ESTIMATION OF THE BEHAVIORAL EQUILIBRIUM EXCHANGE RATE

by

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Abstract

ESTIMATION OF THE
BEHAVIORAL EQUILIBRIUM
ECHANGE RATE OF
UKRAINIAN HRYVNA

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The exchange rate is one of the major economic categories that link the country with the rest of the world. The predictability of the exchange rate is of great importance for economic development. The recent approaches suggest that PPP theory in general does not hold and assert that economic fundamentals influence the equilibrium exchange rate. One of these approaches, namely BEER, relies heavily on the multivariate cointegration techniques between the variables.

This study attempts to reveal the major determinants of the real equilibrium exchange rate of Ukrainian hryvna using the BEER model. It concludes that the productivity differentials and the net foreign assets influence the equilibrium value of real exchange rate, whereas the interest rate is insignificant.

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GLOSSARY

Nominal Exchange Rate – price of one currency in terms of another country's currency (Krugman, Obstfeld, 2000, p.329).

Real Exchange Rate – price of a typical foreign expenditure basket in terms of the typical domestic expenditure basket (Krugman, Obstfeld, 2000, p.329)

Nominal Effective Exchange Rate – the ratio of an index of the period average exchange rate of the currency in question to a weighted geometric average of exchange rates for the currencies of selected countries and the Euro Area (Introduction to IMF International Financial Statistics CD-ROM)

Real Effective Exchange Rate – the real effective exchange rate is a nominal effective exchange rate index adjusted for relative price movements at home country and foreign countries (Introduction to IMF International Financial Statistics CD-ROM)

Purchasing Power Parity theory – asserts that exchange rate between countries is equal to the ratio of their relative price levels, as measure by the money prices of a reference commodity basket (Krugman, Obstfeld, 2000, p.428-429)

Chapter 1

INTRODUCTION

The wide swings of both nominal and real exchange rates of some major currencies have always attracted a lot of attention from economists. The exchange rate is one of the major economic categories that link the country with the rest of the world. All the operations connected with foreign trade and investment deal with the necessity to convert one currency into another. Thus, the stability (or at least predictability) of the future exchange rate is a key issue for successful sustainable development.

Although most of the models developed so far are unable to accurately forecast the future exchange rates, the latest approaches claim to allow the determination of the major factors that cause changes in the exchange rate and to enable detection of the direction of possible misalignment.

Attempts to find a relationship between an exchange rate and macroeconomic variables have been made for a long period of time. The major problem of the "old" concepts is their poor forecasting properties. The statistical framework, described in Johansen's paper "Likelihood-based inference in cointegrated vector autoregressive model", published in 1995, gave rise to a new generation of econometric forecasting models. One of the most popular of this family, namely BEER, attempts to link the effective exchange rate of a currency to a set of economic fundamentals as well as changes therein. The most popular macroeconomic variables that are usually considered are the real interest rate differential between countries (regions), the productivity differential, the relative fiscal stance, time preferences and the accumulated current account.

The advantage of BEER over the similar models stems from two key advantages of utilizing the error-correction technique:

- It allows to deal directly with I(0) and I(1) series, thus excluding the problem of non-stationarity. As a result, model allows incorporating the long-term relationship between the variables, as well as short-run dynamics.
- It makes possible the further disintegration of the total influence of macroeconomic variables into permanent and transitory components within the framework of the model. This decomposition was described by J Gonzalo and C.W. Granger in 1995, and then has been of much interest in the modern economic literature.

The thesis will focus on the analysis of the factors that influence the UAH / USD exchange rate in the medium run within the Behavioral Equilibrium Exchange Rate (BEER) concept. The objectives of the paper are the following:

- To determine the main factors that influence the equilibrium exchange rate of hryvna,
- To estimate the current equilibrium exchange rate and to determine the under/overvaluation of the current exchange rate.

It is worth noting that since the BEER approach is very recent, most of the economic research that describes its application dates to the years 1999-2001 and was published within the working papers series of the IMF and the ECB. Among the first practical findings investigated with model was the undervaluation of the euro against the US$ in 1999-2000 and the forecast of the reverse trend. As Maeso-Fernandez states "while the estimated results are far from being precise, they, nevertheless, may "suggest the direction of misalignment … when discrepancies between the estimated equilibrium values and the actual exchange rate become extraordinary large[1]".

The model I apply in my research is similar to those found in the Maeso-Fernandez et al (2001), and Clark and MacDonald (1998, 2000). The data for the analysis are taken form IFS by the IMF, the Federal Reserve System, the Bundesbank Statistik, publications of ECB, Ukrainian Ukrainian-European Policy and Legal Advice Centre (UEPLAC), Dzerzhkomstat, Ukranews as well as other Ukrainian information sources.

Prior inspection of the data and the model revealed the following problem. Since the new currency "Hryvna" was introduced in 1996 and a new strategy of monetary policy was accepted, it is reasonable to suspect a structural break at this time and to restrict the analysis to monthly data sample of the years 1997-2003. However, because of a "degrees of freedom" problem, we will need to restrict the number of lags in the model.

If, as expected a priori, the study finds evidence of cointegration between the effective exchange rate and interest rate differentials, a complete and correctly specified model will then make it possible to forecast the dynamics of exchange rate over the long run, given the dynamics of other relevant macroeconomics variables or within an autonomous model. Although "de facto" the exchange rate may be different because of the "crawling peg" policy of the Ukrainian central bank, in the long run it would be reasonable to expect the exchange rate to converge to its equilibrium estimate.

