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# Estimating the Equilibrium Real Exchange Rate: An Application to Finland

Prepared by Tarhan Feyzioğlu[1]

Authorized for distribution by Carlo Cottarelli

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## Abstract

An equilibrium exchange rate is here defined as the level that is consistent with simultaneous internal and external balances as specified in Montiel (1996). Exogenous "fundamental" variables determining these balances are identified. Along the lines of Edwards (1994), a reduced form is estimated with the cointegration technique for Finland for the period 1975-95. The estimation produced a reasonable set of equilibrium exchange rates that appreciate with positive shocks to the terms of trade, world real interest rates, and the productivity differential between Finland and its trading partners.

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

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## SUMMARY

The equilibrium real exchange rate (ERER) is investigated by looking at the reduced forms implied by a theoretical model, along the lines of Edwards (1994). The long-run ERER is defined as the level consistent with simultaneous internal and external balances (as specified in Montiel, 1996). Exogenous "fundamental" variables determining these balances are identified, and a reduced form is constructed linking the exchange rate to the fundamentals. Thus, estimating the equilibrium exchange rate does not require deciding the appropriate level of current account balance and the external net position; they are endogenous to the system.

Given the nonstationary nature of the variables, the cointegration technique developed by Johansen (1988 and 1991) is used to estimate the reduced form. This methodology is applied to Finland for the period 1975-95, when large exchange rate swings were experienced. The estimated reduced-form relationships seem to be reasonable. The equilibrium exchange rate appreciates with positive shocks to the terms of trade, world real interest rates, and the productivity differential between Finland and its trading partners. The estimated short-run movements are also as expected: the real exchange rate moves to correct for the disequilibrium, albeit slowly, and it is affected positively by the price differential between Finland and its trading partners, and by deviations from the uncovered interest parity.

## I. Introduction

There is a wealth of theoretical and empirical work on the determinants of the equilibrium real exchange rate. One important strand of the literature is associated with Williamson's seminal work (Williamson 1985), which has its roots in an approach developed at the IMF (Artus 1977).[2] Williamson defines the fundamental equilibrium exchange rate, FEER, as the rate that is consistent with the simultaneous achievement of internal and external balance. Internal balance is defined as the level of economic activity that keeps the inflation rate constant. In Williamson's approach, the concept of external balance contains a normative element: the external position is balanced if the external current account (once adjusted for cyclical movements) can be regarded not only as sustainable (that is, meeting the country's intertemporal budget constraint), but also as "appropriate" (for example, based on desired levels of saving and investment). In order to determine the FEER, it is first necessary to formulate an econometric model for the trade sector that captures the relationships among output, current account, demand, and competitiveness. The FEER is then calculated as the exchange rate that maintains internal and external equilibrium. A critical summary of this approach by Black (1994) points out that serious questions remain concerning the normative choices on the model to be used, particularly the target for the current account.

An alternative approach, followed in this paper, is to investigate the equilibrium exchange rate by looking at the reduced forms implied by a theoretical model, along the lines of Edwards (1994). Similar to Williamson's approach, the long-run ERER is defined as the level that is consistent with simultaneous internal and external balances. These are defined in a theoretical model based on Montiel (1996)--see also Khan and Montiel (1996). This model identifies a set of exogenous "fundamental" variables that determine internal and external equilibrium. A reduced form is then constructed linking the exchange rate to the fundamentals. In this approach, there is no need to decide what the appropriate level of the current account balance and the external net position should be: they are endogenous to the system.

In estimating the reduced form, given the nonstationary nature of the variables, the cointegration technique advocated by Johansen is used (1988 and 1991). This method has the advantage of defining a relationship between the real exchange rate and its determinants that is valid in the long run, even though there may be large deviations in the short run.

This methodology is applied to Finland, a country where the effective exchange rate has been subject to large swings in recent years (Figure 1). Starting in 1986, for instance, the CPI-based real exchange rate first appreciated by some 15 percent, then depreciated by more than 30 percent, and since 1993 has appreciated by approximately 20 percent. In fact, the volatility of Finland's exchange rate is one of the highest among EU countries.

