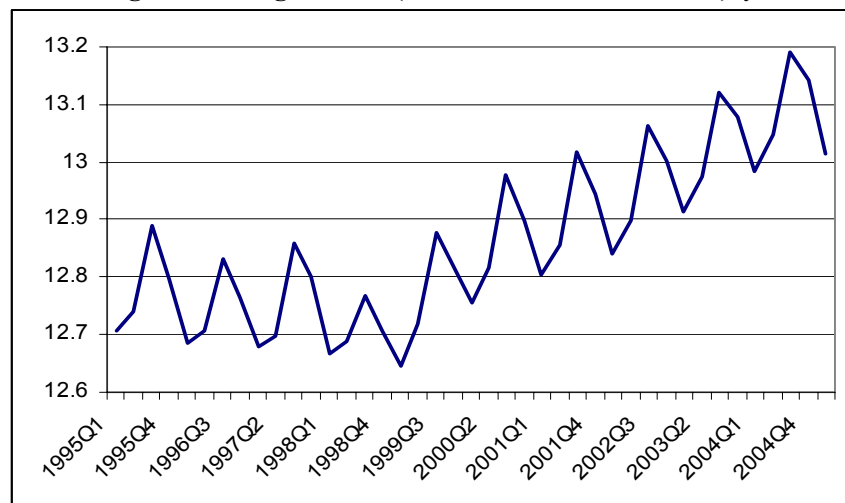


Figure 4.4. Log of RER for imports:  $pmpy_t$  and  $pmpyx_t$

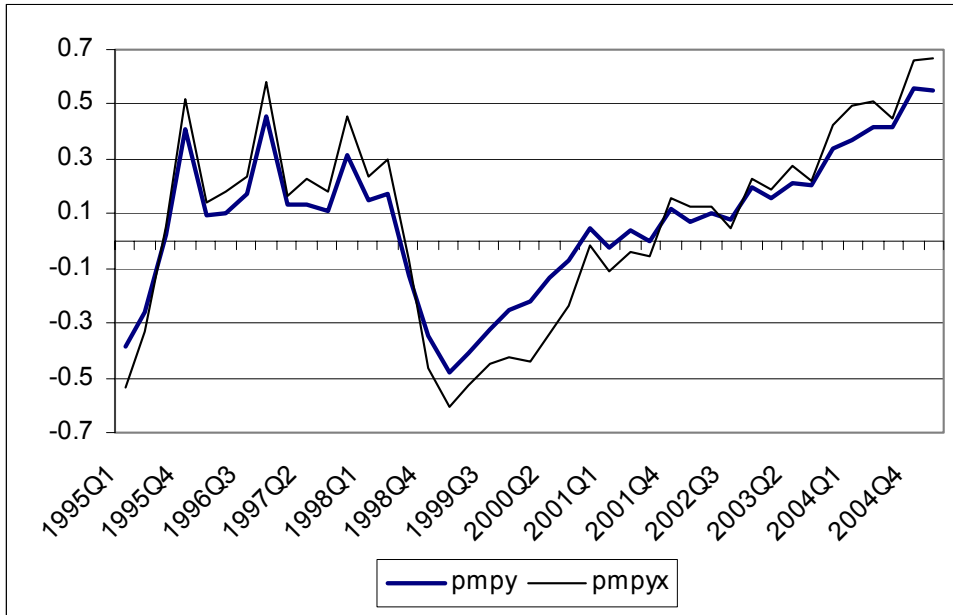
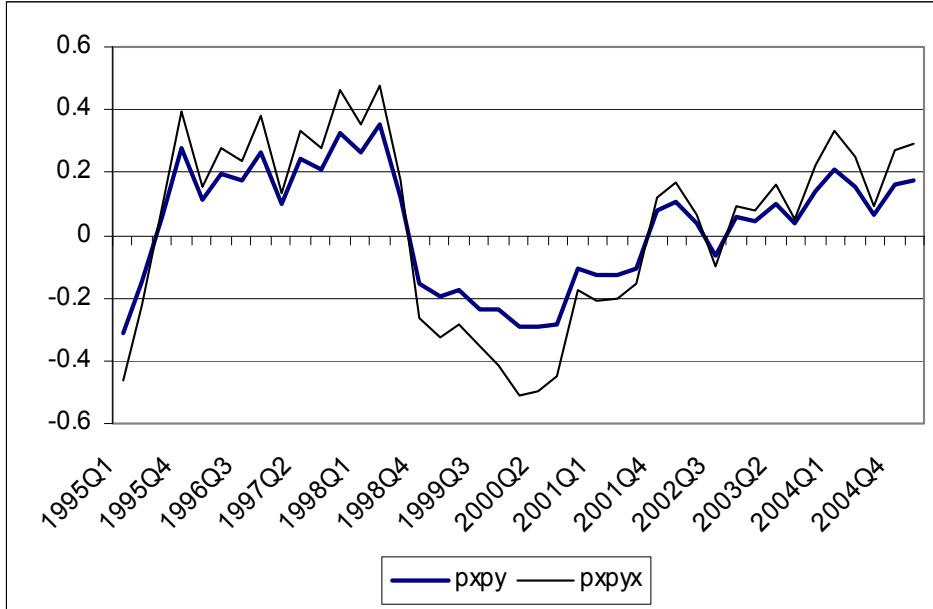
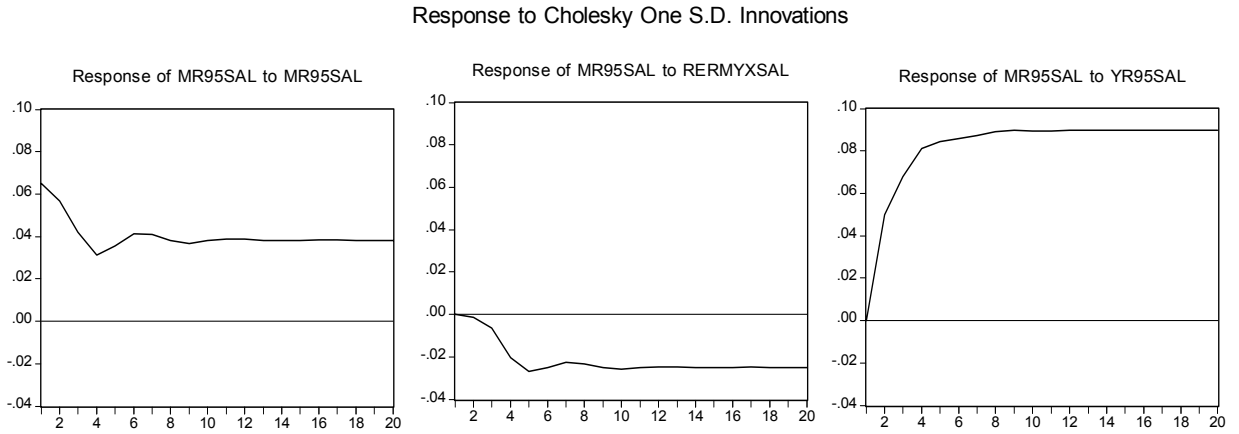