[1] Maeso-Fernandez et all (2001)

CHAPTER 2

LITERATURE REVIEW

Here I present a brief overview of the most important approaches and their practical applications.

The RER is usually defined as $R = EP/P^*$ or $R = EW/W^*$, where R denotes the real exchange rate, E denotes the nominal exchange rate (defined as the price of domestic currency in terms of the foreign currency), P is a domestic price index, W is a domestic cost index. The asterisk denotes the corresponding price and cost indices abroad.

The first attempts to determine the factors that influence the nominal exchange rate began with the development of the Purchasing Power Parity (PPP) theory. This theory postulates that inflation differential between the countries should be reflected in a corresponding change of the nominal exchange rate, so that the real exchange rate is constant over time.

However, numerous studies on PPP failed to find support to the stationarity of the real exchange rate. This led to development of a wide variety of new econometric techniques (for example Augmented Dickey-Fuller test for panel data), which aimed at determining if PPP between major currencies holds. However, no conclusion about the stationarity of RER was made.

The nineties gave birth to a new wave of studies of PPP. As Duval (2001) states, these studies can be divided into three groups: bilateral studies in favor of a weak version of PPP during the recent float, bilateral studies in favor of a strong version of PPP in the very long run, and panel studies in favor of strong version of PPP in the short run.

The first group of studies tried to find cointegration between the nominal exchange rate and price indices in different countries. The rationale behind this approach is a possible variable measurement bias. For example, Duval (2002) argues that given the different methodologies for estimating the price index accepted in different countries, the stationarity of the RER (that is strong version of PPP) is not likely to hold. However, a weak form of PPP, that is a cointegrating vector, may still be present. Although in these studies the cointegrating vector was indeed found (see, for example, MacDonald (1993), Cheung & Lai (1993)), in most cases the magnitude of the estimated coefficients cast doubts about the validity of PPP.

In the second group of studies the authors suggest that non-stationarity of RER stems from the low power of the available unit root tests. In order to overcome this problem the authors extended the sample to cover a hundred years of data. Although some authors managed to find evidence favoring PPP (see for example Frankel (1986), Duval (2001, op.cit.)) mentions several possible sources of problems with this approach. The first may stem from the data having inherent sample selection bias. Since data only for few leading developed countries are available, this may not allow the Balassa-Samuelson effect, which is one of the most important causes of deviations from PPP, to develop (see the discussion later in text). Also, the speed of convergence of RER to PPP appears to be very low. The data also cover both periods of fixed and floating rate regimes, and there's not enough evidence that PPP should hold regardless of the regime. This problem was addressed by Lothian and Taylor (1996). Although the authors did not find any evidence of a structural brake over the change to a floating exchange rate, Duval (2001) argues that this finding should be confirmed in further studies.

The third group of studies applies the unit root test to panel data. The results of these studies are even more ambiguous, with most of the uncertainty here stemming from the underdevelopment of unit root tests. For example, several studies face the problem of non-neutrality of tests: the null was rejected in case of dollar/mark exchange rate, but the tests failed to reject it in case of mark/dollar exchange rate.

As Duval (2001, op. cit.) points out, the next generation of panel unit root tests did not suffer from this problem, but the results again were ambiguous. Some studies confirmed the stationarity of RER, whereas the others did not find evidence in favor of PPP. Since panel unit root tests have been developing for a last decade only, we may see further studies in this area, which would rely on more advanced testing procedures.

However, a different strand of economic theory itself suggests that PPP should not be expected to hold. One of the most convincing arguments for deviations is the well-known Balassa-Samuelson effect, which states that the RER is positively related to the relative productivity in the traded goods sector. Hence, a productivity shock in one country in comparison to the other would cause non-stationarity of the RER. Duval (2001) tests this hypothesis over 1970-1996 for 19 sectors of 14 countries and finds that "long run PPP does not seem to be verified for tradable goods, particularly for three main international currencies".

The uncertainty about the PPP condition has led the way to a completely different concept of the equilibrium exchange rate. The equilibrium condition requires both internal and external balance. Internal balance means the economy works at full output level, inflation is stable and the level of unemployment is at the equilibrium level. The external balance implies that speculative capital flows and changes in official reserves are zero. The concept of equilibrium exchange rate then implicitly assumes imperfect competition (as opposed to PPP concept). The equilibrium RER (ERER) would then depend on both capital and trade flows of a country.

This concept served as a base for three main approaches. The first of them, the Fundamental Equilibrium Exchange Rate (FEER) was described in Williamson (1994). Later, Isard and Faruqee (1998) developed this approach further into the Macroeconomic Balance Approach.

The main feature of the FEER is that it postulates the existence of an equilibrium level of the exchange rate when the economy has achieved both internal and external balance. Internal balance means the country is growing at the long run sustainable growth rate with the unemployment is at the NAIRU level. The external balance assumes that a country has the stable targeted current account balance. Although some economists support a balanced current account, Church

(1998) argues that it need not be the case, since then a country will forego the benefits stemming from a desired positive or negative current account. It is required, however, that the current account flows are counterbalanced by the capital account flows.

Some economists believed that the significant shortcoming of the FEER models is that they do not allow for interactions between stocks and flows within an economy. In other words, the FEER model is based on comparative statics. The approaches that are void of this shortcoming (that is are dynamic in nature) and are most commonly used today are the BEER and the Natural Equilibrium Exchange Rate (NATREX).