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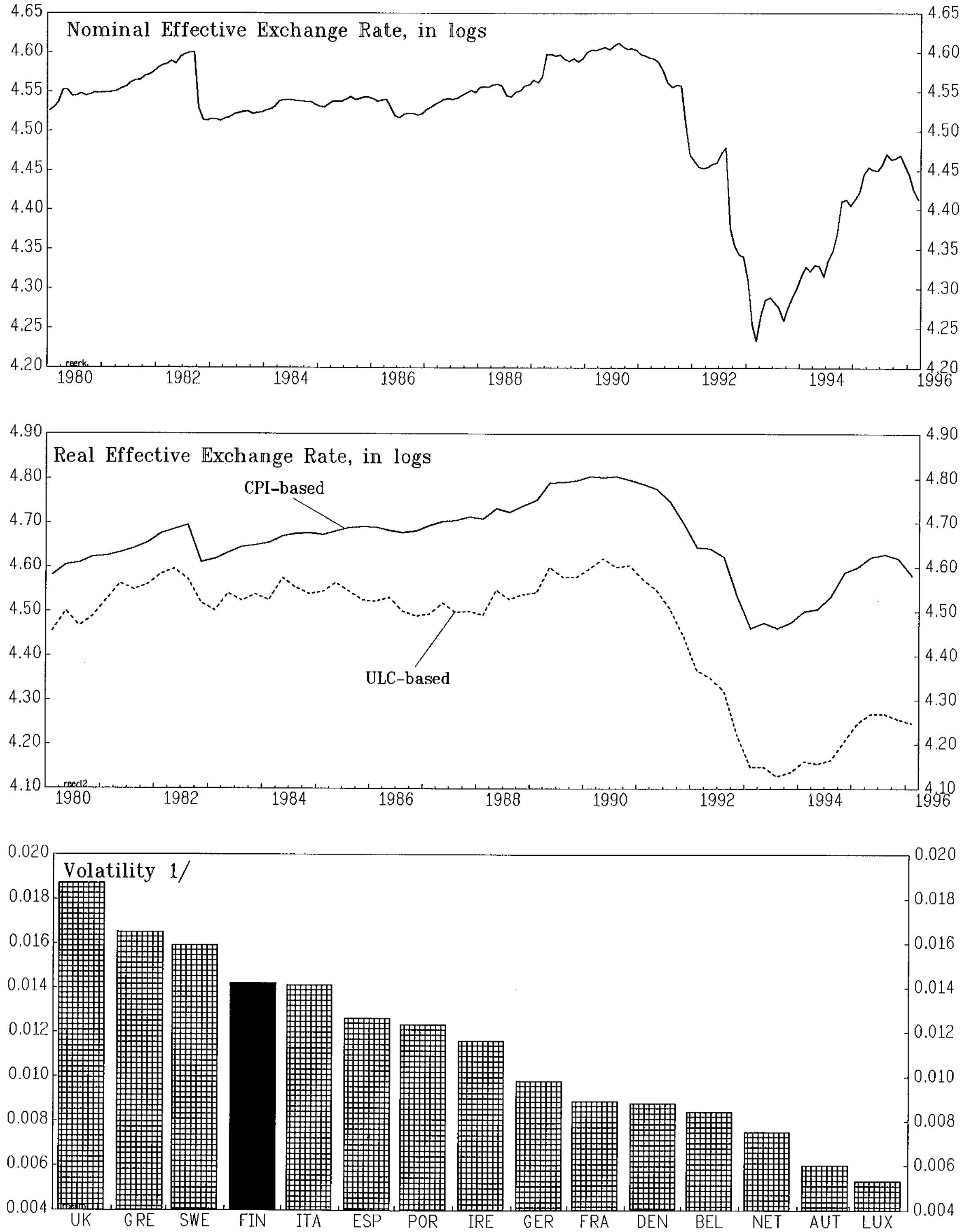
[2]Recent advances in this approach can be found in Williamson (1994). This approach is used for Finland by Hoj (1995) and Saarenheimo (1995).

# Figure 1. Exchange Rates, 1980-96




Source: PDR, Information Notice System.

1/ Standard deviation of the nominal effective exchange rate 1980-97.

The theory of the equilibrium exchange rate is briefly described in Section 2. The effects of the fundamentals on the exchange rate are also discussed. Section 3 is devoted to the key empirical issues: the properties of the data, the cointegration method, the cointegration results and tests, and the implied long-run equilibrium and short-run dynamics. Section 4 presents the conclusions.

## II. Theoretical Underpinnings

### A. The Model

The model is an extension of the two-good small open economy model by Dornbush (1974). The real exchange rate is defined as the relative price of nontraded goods in terms of traded goods, and the nominal exchange rate is assumed to be fixed.[3] The model consists of producers of traded and nontraded goods, representative households that maximize their discounted utility functions, and a consolidated government with a balanced budget.[4]

The producers, households, and the government are modeled as follows. The producers are price takers in the world market. Output is produced with a fixed, sector specific input and homogenous, perfectly mobile labor.[5] Firms in both sectors maximize profits by setting the marginal productivity of labor to the wage rate. The representative household maximizes current and discounted future consumption of traded and nontraded goods, subject to a budget constraint. Each period, the household decides to allocate its net worth between foreign bonds that pay a nominal interest rate $I^*$, and domestic money that reduces the transaction cost of consumption. The public sector consists of the government and the central bank. The central bank works like a currency board: it exchanges currency and passes the interest receipts on the foreign bonds it holds to the government. The government keeps a balanced budget, with lump-sum taxes and purchases of traded and nontraded goods. Regarding external borrowing, the arbitrage condition dictates that the country can borrow with a risk premium that is determined by the country's international indebtedness.

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[3]This assumption has no implications for the determinants of the long-run relationship that is sought in this paper.

[4]The assumption of a balanced budget results in households doing all the borrowing in the economy. The reduced form does not depend on who borrows; this assumption just keeps the model simple.

[5]Of course, this assumption is not strictly true for the Finnish economy, given the large cyclical component of unemployment. However, the long-run results are not affected by this assumption. For a different implementation, see Obsfeld and Rogoff (1995a).

The model, when solved, implies an external and an internal equilibrium condition. External equilibrium is attained when the level of consumption and the real exchange rate lead to a sustainable current account balance:

$$\pi^* a^* = y_T(e) + i^* a^* - (\tau^* + \theta)c - g_T, \tag{1}$$

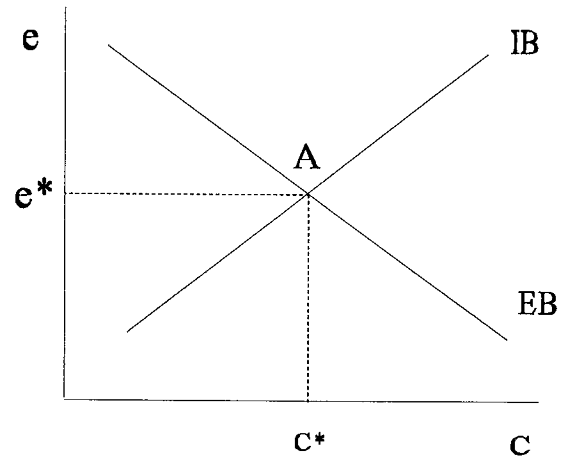
where $\pi^*$ is the world inflation rate, $a^*$ is the net foreign assets of the country, $y_T(e)$ is traded goods output, $e$ is the real exchange rate (relative price of nontraded to traded goods), $i^*$ is the nominal interest rate, $\tau^*$ is the transaction costs associated with consumption, $\theta$ is the share of traded goods in total consumption, and $g_T$ is government consumption of traded goods. The nominal interest rate is determined by the world nominal interest rate $i_w$ and a risk premium that depends on the international asset position of the country. In this equilibrium, the trade surplus is equal to $(y_T(e) - (\tau^* + \theta)c - g_T)$. Interest receipts are equal to net foreign assets times the interest rate: $i^* a^*$. The two components together give the current account balance as the right-hand side of equation (1). The left-hand side shows the portion of net foreign assets that lost value because of inflation. The equilibrium implies that the sustainable current account amounts to the inflationary erosion of the real value of net foreign assets. Put differently, a sustainable trade deficit must equal the real return on the net foreign assets; this in turn depends on the real world interest rate, the risk premium, and the stock of net foreign assets. Since traded goods output depends inversely on the real exchange rate, to sustain the equilibrium, as the exchange rate appreciates, consumption has to fall. This trade-off is depicted in Figure 2 as the external balance locus (EB).

Internal equilibrium is defined by the nontraded goods market:

$$y_N(e) = (1 - \theta)c/e + g_N, \tag{2}$$

where $y_N$ is nontraded goods production, positively related to the exchange rate, and $g_N$ is government consumption of the nontraded good. Given the consumption decisions of the households and the government, this condition defines the equilibrium real exchange consistent with nontraded goods market clearing. An appreciated exchange rate increases the production in the nontraded goods sector, which in turn increases consumption. This relationship is captured with the internal balance (IB) locus in Figure 2.

Figure 2
Internal and External Equilibrium




In the long run, the exchange rate and the consumption level must be consistent with both the internal and the external balance. Figure 2 depicts this equilibrium as the point where the two loci intersect. Of course, the two loci in turn depend on variables that are called fundamentals. A change in the fundamentals shifts the IB and EB loci and changes consumption and the real exchange rate. These fundamentals are discussed in the next section.

### B. Effects of Changes in the Fundamentals

An improvement in the terms of trade is expected to lead to an appreciation in the equilibrium exchange rate. To see this, one can modify the model by splitting tradables into exportables and importables, with the real exchange rate redefined as the price of nontradables in terms of importables. A positive terms of trade shock (an increase in the price of exports relative to the price of imports) causes the output in the nontradables to decline, creating an excess demand in the nontraded goods sector, and shifting the internal equilibrium locus upward. At the same time, the external equilibrium locus shifts upward as well, reflecting the necessity of having an appreciated exchange rate in order to maintain the sustainable trade balance. A new equilibrium in both sectors is obtained as the real exchange rate appreciates.

A change in the world real interest rate is also expected to affect the equilibrium exchange rate. An increase in the world real interest rate increases the local interest rate, and decreases the demand for money, raising savings and improving the net external position. If the country is a net creditor in the international markets, interest receipts increase, and the external balance locus shifts upward as consumption increases at any given exchange rate. On the other hand, if the country is a net debtor in the international markets, as is the case for Finland, the interest payments on existing debt rise. However, as long as the effect of interest payments does not dominate the effect of increased saving, the external balance locus still shifts upward. In this case, to achieve an equilibrium in the external sector, the country moves upward on the internal equilibrium locus as real exchange rate appreciates and consumption increases.

A positive relative productivity shock in the tradable sector is expected to cause the real exchange rate to appreciate. An increase in the productivity of the traded goods sector relative to the nontraded goods sector results in an expansion of the traded goods sector at the expense of the nontraded goods sector. Similar to a positive terms of trade shock, such a shift creates an excess demand for nontraded goods, which can be eased by a real appreciation of the exchange rate. This implies an upward shift of the internal equilibrium locus. The positive productivity shock improves the trade balance, which also requires a real appreciation to keep the trade account at a sustainable level.

Finally, government decisions on its consumption level and trade policy have effects on the real exchange rate. If government consumption of nontraded goods increases, this spurs production in the nontraded goods sector as the exchange rate appreciates. Conversely, if government consumption of traded goods increases, the trade balance deteriorates, and a depreciation is necessary to achieve external balance. Also, a reduction in an export subsidy has a similar effect on the internal balance as a deterioration of terms of trade: The internal balance curve shifts downward as the increase in nontradables creates excess supply. The external balance also shifts downward, similar to a terms of trade change, but without the income effect. As a result, the exchange rate depreciates.