Figure 4.5. Log of RER for exports:  $p_xpy_t$  and  $p_xpyx_t$

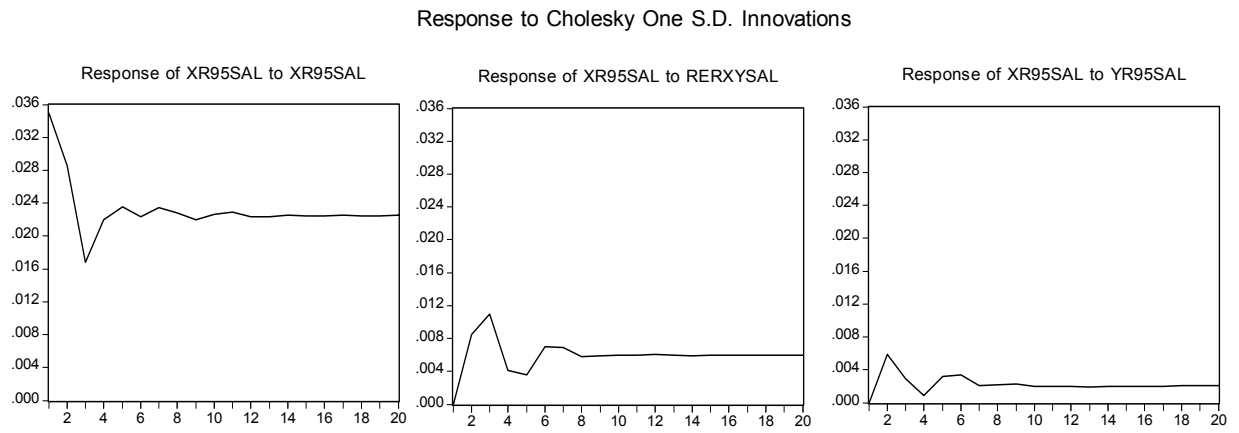


**Figure 5.1. Impulse response functions: demand for imports, RER=RER<sub>Y</sub>, SA**



$$MR95SAL = msa_t, RERMYXSAL = pmpyxsat, YR95SAL = ysa_t$$

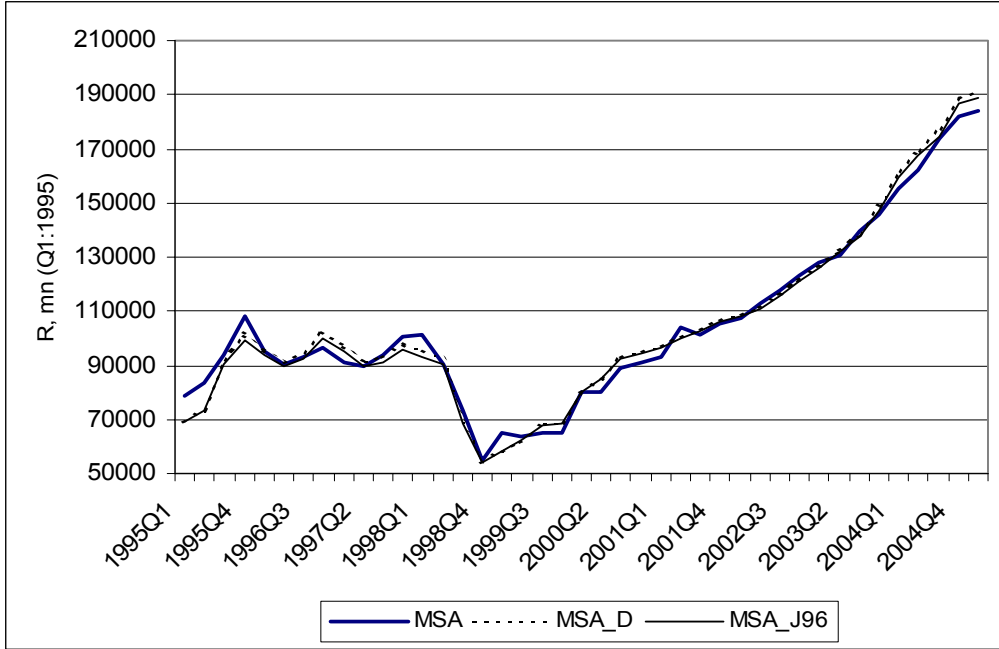
**Figure 5.2. Impulse response functions: supply of exports, RER=RER<sub>X</sub>, SA**



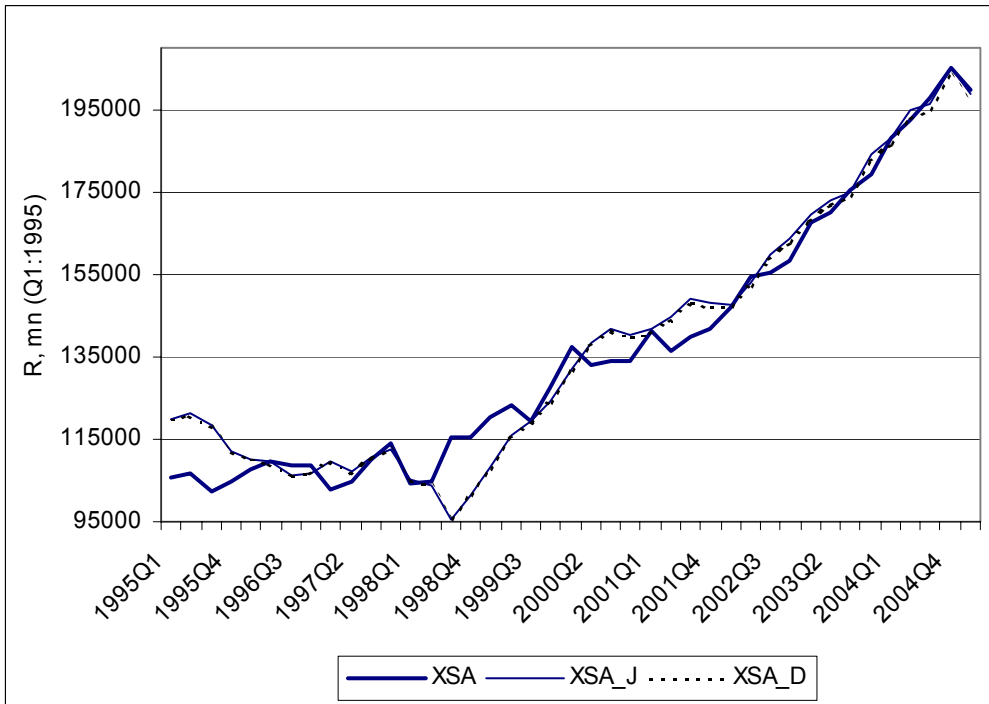
$$XR95SAL = xsa_t, RERXYSAL = pxpysat, YR95SAL = ysa_t$$