The BEER approach was developed by Clark and MacDonald (1999), and since then has become popular in international economics. Like many other models it is based on cointegrating relationship between variables. The peculiarity of this approach is that it is mostly econometrical rather than economical. The set of variables, which are expected to influence the exchange rate, are plugged into the equation and then either an error correction model or a vector error correction model is applied. The most common variables in the analysis include the real interest rate differential, the productivity differential to capture the Balassa-

Samuelson effect, the relative fiscal stance and the accumulated current account balance.

A further evolution of the BEER approach is connected with the development of statistical procedures, which could distinguish between permanent and transitory effects of variables (see Gonzalo and Granger(1995)), thus allowing the derivation of the Permanent Equilibrium Exchange Rate (PEER). As Maeso-Fernandez et al (2001) claim, the PEER methodology models a time-varying RER but at the same time "places even less normative structure on the model and its computations". The model can clearly contain different key macro variables, such as the real price of oil, terms of trade, and net foreign assets, which are expected to influence the real exchange rate. Thus, we can view the BEER/PEER approach is as more an econometric than a theoretical one. As Duval (2001) points out, the significant advantage of this model is that it possesses a dynamic adjustment to the long-term equilibrium level and captures the Balassa-Samuelson effect.

The NATREX model, as opposed to the BEER model, has a solid background in economic theory. It represents a set of reduced form exchange rate equations taken from a global macroeconomic model. The regressions attempt to link RER with the current account, savings and investments. The distinguishing feature of the NATREX model is that there is a distinction between the long and medium run, which as Detken and Martínez (2001) point out, consists in slow convergence of current account and net foreign assets variables to a steady state. Similarly to the BEER model, the NATREX approach is also open to different possible model specifications.

Recently a number of studies have been conducted, which aimed to estimate the RER and also attempted to determine the factors that influence it in the medium and long run. Most of them focus on the weak performance of euro and try to evaluate, whether this performance is in line with fundamentals or there is a misalignment between the nominal exchange rate and the expected real exchange rate.

Duval (2002, op. cit.) is a comprehensive study, in which the author compares the different PPP vs. macroeconomic approaches. He also built a combined BEER/NATREX model and then applied it to Germany, Italy and France, considering them to be a proxy for the euro area. He then estimates the euro/dollar real exchange rate and comes to the conclusion that the combined BEER/NATREX model clearly demonstrates an advantage over PPP models and naïve random walk models on "direction of misalignment" and speed of convergence criteria. In other words, his BEER/NATREX model seemed to overcome the major problems of PPP approach and showed better performance at detecting under/overvaluation of a particular currency and suggested the probable direction of further movement. The author also notes that when comparing the BEER and the NATREX models, the latter should be preferred, at least on the basis of theoretical reasons.

An example of applied FEER model is Church (1998). The author addresses the question of overvaluation of British Pound relative to Deutsche Mark. He suggests that this overvaluation should catch attention of policy makers when fixing the exchange rate, if the UK is considering entering a monetary union. He concludes that if the nominal exchange rate is fixed at an overvalued level, it would put pressure on the UK to keep its inflation below the level of the monetary union, which could be a difficult problem given the wage and price rigidities in the UK.

Maeso-Fernandes et al (2001) applies the BEER model to a sample of quarterly data that cover the period from 1975 to 2000. They use the 1975-1998 period to apply Johansen's procedure to estimate four different specifications and leave the 1999-2000 period to test the model out-of-sample. The authors found that the RER of euro depends mostly on productivity and real interest rate differentials, as well as external shocks coming from changes in oil prices. They also came to the conclusion that euro was not in line with underlying fundamentals in 1999-2000.

MacDonald (2001) claims that productivity, real interest rate differentials and terms of trade play a significant role in the movement of the RER of the New Zealand dollar and suggests that the New Zealand dollar has been significantly undervalued since 1999.

Rajan et al. (2000) applies the Equilibrium Real Exchange Rate and the NATREX models to find out whether the currency crisis in Thailand, when a Thai baht, formerly pegged to the US dollar, was devalued, could have been forecast. The authors regressed the RER on the real interest differential, real government spending, productivity index and the terms of trade. Their main conclusion was that because of the macroeconomic situation, the existing baht/dollar peg was not optimal and should have caused concern for policy makers.

In an interesting study of behavior of the RER in transition economies De Broeck and Sløk (2002) find that in most transition economies there is a clear trend of RER appreciation, which is driven mainly by the growth of productivity levels (De Broeck and Sløk, 2002). Their conclusion is that since ex-USSR countries are at the very beginning of their transition towards a market economy, the appreciation of their national currency should be expected.

Another practical application of the RER model to transitional economies was made by Ódor Ľudovít and Katarína Kohútiková (2001). Using several methods including BEER, the authors tried to forecast the over/undervaluation of the Slovak crown using 1995-2001 data. Although the results of different models were quite similar, the authors suggest that the BEER approach is of major interest when forecasting the exchange rate.

The approach that is used in this thesis is based on BEER model. The variables of major interest are the nominal exchange rate of hryvna vs. US dollar, euro, Russian rouble, CPI indicators for the respective countries, relative prices of tradable vs. non-tradable goods, the indicators of fiscal stance and the current account. Most of the variables are non-stationary, hence, the VECM is an appropriate specification of the model. A single-equation estimation (ECM model) will also be estimated in an attempt to find a more parsimonious, and hence a more efficient model. The data will be taken on a monthly basis covering the years 1996-2002.