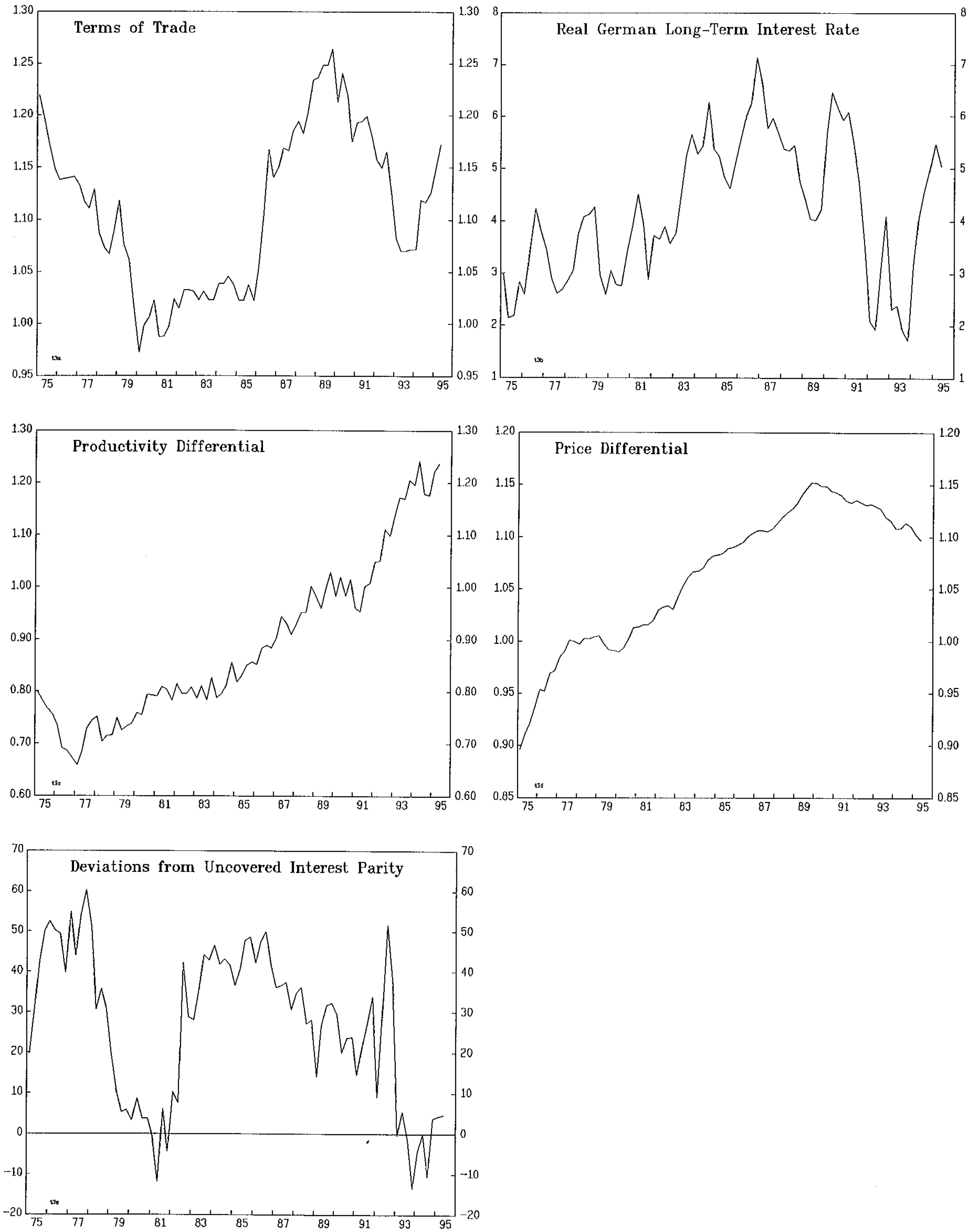
## III. Empirical Framework and Results

### A. Data

The data set spans two decades, starting in the first quarter of 1975 and ending in the second quarter of 1995 (Figure 3). All variables, except the interest rate, are in logarithms. For the real exchange rate, *reer*, the CPI-based real effective exchange rate calculated by the IMF, is used.[6] An increase in the rate means an appreciation. The productivity variable, *prod*,

[6]This definition differs from the real exchange rate in the theoretical section. For simplicity this paper concentrates on the CPI-based real exchange rate rather than that based on the relative price of tradables and nontradable goods or on the relative unit labor cost. For a detailed analysis of the difference between these definitions, see Lipschitz and McDonald (1992) and Hinkle and Nsengiyumva (1996).

# Figure 3. Determinants of Real Exchange Rates




Sources: International Financial Statistics, Bank of Finland, Competitiveness Indicator System, and staff calculation is the difference in productivity in the manufacturing sector between Finland and its trading partners.[7] The world interest rates, *r*, is the long-term real interest rate in Germany, deflated with CPI. The terms of trade, *tt*, are the price of exports relative to the price of imports.

Additional variables that are not directly taken into account in the theoretical section are also considered. The structure of trade, and therefore the exchange rate, permanently shifted as trade with the Former Soviet Union collapsed. This effect is captured with a dummy variable, *dum91*, which is unity starting in the first quarter of 1991. There are also large, one-time jumps in the real exchange rate because of devaluations. These points are singled out by using a dummy variable, *dumdev*, that is unity during the devaluation periods. Furthermore, as mentioned in Section 2, there are frictions both in the labor and the goods markets. These frictions do not let prices adjust immediately, as is assumed in the model. To capture these effects, the price differential between Finland and its trading partners, *ppoth* is used. For similar reasons, deviations from uncovered interest parity, *uip*, calculated by assuming perfect foresight, are also used.[8]

Government consumption and tariffs, quotas, and export subsidies that are discussed in the theoretical section are not included. Government consumption decomposed into tradable and nontradable goods is not available. Using the aggregate consumption variable would not be very meaningful, since variation in consumption because of different factors may bring completely opposite effects. A summary index of protection is not available in a usable form either.

Special attention is given to the time-series properties of the variables. Since fundamentals are defined as variables that affect the real exchange rate in the long run, they should have the same order of integration as the real exchange rate. If the real exchange rate is stationary, in the sense that it reverts to a particular mean, then the fundamental should be stationary too, and the standard econometric estimation procedures can be utilized. However, if the exchange rate is nonstationary, then any stationary variable cannot be a fundamental. This is because any variable that stochastically drifts permanently away from its mean cannot be affected in the long run by a variable that reverts to its mean; the effects remain only in the short run. Of course, nonstationary variables should be examined under the framework of cointegration.