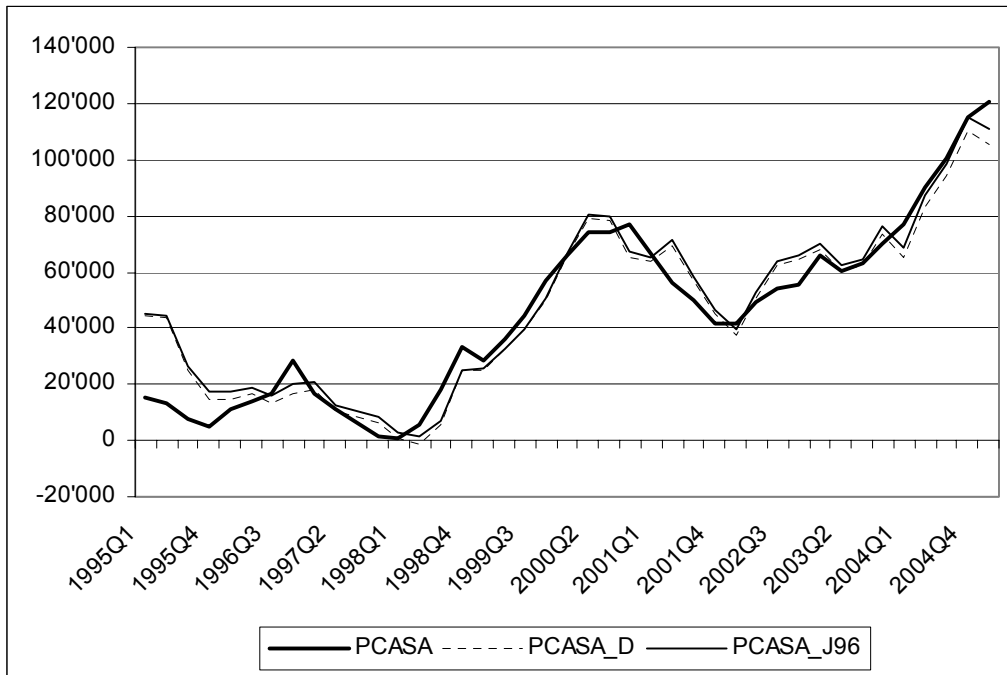
**Figure 5.3.1. Imports (RER=RERM<sub>Y</sub>): actual, Johansen (J) and DOLS (D) estimates, constant roubles (Q1:1995), SA**



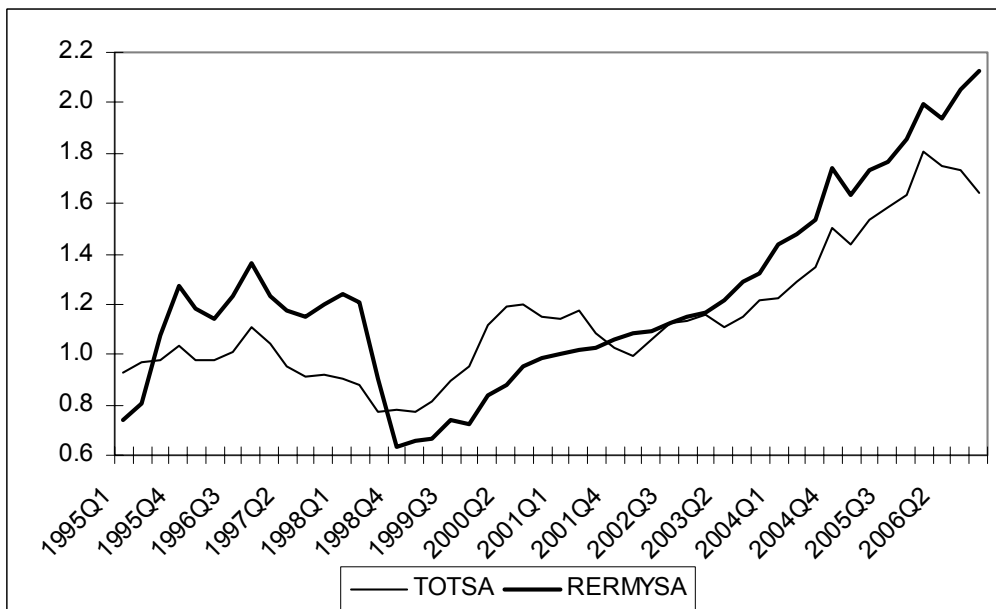
**Figure 5.3.2. Exports (RER=RERX<sub>Y</sub>): actual (XR95SA), Johansen (J) and DOLS (D) estimates, constant roubles (Q1:1995), SA**



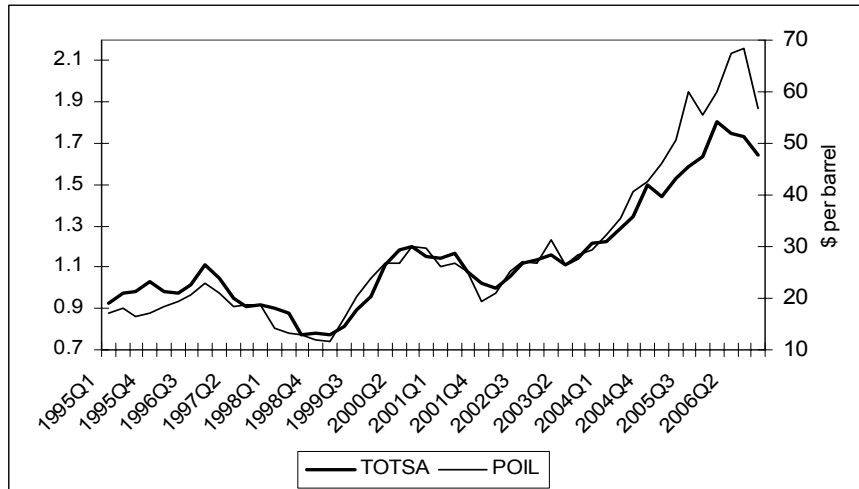
**Figure 5.3.3. Primary current account in terms of foreign currency (RER=RERM<sub>Y</sub>): actual, Johansen (J) and DOLS (D) estimates, SA**



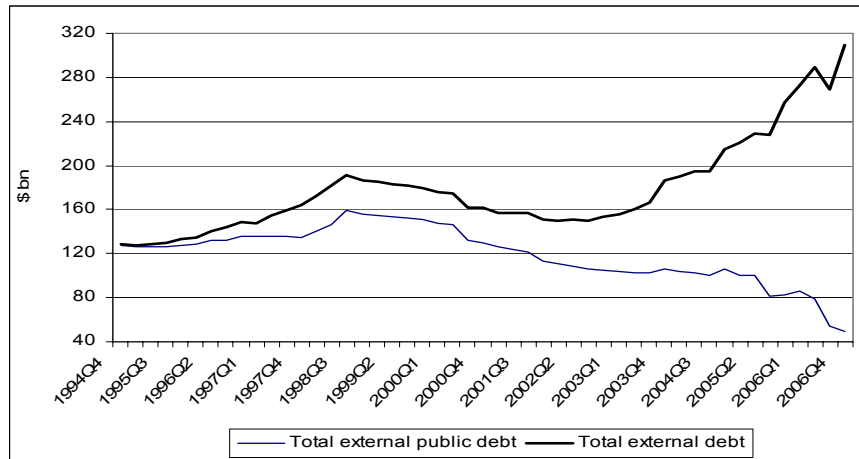
**Figure 6.1.1. Terms of trade (TOT) and RER for imports (RERM<sub>Y</sub>), SA**