Chapter 3

THE DEFINITION OF VARIABLES

The model applied is similar to the one applied in Maeso-Fernandez et al. (2001) and Clark and MacDonald (2000, op. cit.).

The uncovered interest rate parity (UIP) states that ignoring risk premia

$$E_t (\Delta s_{t+k}) = -(i_t - i_t^*), \qquad (1)$$

where s_t is nominal exchange rate at time t (in units of foreign currency per unit of domestic currency), it is the nominal interest rate at time t for deposits maturing at time t+k, E_t is a conditional expectations operator, Δ is a first difference operator, * denotes a foreign variable. Hence, $E_t (\Delta s_{t+k})$ represents an expected change in the nominal exchange rate over the t+k time frame. To come to real terms we need to subtract the expected inflation differential

$$Et (\Delta pt+k - \Delta pt+k^*) \qquad (2)$$

from both sides of the equation. The final expression will give us the real exchange rate, q:

$$q_t = E_t(q_{t+k}) + (r_t - r_t^*), \tag{3}$$

or, equivalently

$$E(\Delta q) = - (r_t - r_t^*).$$

This expression shows that the current real exchange rate depends on the ex ante expectation of the real exchange rate at time t+k and the real interest rate differential. Further, following Maeso-Fernandez et al methodology, q_t' will denote the current equilibrium exchange rate and $\bar{q}$ – the long run equilibrium exchange rate. Let θ denote the speed of convergence of the current real exchange to long-term equilibrium value. Thus we arrive at the following equation:

$$q_t' = \bar{q} + 1/\theta \cdot (r_t - r_t^*) \tag{4}$$

The next step in the analysis is to determine the factors that will possibly influence the long run EER. The most important is the Balassa-Samuelson effect, tnt, which measures the ratio of tradables goods versus non-tradables and is a proxy for productivity differential among countries.

Denoting the share of traded goods in domestic country as α, the share of traded goods in a foreign country as β, (logarithm of) price of traded goods as p^T, (logarithm of) price for non-traded goods as p^N, then we obtain the following equations for price changes in domestic and foreign countries

$$p_t = \alpha \cdot p_t^T + (1-\alpha) \cdot p_t^N ,$$

$$p_t^* = \beta \cdot p_t^{*T} + (1-\beta) \cdot p_t^{*N}$$

If the arbitrage condition for internationally traded goods holds then we obtain the following equation:

$$\overline{q}_t = q_t^T + \alpha \cdot (p_t^N - p_t^T) - \beta \cdot (p_t^{*N} - p_t^{*T})$$

Hence, the increase in productivity in traded goods sector will lead to appreciation of the real exchange rate.

Another variable of interest is the productivity differential, *prd*, which will be estimated as GDP per employee. This variable is included as another proxy for productivity differentials. Ideally this variable should have the same expected sign as the previous variable, but since they address the different effects of increase in productivity, it may happen that they will have conflicting signs.

Lane and Milesi-Ferretti (2000) found a significant long-term relationship between the net foreign assets and the real exchange rate. The authors claim that the increase in country's liabilities, controlled for all other common indicators, leads to depreciation of the currency. They suggest that net foreign assets should be used in estimation of the real exchange rate.

Hence, the model of interest will be the following:

$$q_t' = \bar{q}(tnt, prd, nfa) + (1/\theta)\cdot(r_t - r_t^*) \quad (5)$$

or

$$q_t' = q_t^T + \alpha \cdot (p_t^N - p_t^T) - \beta \cdot (p_t^{*N} - p_t^{*T}) - \gamma \cdot (g_t - g_t^*) + \frac{1}{\theta}(r_t - r_t^*)$$

As can be seen, the real interest rate differential is assumed not to influence the long-term equilibrium exchange rate. As Clark and MacDonald point out, the real interest rate usually indicates the fluctuations in the business cycle rather then long-term movement.

Chapter 4

ECONOMETRIC METHODOLOGY

The econometric methodology is based on Engle-Granger's and Johansen's cointegration analysis between the variables.

The starting expression is the VECM representation of the model:

$$\Delta y_t = \alpha + \sum_{i=1}^{p-1} \Phi_i \Delta y_{t-i} + \Pi y_{t-1} + \varepsilon_t \quad , \qquad (5)$$

where y_t is a (n*1) vector of variables under analysis, μ is a (n*1) vector of constants, Φ is a (n*(k-1)) matrix of short-run coefficients, et vector of error terms, Π is a (n*n) matrix of coefficients. If matrix Π has a reduced rank (0<r<n), than it can be split into two matrices:

- *(n*r)* matrix of loading coefficients α, which measures the speed of convergence to equilibrium, and
- *(n*r)* matrix of cointegrating vectors β, which represents the long-run equilibrium relationship.

It follows that $\Pi = \alpha\beta'$.

Johansen also suggested the moving average representation of the equation (5):

$$y_t = C\sum_{i=1}^{n}\varepsilon_i + C\eta + C(L)(\varepsilon_t + \eta)$$, where

$$C = \beta_{\perp}(a_{\perp}^{'}(I - \sum_{1}^{k-1}\phi_i)\beta_{\perp})^{-1}\alpha_{\perp}^{'} = A\alpha_{\perp}^{'}$$

and $\alpha_{\perp}$ and $\beta_{\perp}$ are the orthogonal complements of α and β. $\alpha_{\perp}$ spans the space of the common stochastic trends, i.e. it identifies the linear combination of variables that form the common trends or driving forces of the system. The matrix '*A*' represents the loading factors of the common trends, which indicates to what extent each trend influences each variable. The *C* matrix measures the combined influence of the orthogonal components, i.e. the long-run effect of shocks to the system.