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[7]The theoretical section emphasized the productivity difference between the tradable and nontradable sectors, but such data are not readily available. The productivity measure, and the expected effect on the exchange rate, still hold, given the definition of the real exchange rate.

[8]Another structural change, the liberalization of the capital account, has occurred within the sample. However, the changes were spread over several years; more importantly, there are indications that the restrictions were not binding even prior to their removal (see Kovanen 1995). Therefore, this structural break is not modeled.

The univariate statistical properties of the variables are summarized in Table 1.[9] The real effective exchange rate appears to contain a unit root: neither the Augmented Dickey-Fuller (ADF) test nor the Phillips-Peron (PP) test rejects the null hypothesis of a unit root, and the estimated roots are very close to unity.[10] This result is in line with other findings in the literature.[11]

Table 1
Time Series Properties of Individual Series

| Variable | Trend | Lags | ADF | PP |
|---|---|---|---|---|
| *reer* | No | 3 | -2.34 | -2.24 |
| *tt* | No | 2 | -1.41 | -1.65 |
| *r* | No | 2 | -3.20** | -2.64* |
| *prod* | Yes | 1 | -3.74** | -3.93** |
| | No | 1 | 0.85 | 0.97 |
| *ppoth* | No | 3 | -2.39 | -3.76*** |
| *uip* | No | 0 | -2.59* | -2.54 |

The unit root test results are mixed and inconclusive for some of the fundamentals. The existence of a unit root cannot be rejected in the case of the terms of trade. By contrast, the hypothesis of a unit root in the German long-term real interest rate can be rejected at the 5 percent level if the ADF test is used, and at the 10 percent level if the PP test is used. For the productivity differential, the null hypothesis can be rejected at the 5 percent level, irrespective of the type of the test, in favor of stationarity around a deterministic trend. The existence of a trend could at least be explained partly by the high investment ratio in Finland relative to its

[9]In all the tabulations, three stars means that the test statistic is significant at 1 percent probability, two stars at 5 percent probability, and one star at 10 percent probability.

[10]The results do not change when a break in 1991 is considered.

[11]For example, see Juselius (1995). For an exception, see Lothian and Taylor (1996), who found mean reversion in the US dollar/pound and franc/pound real exchange rates that span almost two centuries.

trading partners. If a deterministic trend in modeling the productivity differential is not included, the existence of a unit root is not rejected. The price differential (*ppoth*) appears strongly stationary under the PP test, but nonstationary under the ADF test. The *uip* variable has the opposite characteristic.

### B. Methodology

The cointegration technique is used to investigate the relationship between the real exchange rate and its fundamentals. As discussed above, there is a strong indication that the CPI-based real exchange rate in Finland does not tend to revert to any mean. Stochastic and deterministic trends are also found in the fundamentals. Such statistical properties of the data require the use of the cointegration technique, which is suitable for handling nonstationary data to search for a relationship between the variables of interest.[12] Another characteristic of cointegration is that the relationship that is found will hold in the long run, which is more appropriate for the fundamentals. The cointegration technique can also shed some light on the possible stationarity of some of the fundamentals: if a variable is stationary, then it should not statistically affect the cointegration relation and could be omitted.

For estimation, the full information maximum likelihood system approach is used (Johansen (1988, 1991), and Johansen and Juselius (1990)). The long-run relationship between the real effective exchange rate and the fundamentals is defined as follows:

$$e_t = x_t'\beta + z_t, \tag{3}$$

where $e_t$ is the real effective exchange rate, $x_t$ is the vector of the fundamentals, $\beta$ is the vector of cointegrating coefficients, and $z_t$ is the error term. If the exchange rate and the variables that are considered to be fundamentals form an equilibrium, then they should not deviate from each other too much for too long. This means that the error $z_t$ should be stationary. The exchange rate that is predicted from this equation is the long-run equilibrium rate that is defined by the fundamentals at each time period $t$.

The short-run dynamics consistent with the long-run equilibrium are modeled as an error correction mechanism (ECM):

$$\Delta e_t = \alpha z_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta e_{t-i} + \sum_{i=0}^{q} \delta_i \Delta x_{t-i} + \sum_{i=0}^{s} \xi_i \Delta w_{t-i} + \epsilon_t. \tag{4}$$

[12]Edwards (1994) uses least squares method in searching for the fundamentals. Elbadawi (1994) and Faruqee (1995) use the cointegration method, but within different theoretical frameworks.

Here, the change in the exchange rate is affected by its past changes, and by changes in fundamentals and other short-run variables, $w_t$. More important, it is affected by past deviations from the equilibrium. If, for instance, the exchange rate in the last period was overvalued relative to the fundamentals, then $z_{t-1}$ is positive. In this period, the exchange rate corrects itself by an amount dictated by the coefficient $\alpha$. Contemporaneous values of the fundamentals can be introduced on the right hand side if such variables are weakly exogenous, in the sense that in the long run they are not influenced by the disequilibrium. The coefficients of the contemporaneous differenced variables can also be interpreted as short-run elasticities. Lagged differenced values of the exchange rate and the fundamentals are introduced to whiten the error.

The full information maximum likelihood system approach for the estimation of (3) and (4) is the most efficient among the alternatives, if the assumptions on the data-generating processes of the random shocks to the system are valid (see Hamilton 1995). The errors should have normal distribution, should not be serially correlated, and should not have any conditional heteroscedasticity or nonlinearity. The diagnostic tests are performed by estimating an unrestricted VAR with sufficient lags to eliminate any remaining serial correlation, and then checking the properties of the residuals. The Jarque-Bera and the portmanteau tests are used to check for normality and serial correlation. For nonlinearities, squared terms of the variables are tested for significance.