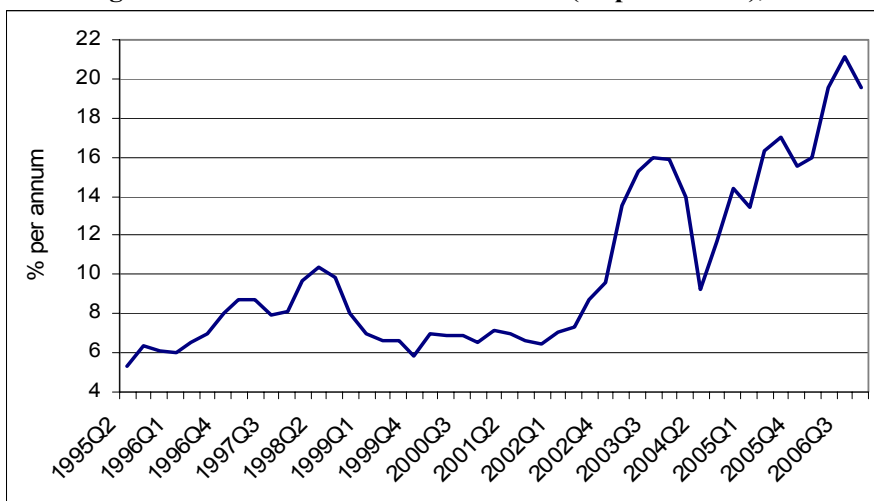
**Figure 6.1.2. Terms of trade (TOT, SA) and world oil prices (\$ per barrel)**



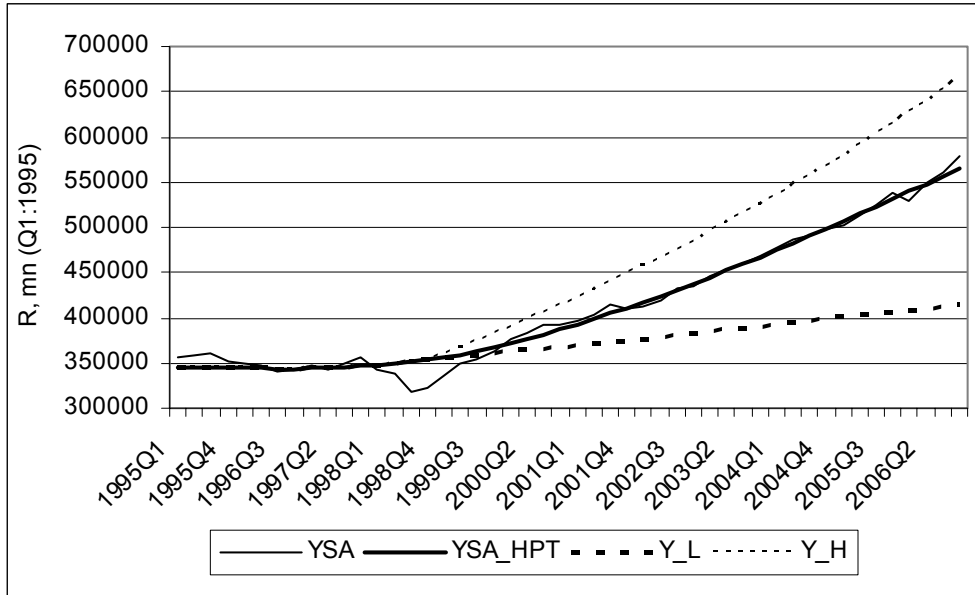
**Figure 6.1.3. Total external debt and public external debt of Russia, \$ bn**



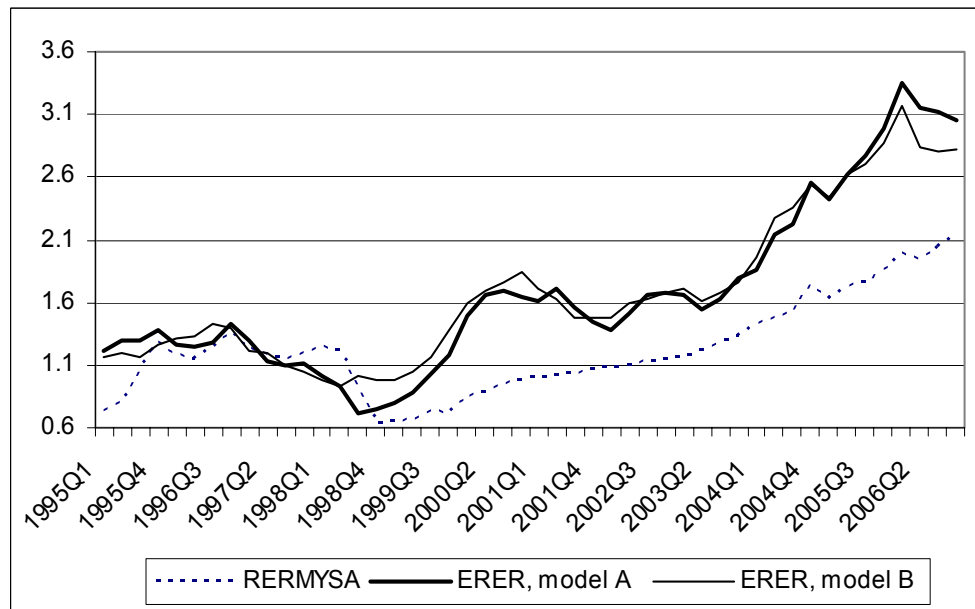
**Figure 6.1.4. Real effective interest rate (% per annum), SA**



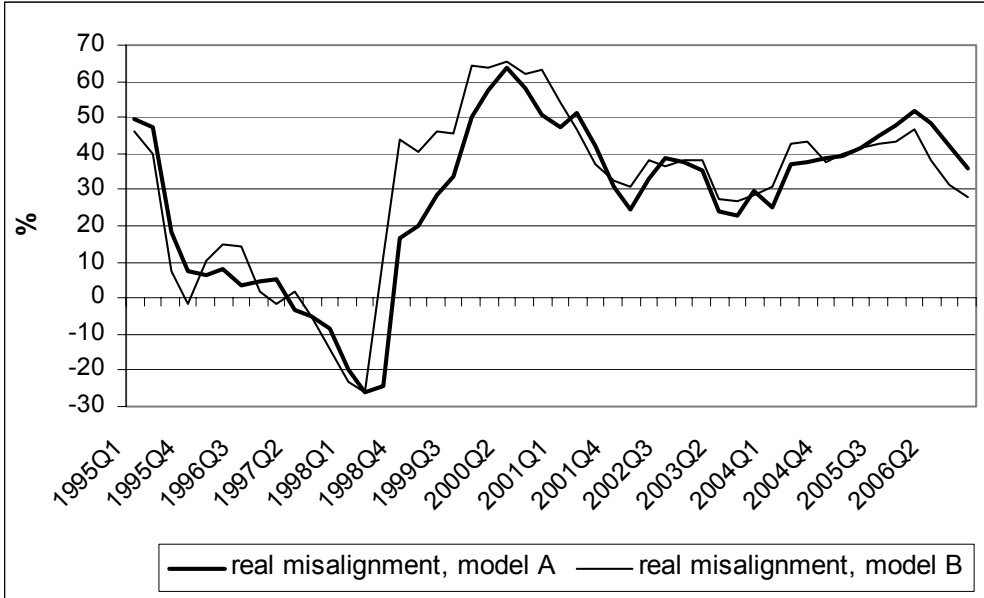
**Figure 6.1.5. GDP (in constant roubles, Q1:1995, SA): actual, HP trend (HPT), higher growth scenario (H) and lower growth scenario (L)**