Gonzalo and Granger propose to decompose the non-stationary time series into stationary and non-stationary series, that is:

$$y_t = P_t + T_t.$$

Then if there's a cointegrating relationship between the variables, the number of non-stationary elements is smaller than the number of series. This enables us to further decompose the time series into permanent and transitory components, as

$$P_t = \beta_\perp (a_\perp^{'} \beta_\perp)^{-1} \alpha_\perp^{'} y_t = A_1 f_t$$

$$T_t = \alpha(\beta' \alpha)^{-1} \beta y_t = A_2 \beta' y_t ,$$

and derive the Permanent Equilibrium Exchange Rate.

Chapter 5

DATA DESCRIPTION

In my estimation I used the following variables as possible determinants of real exchange rate: two different proxies for productivity differential, interest rate differential and net foreign assets. The description of the variables is given below.

1) Real effective exchange rate (*reer*)

The monthly data on CPI based multilateral REER are available from International Financial Statistics database. According to the IMF methodology, the real effective exchange rate is a nominal effective exchange rate index adjusted for relative price movements at home country and foreign countries. The nominal effective exchange rate is, in turn, is the ratio (expressed on base 1995=100) of an index of the period average exchange rate of the currency in question to a weighted geometric average of exchange rates for the currencies of selected countries and the Euro Area. In this case we have a Ukrainian currency index over the foreign currency index. An increase in REER would indicate the real appreciation of the home currency. In the analysis the log of this variable is used.

The ADF-test does not allow rejecting the null of unit root in levels, but clearly rejects it in first differences[2]. The diagram also clearly shows the downward trend in the behavior of the variable[3].

2) Trade weights

Although this variable does not enter any of the equations directly, it is used in estimation of three other variables. The trade weights were calculated using the Derzhkomstat (State Committee for Statistics) volume of trade data for 1997 - 2002, with three major trade groups: Russia, Europe (represented by Germany, Italy, Spain and the Netherlands) and the rest of the world. The monthly data covering years 1997-1998 were taken "as is", whereas the quarterly data for years 1999-2002 were equally distributed between the three months of the respective quarter.

3) Productivity differential (*prd_tw*)

This variable serves as a direct proxy for differences in productivity changes in Ukraine and its trading partners. The variable is calculated as a (logarithm of) the ratio of GDP per employee in Ukraine and its major trading partners.

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[2] The results of the ADF test are sensitive to autocorrelation in residuals. To address this issue the lagged regressand values were added to the ADF test equation as regressors. The number of lags was taken so that results of LM serial correlation test showed no serial correlation in residuals in ADF test equation.

[3] See Appendix 1

The nominal GDP data for Russia and Ukraine in national currency units were converted into nominal dollars with the official exchange rate, whereas for Germany the monthly GDP index data were utilized[4].

The quarterly data on the number of employed for Ukraine were taken from UEPLAC and then linearly interpolated to get monthly data. For Russia, the number of unemployed (in nominal terms) and percentages of labor force was taken to arrive at an estimate of total labor force and then by subtracting the amount of unemployed converted to the estimate of employed in the economy. The monthly data on employment for Germany were taken from the Bundesbank Statistik.

For the *prd_tw* variable the weight for Russia represents the share of Russia in total trade. The remaining weight, however, was assigned to the productivity indicator of Germany. In other words, German productivity data were taken as a proxy for the rest of the countries. This variable enters the equation in logs.

The ADF test indicates the non-stationarity of *prd_tw* in levels, whereas it clearly rejects such non-stationarity in first differences.

[4] It can be shown that an index number with the fixed base can be used instead of GDP if the variable is expressed in logarithm (which is the case). Then the only coefficient that becomes unreliable is the intercept, with all slope coefficients being unchanged.

3) Tradables/nontradables (*tnt_tw*)

This variable serves as another proxy for productivity differential. Whereas the data on tradable and non-tradable goods are not directly available[5], one of the most popular proxies is the (logarithm of the) ratio of CPI to PPI. Ideally one would expect this variable to be correlated with *prd_tw*. However, as Maeso-Fernandez et al point out, this will not necessarily be the case. For example, the increase productivity in the non-tradable sector of the economy would lead to an increase in *prd_tw,* but to the decrease in ratio of prices in non-tradable/tradable sectors.

The monthly data for all countries were taken from IFS database. The weighting scheme that was used to estimate the CPI/PPI ratio for main trading partners was different from the one used in estimating the *prd_tw* variable: weights for the three major trading groups were assigned to CPI/PPI ratio of Russia, Germany and the USA.

The diagram clearly shows the sudden fall in this variable during the summer of 1998, which corresponds to the Russian crises. At that time the CPI in Ukraine was growing at a slower rate than the PPI, whereas in Russia the opposite happened. It should be noted, however, that such pattern in data still remains if we exclude Russia from synthetic variable of Ukrainian trade partners. This indicates that the Russian crises had a significant influence on the Ukrainian economy, and caused large deviations in CPI/PPI ratio. Because of this structural break, the apriori expected sign of this variable is ambiguous.

The ADF test suggests that this variable is non-stationary in levels and stationary in first differences.

4) The real interest rate differential (*ird_tw_12*)

This variable indicates the difference between the real interest rate in Ukraine and the weighted average of the major trading partners. The money market rate for both countries was used as a proxy for the medium term interest rate. This is the best rate for which the data are available, and is consistent for all the regions.