Testing the existence of a relationship between the set of fundamentals and the real effective exchange rate is carried out by the Johansen cointegration test. Once cointegration is established, the significance of each variable in the cointegrating vector is tested. Accepting the insignificance of a variable may mean that that variable is not a fundamental. The fundamentals are also tested for weak exogeneity for the robustness of the model.

Next, the short-run adjustment is modeled by incorporating the cointegrating vector obtained from the Johansen procedure into the ECM. A search for the correct lag length is done from general to specific by starting with the longest lag length for all variables, and eliminating the insignificant ones.

## C. Results

### Cointegration diagnostics and results[13]

In the unrestricted VAR, three lags of the real exchange rate and its fundamentals are included. As fundamentals, terms of trade, the German long-term real interest rate, and the productivity differential are used. Time series properties justify using the terms of trade because there is strong evidence that this variable is nonstationary. The evidence for the interest rate and the productivity differential variables is less clear. Given the motivation in the

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[13]The results are obtained by using Eviews and PcGive econometric software packages.

theoretical section, these variables are included nevertheless; their relevance can also be checked in the form of testing for exclusion (see below). The shift dummy for the collapse of trade with the Soviet Union, the dummy that indicates the devaluation periods, and a trend term to explain the trend in the productivity differential variable are also included.

The outcome of the diagnostic tests on the residuals is of interest: if there are no indications against the validity of the assumptions for system estimation, the Johansen procedure can be used. The results of the diagnostic test are presented in Table 2. None of the test statistics rejects the null hypothesis in question. Three lags seem to be sufficient to eliminate any serial correlation in the residuals. The assumptions of normality and conditional homoscedasticity are not rejected for any of the residuals. There are no signs of a nonlinear relationship in the system, either.

Table 2
Diagnostic Tests

| | Test | Test Distribution | Test Statistic |
|---|---|---|---|
| reer equation | serial correlation | $\chi^2(9)$ | 16.89 |
| | normality | $\chi^2(2)$ | 4.52 |
| | ARCH | F(4,55) | 0.53 |
| | nonlinearity | F(27,35) | 1.75 |
| The whole VAR system | serial correlation | $\chi^2(36)$ | 122.24 |
| | normality | $\chi^2(8)$ | 8.72 |
| | nonlinearity | F(270,270) | 0.74 |

The results of the cointegration tests are shown in Tables 3 and 4. The trace statistics, adjusted for the degrees of freedom, point to a single cointegrating vector. Unadjusted for the degrees of freedom, both the trace statistic and the eigenvalue statistics indicate the existence of a cointegrating vector, and trace statistics hint at a second cointegrating vector.[14] There

[14]The unadjusted figures are also shown to give a sense of the lack of power that is due to a small sample.

may be a second cointegrating vector, especially if it is believed that the productivity differential is stationary, since it dominates the second cointegrating vector with its large coefficient.

Table 3
Cointegration Results

| Ho: p = number of cointegrating vectors | Eigenvalue statistics | | Trace statistics | |
|---|---|---|---|---|
| | Adjusted for d.f. | Unadjusted for d.f. | Adjusted for d.f. | Unadjusted for d.f. |
| p == 0 | 29.19 | 34.42** | 69.91*** | 82.43*** |
| p <= 1 | 21.62 | 25.49 | 40.72 | 48.02** |
| p <= 2 | 13.59 | 16.03 | 19.10 | 22.52 |
| p <= 3 | 5.51 | 6.50 | 5.51 | 6.50 |

Table 4
Cointegrating Vector Coefficients

| | *reer* | *tt* | *r* | *prodf* | *dum91* | *trend* |
|---|---|---|---|---|---|---|
| 1 | 1.00 | -0.90 | 0.09 | 3.75 | 0.18 | -0.03 |
| 2 | 1.00 | -0.10 | 0.40 | -2.60 | -1.17 | -0.00 |
| 3 | 1.00 | -0.74 | -0.03 | 0.23 | 0.05 | -0.00 |
| 4 | 1.00 | 13.14 | -0.43 | -14.29 | 1.14 | 0.00 |

The results of the exclusion and exogeneity tests are given in Table 5. The exclusion restrictions are all rejected, at least at the 10 percent significance level, lending support to the hypothesis that the real exchange rate and the vector of fundamentals are of the same order of integration. More important, these results imply that the terms of trade, real interest rate, and productivity affect the exchange rate in the long run.

Table 5
Exclusion and Exogeneity Tests 1/

| Variable | Test of exclusion from the fundamentals | Weak exogeneity test |
|---|---|---|
| *tt* | 2.66* | 0.15 |
| *r* | 3.66* | 0.03 |
| *prod and trend* | 12.00*** | 8.67*** |

1/ All tests have $\chi^2$ distributions with 1 degree of freedom, except the tests on prod and trend, where there are 2 degrees of freedom.

The tests also show that the terms of trade and the real interest rate are exogenous to the system, as expected. However, weak exogeneity in the case of the productivity differential is rejected.[15] It is conceivable that productivity can deviate from its trend because of some common factors that affect the exchange rate. Nevertheless, this effect can only be in the short run and cannot justify a feedback to productivity in the long run.

Given the theoretical discussion, all the fundamentals are modeled as exogenous, and the cointegration relation is estimated with this maintained assumption. The results imply that the equilibrium real exchange rate (*erer*) is determined as follows:

$$erer = 4.85 + 0.37{*}tt + 0.031{*}r + 0.85{*}prod - 0.14{*}dum91 - 0.006{*}trend. \qquad (5)$$

The coefficients are of the expected sign: the real exchange rate appreciates in the long run if the terms of trade improve, or the interest rate rises, or the productivity differential increases above the trend.