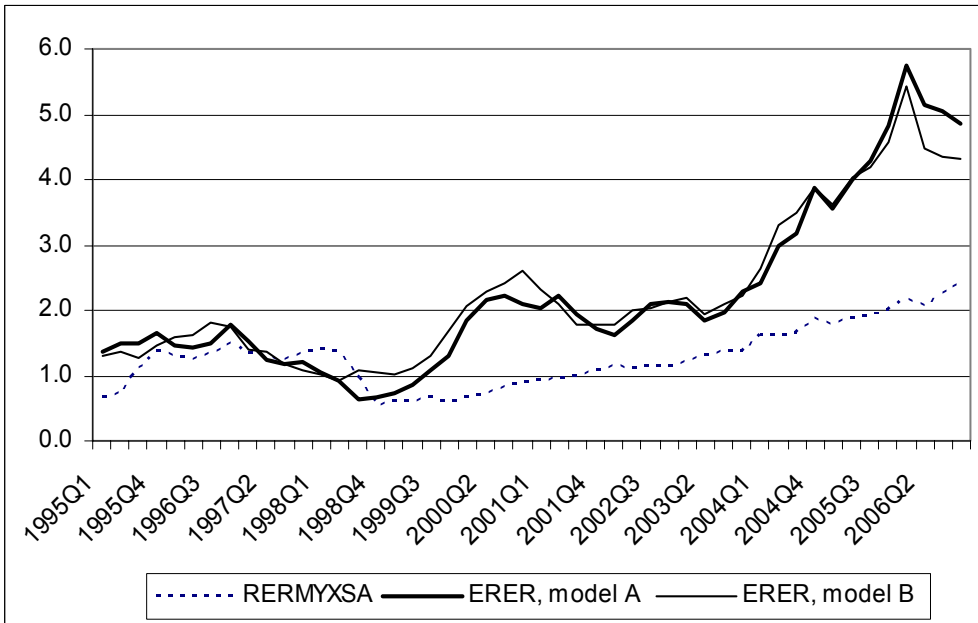
**Figure 6.2.1. ERER baseline simulation ( $RER=RERM_Y$ , SA): actual  $RERM_Y$ ,  $ERER_A$  and  $ERER_B$**



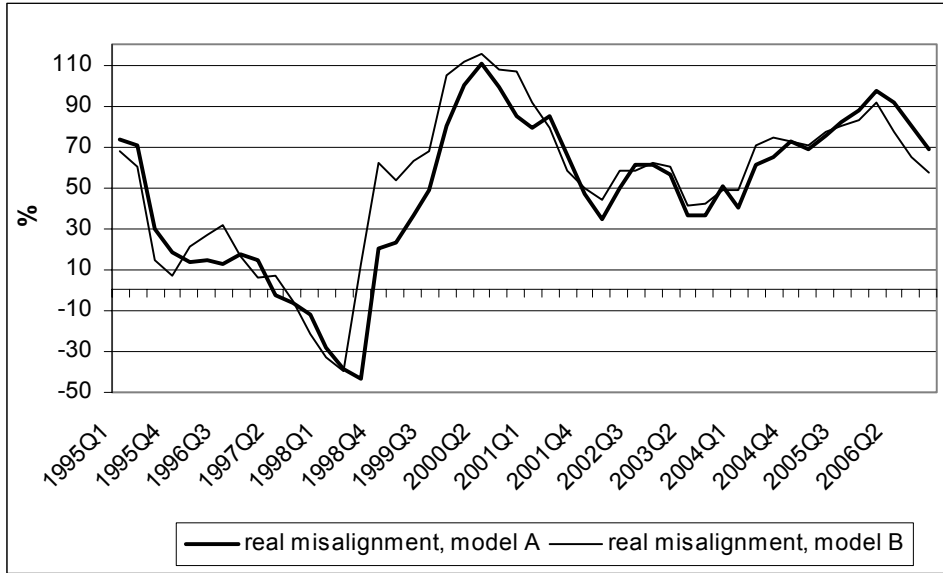
**Figure 6.2.2. Real misalignment, baseline simulation ( $RER=RERM_Y$ , SA):  
model A and model B, %**



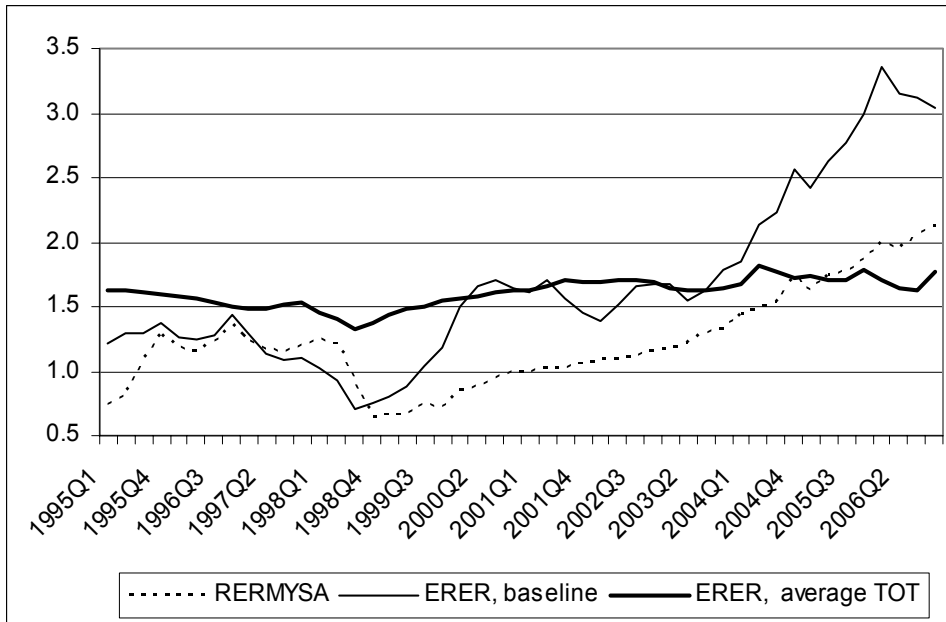
**Figure 6.2.3. ERES baseline simulation ( $RER=RERM_{YX}$ , SA):  
actual  $RERM_Y$ ,  $ERER_A$  and  $ERER_B$**



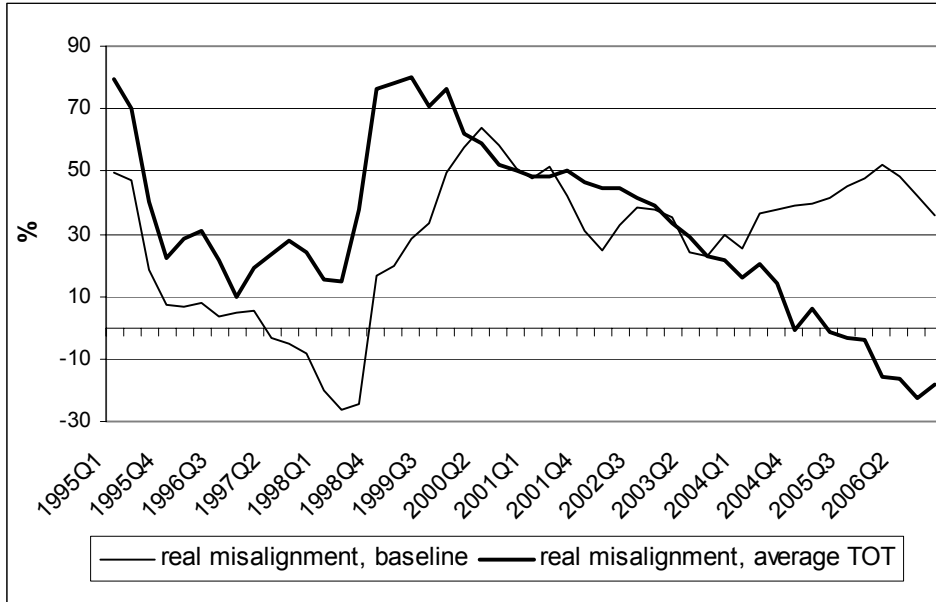
**Figure 6.2.4. Real misalignment, baseline simulation ( $RER=RERM_{YX}$ , SA):  
model A and model B, %**