The nominal money market rate was discounted by the trailing CPI of the past 12 month to obtain the real future expected interest rate. However, this method implicitly assumes that the individuals make their forecasts of the CPI and, as a result, of the future real exchange rate on the basis of last year's data. This means that their forecasts are somewhat backward looking. To make a forward looking forecast one may need data from monthly surveys of expected inflation in future. This kind of data is unavailable in Ukraine.

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[5] Alternatively one could use the data for economy sectors that produce tradable or non-tradable goods as

The ADF test suggests rejecting the null hypothesis of a unit root in the levels of this variable, which is consistent with the prior expectations and other studies.

5) The net foreign assets variable (*nfa*)

This variable describes the movement of the net foreign assets variable, defined as a percentage of the Ukrainian GDP. The data were taken from the IFS and UEPLAC databases. The ADF test indicates that this variable is difference stationary. The results of the stationarity test are summarized in table below.

Table 1. Results of the ADF test

Variable	Number of lags in ADF test	Test statistic	5% Critical value
d(reer)	2	-5.6557	-2.9042
d(prd_tw)	2	-5.4367	-2.9101
d(tnt_tw)	2	-2.9394	-2.9101
d(nfa)	2	-3.6328	-2.9101
ird_tw_12	2	-3.8437	-2.9035

suggested by Duval (2001). However, these data was also not available in the consistent form.

Chapter 6

ESTIMATION

As follows from the previous section most of the variables, including the real effective exchange rate, in our data sample are non-stationary. The next step is to determine whether there is a cointegrating vector between the non-stationary variables, i.e. to determine whether a linear combination of these variables is stationary. Since the *ird* variable is stationary it will not be included in the cointegrating equation.

The cointegrating vector can be found by either the Granger two step procedure or by the Johansen cointegration test. The second way is more appropriate for the vector error-correction specification of the model, since it incorporates all the available information into the likelihood function.

The Johansen cointegration test reports no cointegration at 5% level between the variables. However, one may assume that the productivity differential may influence the real exchange rate after a lag. An attempt was made to find cointegration between the current values of exchange rate and net foreign assets variable and lagged productivity differential. In this model the Johansen cointegration test suggests that one cointegrating vector is present (at 5 %

confidence level) with one and four lags included into the model6. The results of the cointegration tests are summarized in the tables below.

Table 2. Significance of the Cointegrating Vectors (Trace Test)

H_0: r	Eigenvalue	Trace Statistic	5% Critical Value	1% Critical Value
0	0.510090	63.12835	53.12	60.16
1	0.268171	26.02464	34.91	41.07
2	0.153766	9.789777	19.96	24.60

Table 3. Significance of the Cointegrating Vector (Max Eigenvalue test)

H_0: r	Eigenvalue	Max Eigen Statistic	5% Critical Value	1% Critical Value
0	0.510090	37.10371	28.14	33.24
1	0.268171	16.23486	22.00	26.81
2	0.153766	8.681857	15.67	20.20

[6] Ideally twelve lags should be included into the model to address the seasonality and autocorrelation issue. However because the data sample is not large enough, inclusion of all the lags is not feasible because of the degrees of freedom problem mentioned earlier. On the other hand, one should strongly suspect the presence of autocorrelation in monthly time series and hence include a sufficient number of lags. The other studies use either yearly data sample (with one lag included) that covers at least several decades or quarterly data by again extending the sample.

The next step is to build an appropriate VECM model. At this stage an observation-specific dummy variable for the ninth month of 1998 was introduced to capture any influence of Russian crises. In all the model specifications this variable is highly significant.

One of the productivity variables, namely the *prd* has the wrong sign. This is not very unexpected, since the productivity differential has been constantly growing in the sample period, whereas the depreciation of the real exchange rate was observed. Also, the interest rate differential is insignificant. Although the last finding might be in contradiction with theory, it is in line with empirical findings (see for example, Maeso-Fernandez et al (2001)

The multivariate normality test cannot reject the normality of the residuals at 5% p-value, although rejects it at 10 % value. This result enables us to use inference procedures for the VAR part of the VEC model. On the other hand, LM test suggests the presence of first and third order serial correlation.

The adjustment matrix is given below. It suggests that cointegrating vector is significant at 5 % level and is within the interval (-1;0) in the REER, PRD_TW and TNT_TW equations and is insignificant in NFA equation of the model.

The adjustment coefficient of the main *reer* equation is somewhat high. It shows that approximately 17 % of a deviation from the equilibrium level will be eliminated in one month, which corresponds to approximately 90% elimination in one year[7]. This is, however, broadly consistent with Clark and MacDonald (2000), which report 70% elimination within one year. They also assert that this is a main advantage of the exchange rate models, which are conditional on fundamentals. In the studies where REER was conditioned solely on lagged values of REER, the half-life period was around 20 years.

Table 4 . The Adjustment Coefficients Martrix

Dependent Variable of the Equation	Adjustment Coefficient	T-statistic
reer	-0.169087	-2.03
tnt_tw	-0.149416	-2.33
prd_tw	-0.803059	-2.87
nfa	-0.160643	-0.24

The diagram in Appendix 3 shows the impulse response function for each variable incorporated in the VECM model.