The short-run adjustment mechanism is modeled as an ECM. The implied error correction vector, $z_{t-1}$, from the Johansen procedure is used in the ECM, together with current

[15]This test is conducted jointly with the trend variable because the trend in the cointegrating equation was included only to model the trend in the productivity variable. If productivity is not included, the trend should not be included in the cointegrating vector either.

and past differenced fundamentals and other variables that affect the real exchange rate in the short run. Any variable that is not significant is excluded. The results are as follows:[16]

$$\underset{}{\Delta reer_t} = \underset{(0.10)}{0.54} - \underset{(0.02)}{0.11}{*}z_{t-1} + \underset{(0.07)}{0.29}{*}\Delta reer_{t-1} + \underset{(0.06)}{0.15}{*}\Delta reer_{t-2} + \underset{(0.25)}{0.59}{*}\Delta ppoth_t$$

$$- \underset{(0.002)}{0.005}{*}\Delta r_{t-1} + \underset{(0.015)}{0.077}{*}\Delta uip_t - \underset{(0.018)}{0.047}{*}\Delta uip_{t-1} - \underset{(0.006)}{0.037}{*}dumdev_t. \qquad (6)$$

All the coefficients are highly significant. The price differential has the expected sign: a higher price level in Finland leads to an appreciated real exchange rate in the short run. Similarly, a positive deviation from the uncovered interest parity leads to an appreciated exchange rate, although the effect is mostly reversed in the next period. As model validation, both lagged dependent variables are significant, justifying the use of three lags in levels, and the adjustment coefficient is almost identical to the one estimated in the Johansen method.

**Implications**

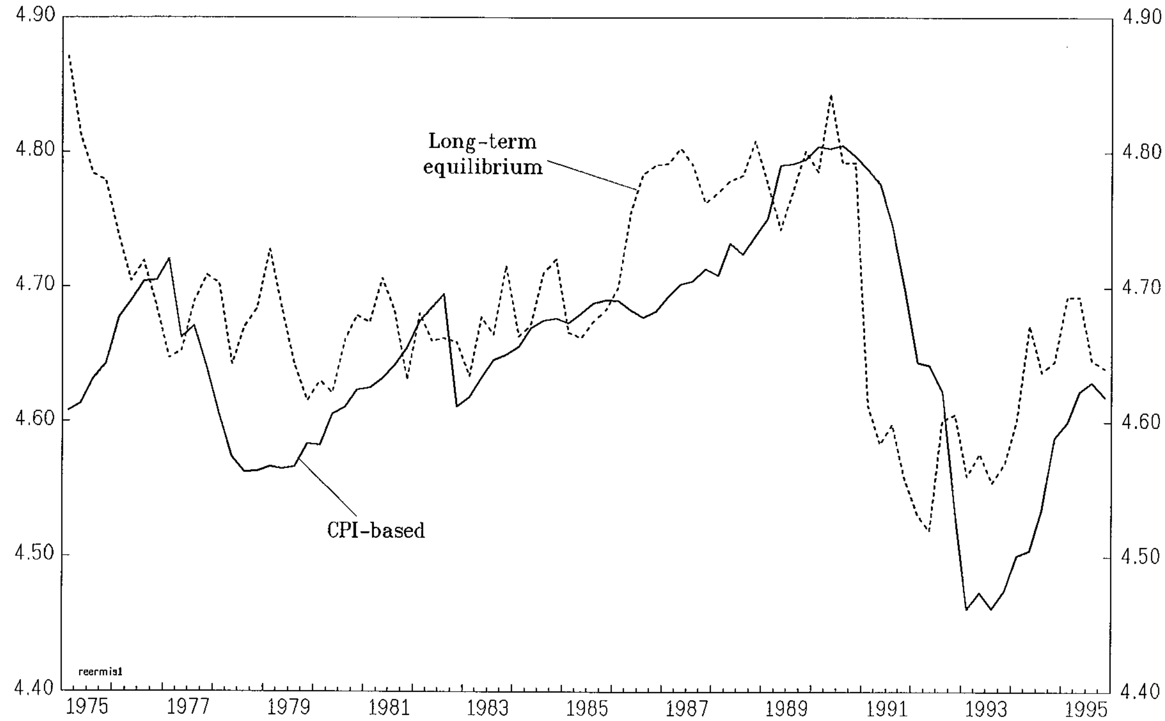
The fundamentals imply a long-run equilibrium exchange rate at each point in time that is calculated from the cointegrating vector estimated above (Figure 4). The movements of these estimated equilibrium rates can be explained by combining the individual effects of each of the fundamentals.