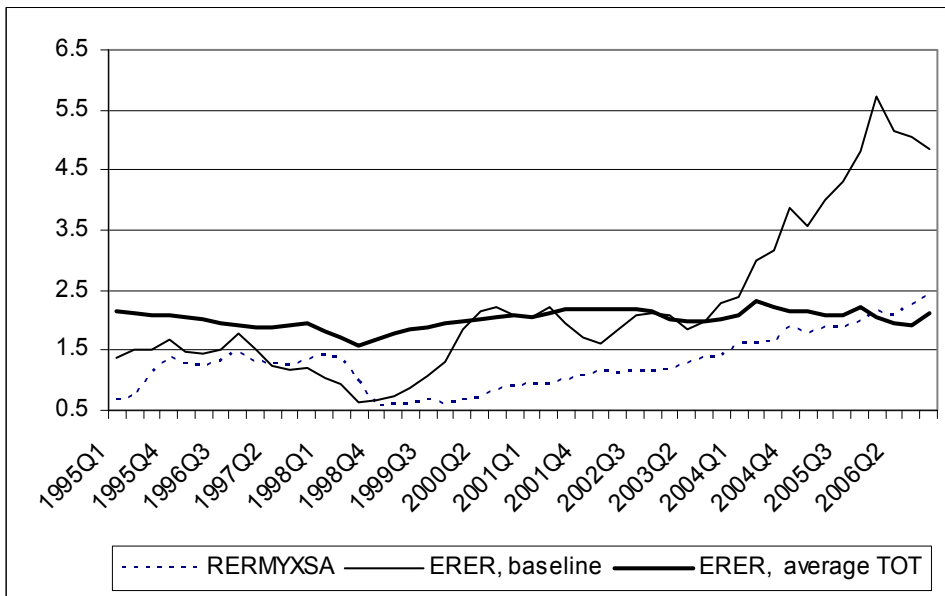
**Figure 6.3.1. ERES, sensitivity analysis ( $RER=RERM_Y$ , SA):  
sample average TOT (oil price=\$29/barrel)**



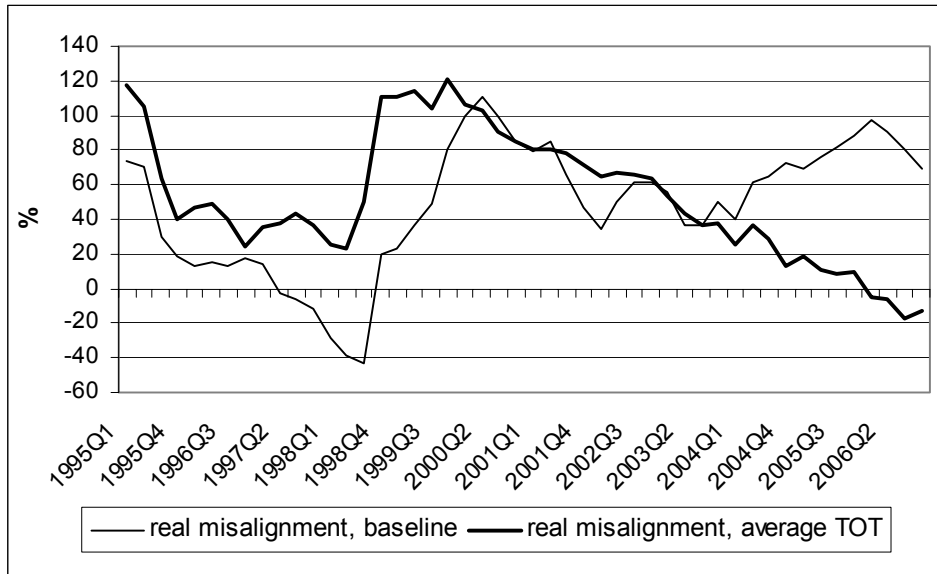
**Figure 6.3.2. Real misalignment, sensitivity analysis (RER=RERM<sub>Y</sub>, SA):  
sample average TOT (oil price=\$29/barrel), %**



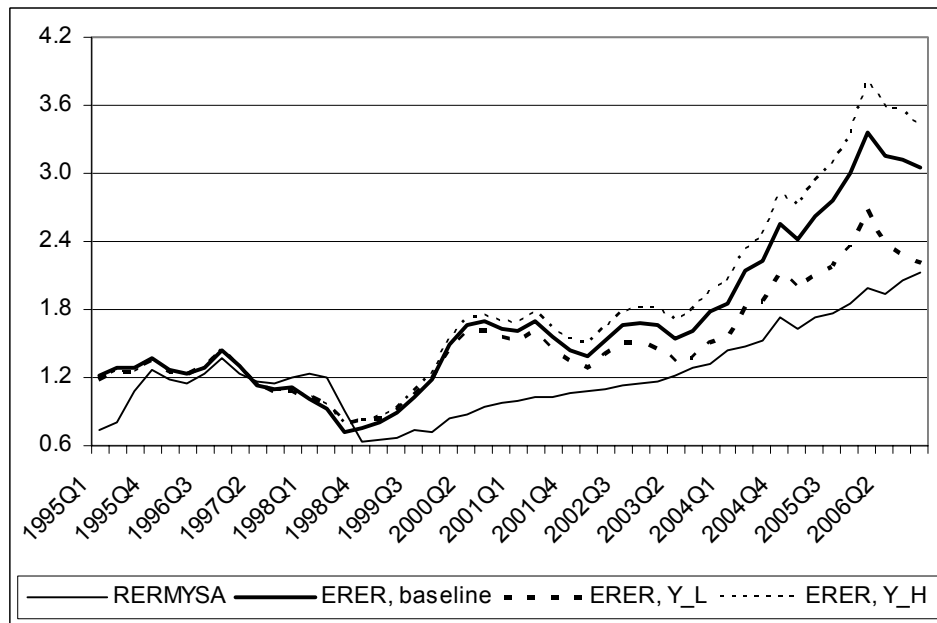
**Figure 6.3.3. ERES, sensitivity analysis (RER=RERM<sub>YX</sub>, SA):  
sample average TOT (oil price=\$29/barrel)**



**Figure 6.3.4. Real misalignment, sensitivity analysis (RER=RERM<sub>YX</sub>, SA):  
sample average TOT (oil price=\$29/barrel), %**