7 The calculation is 17 % will be eliminated in one month, 17 % of the remaining gap in the next month etc.

It is apparent from the figure that all the variables converge to a constant other than zero, which may be an indication that the model is non-stable. Although this is a common finding in such studies, a further diagnostic check may shed some light. Appendix 4 reports the roots of characteristic polynomial

As can be seen, there are 3 roots of inverse polynomial that are equal to unity. This is a requirement of the VECM specification. However, all the rest of the roots lie within the unit circle, as it should be. This may be viewed as an indication of model stability. The diagram in Appendix 5 plots the inverse roots of the polynomial.

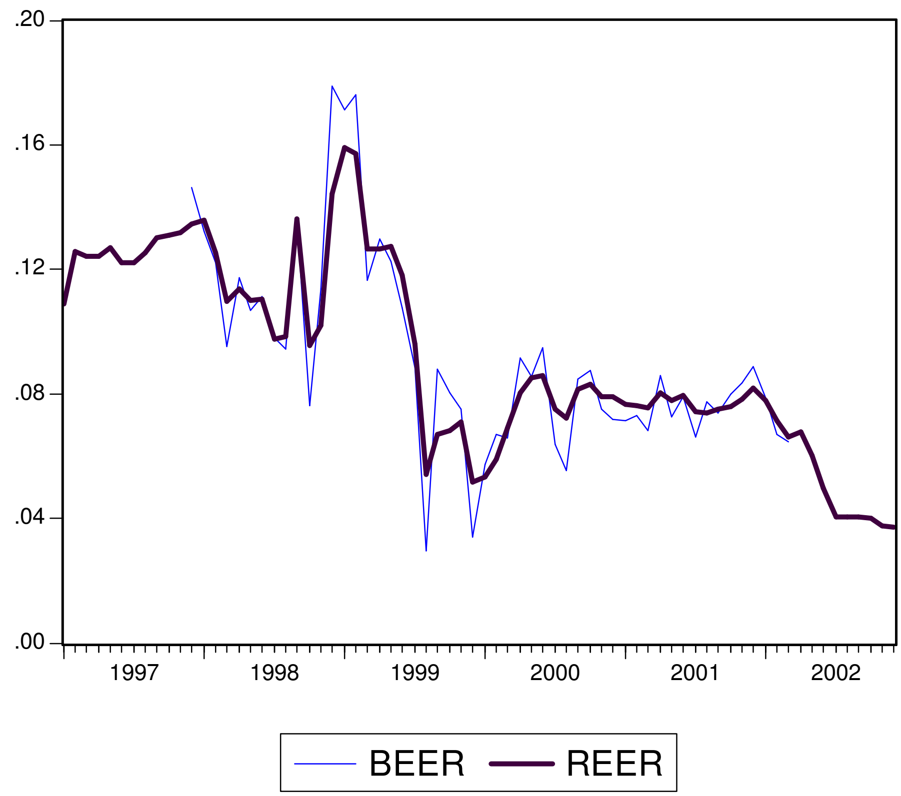
The BEER and the REER are shown on the Fugure 1 below. As can be seen, the BEER is more volatile (which is as expected mainly because it uses monthly time series) however the model provides quite a good fit to the data. Also the diagram suggests that the hyrvna is broadly in line with our forecasts.

However, I would not put much weight on this conclusion mainly because of the high volatility of the estimated exchange rate.

The next step in the analysis is to check the model for a change in variables.

This results in 89.3% elimination in twelve months.

Figure 1. The comparison of BEER and REER



If we replace the trade weighted interest rate differential with the real interest rate differential between hryvna and US dollars, this will cause the absolute values of the coefficients to change to a small degree, but the variables remain statistically significant and signs remain unchanged. The interest rate differential also does not seem to impact the real exchange rate.

CONCLUSIONS AND POLICY IMPLICATIONS

The aim of the study is to determine the factors that influence the equilibrium exchange rate and to determine the equilibrium exchange rate for the Ukrainian hyrvna on the basis of the BEER model.

As can be seen, the productivity differential between Ukraine and abroad and the net foreign assets variables seem to influence the real exchange rate in the short to medium run. It is currently impossible to check whether this influence is temporary or not and will it persist over time because of a very short sample. The macroeconomic variables develop with a significant lag, and hence one should ideally use quarterly data with a much larger data sample.

I also found a weak evidence of the real exchange rate of hryvna being at the equilibrium level in the beginning of 2002. However, for a number of reasons this result cannot be heavily relied on. First and foremost, the data sample is monthly and covers a short time span. This leads to large volatility in underlying variables. Secondly, the proxies that I used in the model, although shown to influence the real exchange rate, may still suffer from the quality of the original data.

It will be interesting to make a further decomposition of the time series into permanent and transitory component, following the Gonzalo and Granger methodology. However, the results of this decomposition are econometrically involved and may be very sensitive to the problems with data.

Although no model developed so far can forecast the exchange rate well, the BEER model can in general trace the direction misalignment reasonably well. This study finds that the exchange rate in the early 2002 was broadly in line with fundamentals, which gives support to the 'crawling peg' exchange rate policy of the National Bank of Ukraine. That means that if the fundamentals are stable over the future, it is likely that there will be no strong pressure on the Ukrainian currency to depreciate or appreciate, and hence we should not expect sudden changes in the exchange rate.

The estimation of BEER models can be performed by the National Bank of Ukraine. The major point will be to monitor the quality of the data under the analysis and to attempt to use different variables, which might still result in a better model specification. The major limiting problem, however, is that of the degrees of freedom and it is likely to persist in the nearest future.