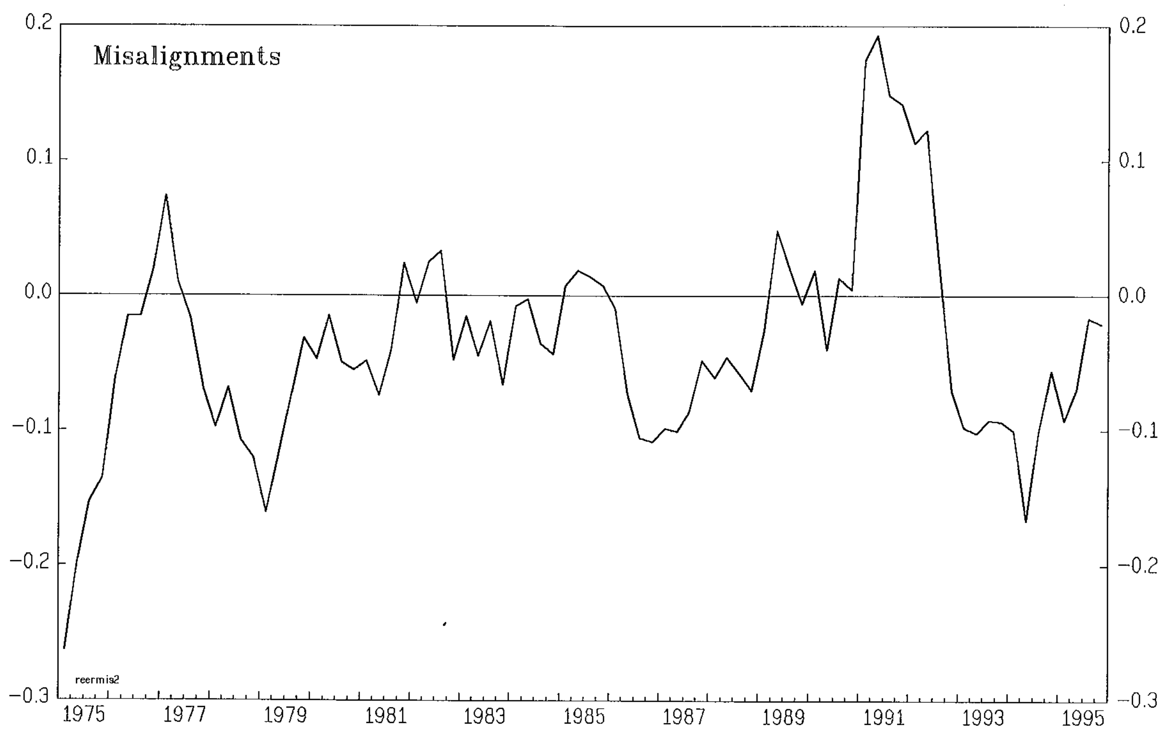
At the beginning of the sample, in 1975, there was a sharp decline in the equilibrium exchange rate as the terms of trade and the productivity differential fell. Subsequently, the equilibrium exchange rate seems to have been quite stable until the mid-1980s. During this period, the impact of a decline in the terms of trade was roughly offset by the effects of an increase in the world real interest rate and more rapid productivity growth.

In the past decade, the equilibrium exchange rate seems to have had two major shifts. In 1986, the equilibrium rate appreciated sharply, owing to a strong improvement in the terms of trade. The effect of a further improvement in the terms of trade in late 1980s was offset by that of a sharp decline in interest rates. This appreciated level of equilibrium was maintained until the beginning of the 1990s when the decline in world interest rates and relative productivity and a deterioration of the terms of trade caused the equilibrium rate to depreciate dramatically below the early 1980s level. This depreciation was also influenced by the collapse of trade with the Soviet Union. More recently, the recovery of the terms of trade and the

[16]The figures in parentheses are standard errors. All $t$-statistics are significant at 5 percent probability. Also, for the regression, $R^2 = 0.81$, and $F$-statistic = 38.48 with prob($F$-statistic) = 0.00.

## Figure 4. Equilibrium Real Effective Exchange Rate, 1975-95
(In logs)




Source: Staff calculations.

interest rate, combined with a sharp increase in relative productivity, has pushed up the equilibrium rate. However, since the structure of trade with the Baltics and Commonweath of the Independent States has changed, the previous equilibrium level has not been attained.

The actual exchange rate has sometimes deviated from the estimated long-run equilibrium exchange rate for long periods (Figure 4). As the equilibrium rate appreciated in 1986, the actual exchange rate remained undervalued for approximately three years, until 1989. When the equilibrium rate depreciated at the end of 1990, the actual exchange rate remained overvalued for two years before the markka was floated and the actual rate surpassed the equilibrium rate.[17] Subsequently, the markka stayed undervalued until 1995, when the markka seems to have converged back to a level that is broadly in line with the fundamentals.

The ECM can shed some light on the nature of these large deviations. The adjustment coefficient that captures how much a deviation from equilibrium influences the exchange rate is small: it takes approximately one and a half years for half of the adjustment to take place. Also, none of the contemporaneous differenced fundamentals is significant, implying that the short-run influence of the fundamentals is minimal.

The short-run deviations are explained primarily by the price differential between Finland and its trading partners, and deviations from uncovered interest parity. An increase in local prices relative to the prices of Finland's trading partners is not immediately reflected in the nominal exchange rate, and this leads to periods of overvaluation. This is a sign that there are substantial frictions in the labor and the goods markets. Similarly, there are important deviations from uncovered interest parity. As expected, an increase in the local interest rate (without a corresponding increase in the world interest rate) decreases consumption and leads to capital inflows, causing the exchange rate to appreciate.

## IV. Conclusions

The results of the estimation of the reduced form relationship between the real exchange rate and the fundamentals seem to be reasonable: the equilibrium real exchange rate appreciates with positive shocks to the terms of trade, world real interest rates, and the productivity differential between Finland and its trading partners. The short-run movements are also affected positively by the price differential between Finland and its trading partners, and by the deviations from the uncovered interest parity. The implied equilibrium pattern fits

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[17]The sharp decline in the estimated long-run exchange rate is partially due to the dummy variable set to switch in 1991, to capture the collapse of trade with the Soviet Union. Even though the largest one-time decline is in 1991, signs of weakening trade were present earlier. Since a smooth dummy is not used, the equilibrium exchange rate could have been overestimated just before 1991.

well with the expectations. The results also indicate that the real exchange rate deviates for long periods of time from its equilibrium value, and that the short-run influence of the fundamentals is minimal.

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