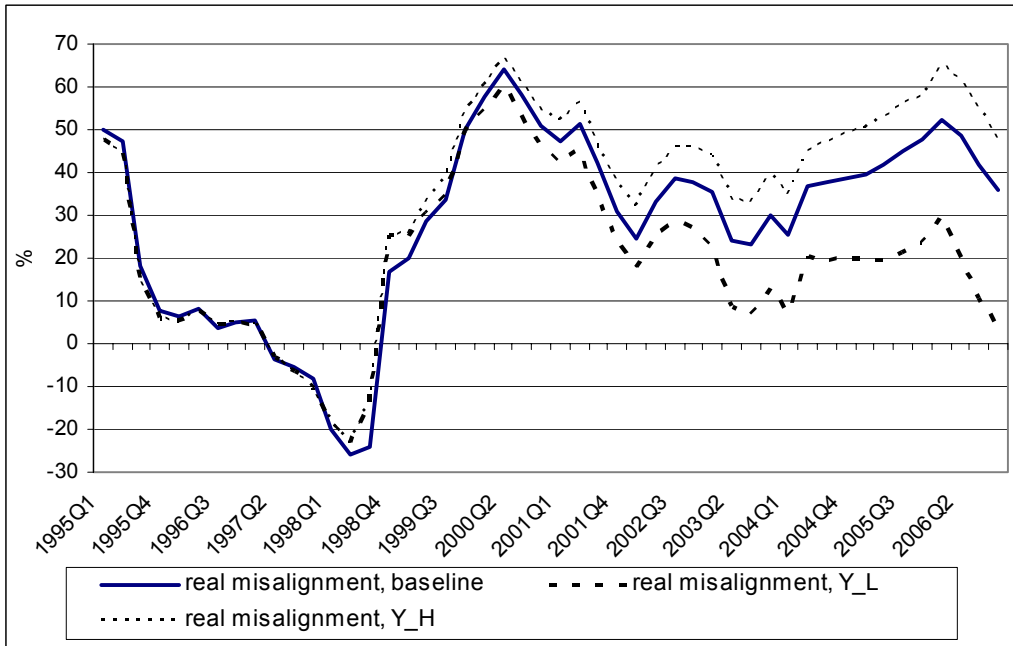


**Figure 6.3.5. ERES, sensitivity analysis (RER=RERM<sub>Y</sub>):  
higher growth scenario(Y\_H) and lower growth scenario (Y\_L).**

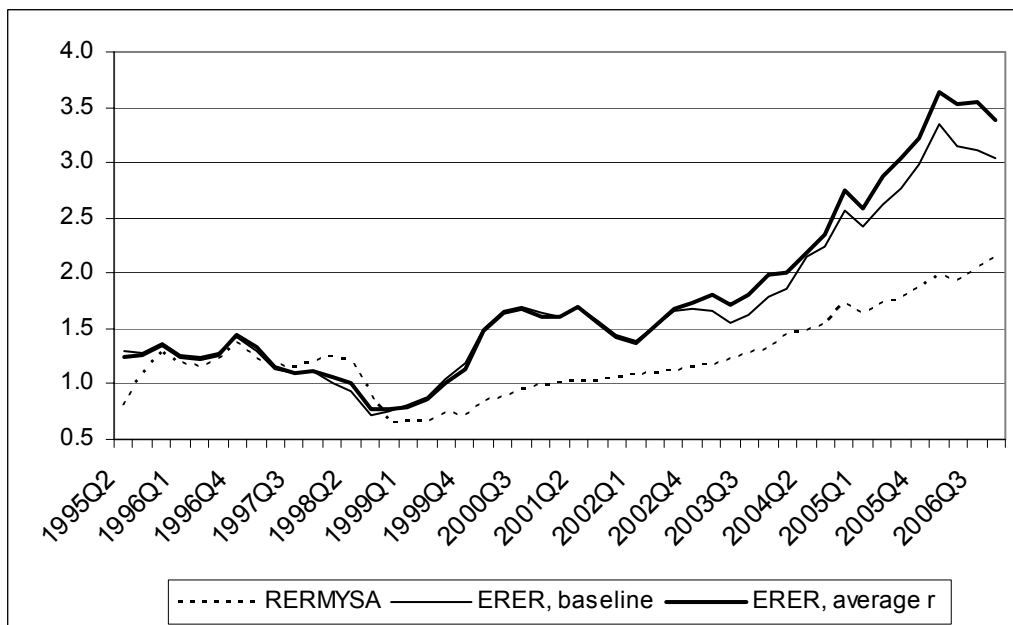




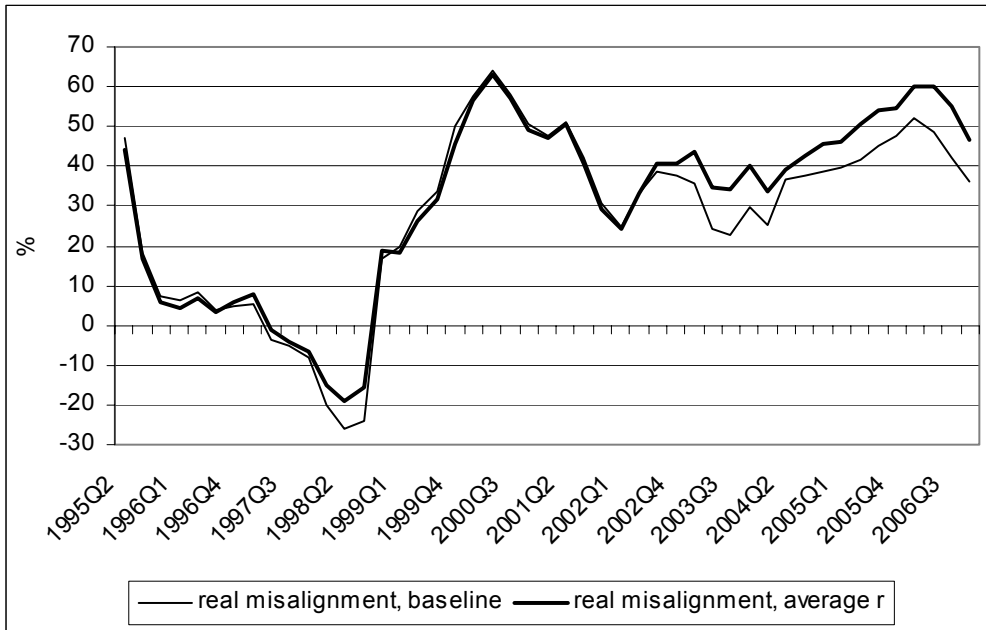
**Figure 6.3.6. Real misalignment, sensitivity analysis (RER=RERM<sub>Y</sub>, SA): higher growth scenario (Y\_H) and lower growth scenario (Y\_L), %.**



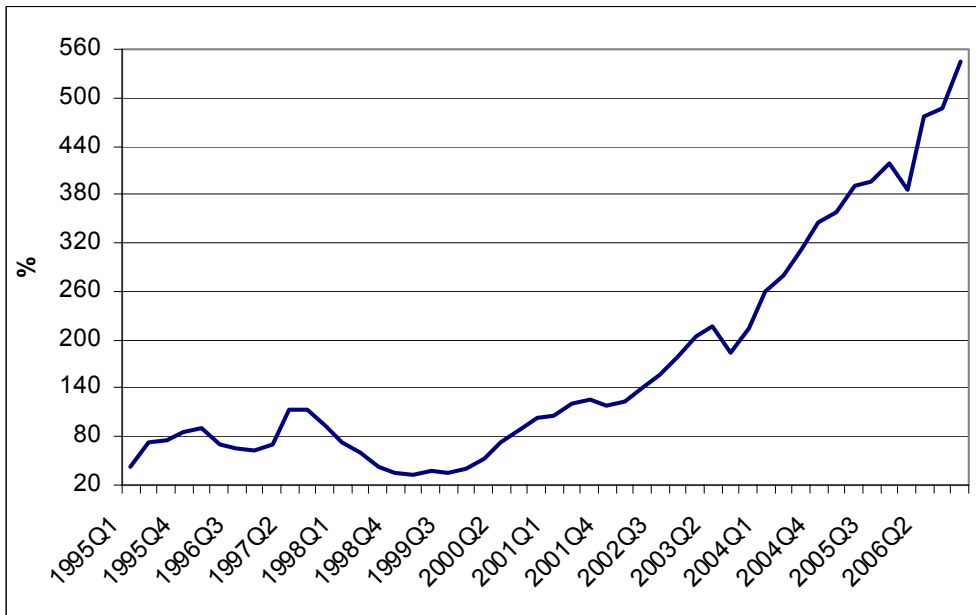
**Figure 6.3.7. ERES, sensitivity analysis (RER=RERM<sub>Y</sub>, SA): average real effective interest rate**



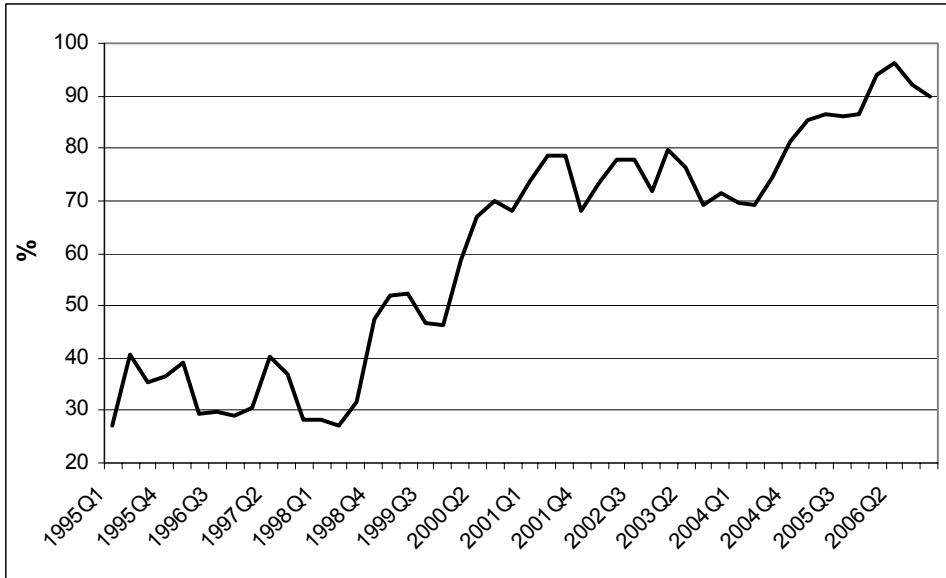
**Figure 6.3.8. Real misalignment, sensitivity analysis (RER=RERM<sub>y</sub>, SA): average real effective interest rate, %.**



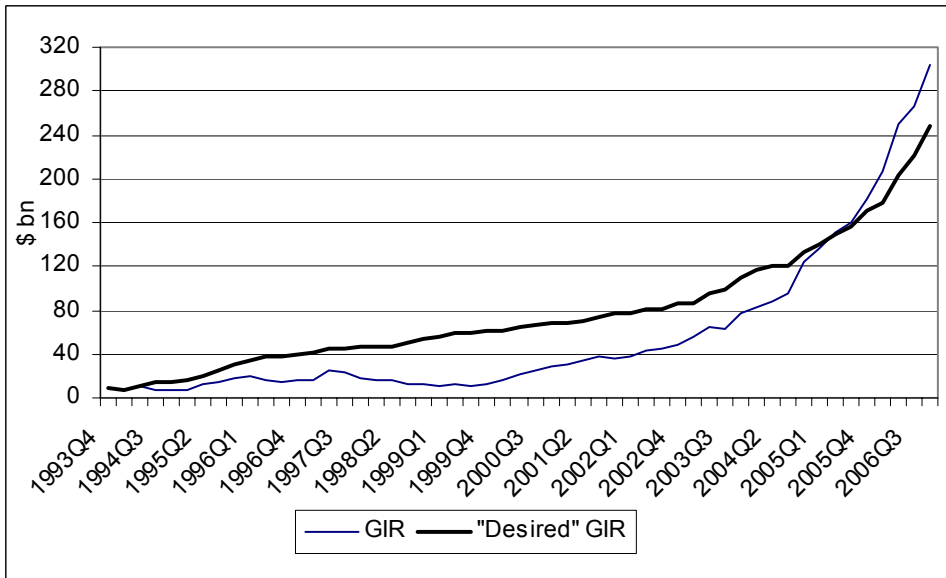
**Figure 6.3.9. Share of short-term external debt covered by Gross International Reserves, %**



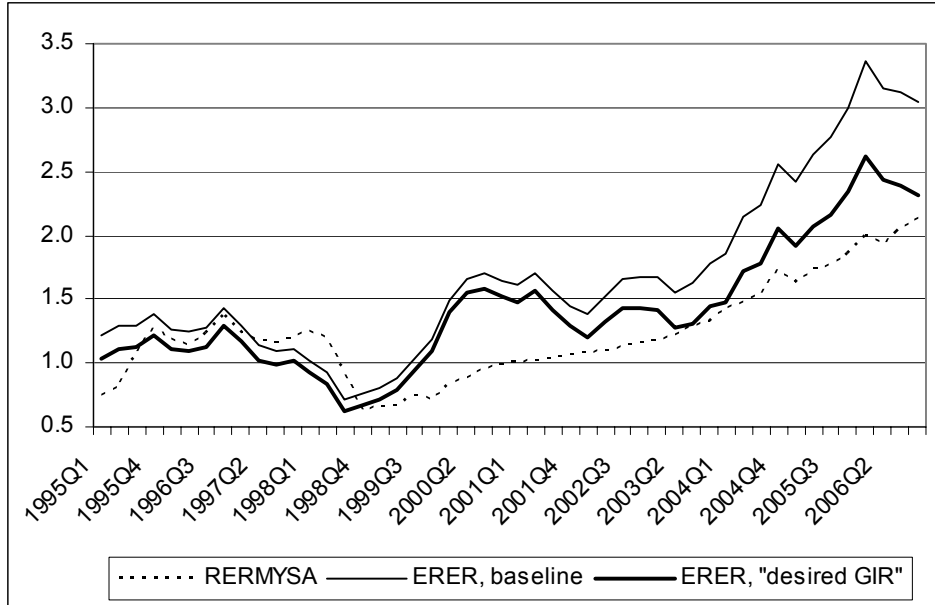
**Figure 6.3.10. Share of M2 covered by Gross International Reserves, %**



**Figure 6.3.11. “Desired” and actual Gross International Reserves (GIR), \$ bn**



**Figure 6.3.12. ERES, sensitivity analysis (RER=RERM<sub>Y</sub>, SA):  
“desired reserve accumulation” scenario**



**Figure 6.3.13. Real misalignment, sensitivity analysis (RER=RERM<sub>Y</sub>, SA):  
“desired reserve accumulation” scenario, %**