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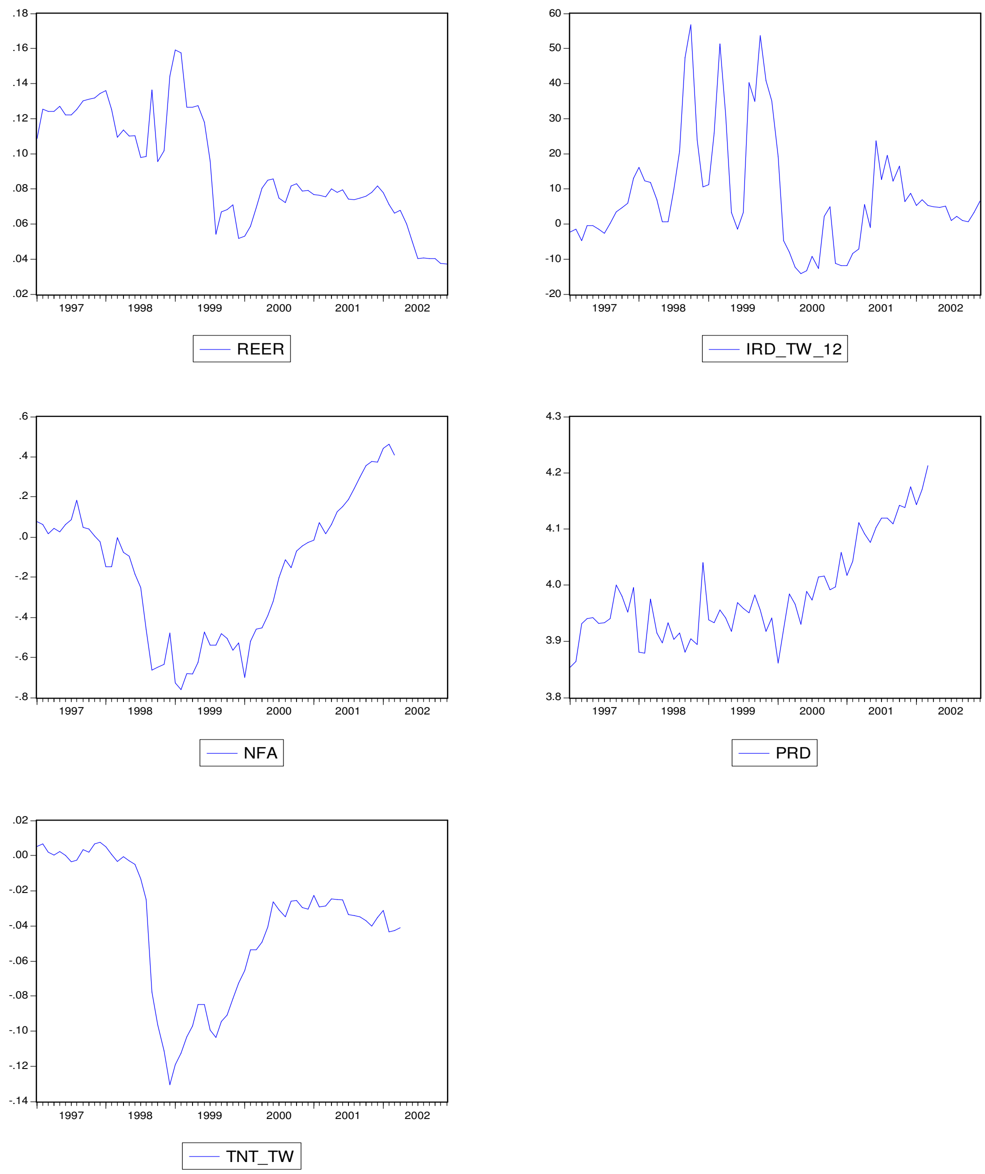
APPENDIX 1

Diagram 1.1 Evolution of the variables



APPENDIX 2

Table 2.1 The E-views output of the VEC model

Vector Error Correction Estimates
Date: 05/26/03 Time: 05:01
Sample(adjusted): 1997:12 2002:03
Included observations: 52 after adjusting endpoints
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1			
REER(-1)	1.000000			
TNT_TW(-7)	-0.027839			
	(0.14929)			
	[-0.18648]			
PRD(-7)	0.661807			
	(0.13847)			
	[4.77935]			
NFA(-1)	-0.106201			
	(0.03011)			
	[-3.52734]			
C	-2.744750			
Error Correction:	D(REER)	D(TNT_TW(-6))	D(PRD(-6))	D(NFA)
CointEq1	-0.169087	-0.149416	-0.803059	-0.160643
	(0.08320)	(0.06418)	(0.28023)	(0.64597)
	[-2.03235]	[-2.32811]	[-2.86568]	[-0.24868]
D(REER(-1))	-0.002296	0.062152	0.287678	-0.197240
	(0.15788)	(0.12179)	(0.53178)	(1.22582)
	[-0.01454]	[0.51033]	[0.54097]	[-0.16090]
D(REER(-4))	-0.136768	-0.191508	-0.725217	-0.197301
	(0.17120)	(0.13206)	(0.57664)	(1.32923)
	[-0.79890]	[-1.45013]	[-1.25766]	[-0.14843]
D(TNT_TW(-7))	-0.303869	0.193247	-1.840682	-0.895736
	(0.21685)	(0.16728)	(0.73041)	(1.68369)
	[-1.40129]	[1.15523]	[-2.52007]	[-0.53201]
D(TNT_TW(-10))	0.151029	-0.247010	-0.026082	-0.046614
	(0.20464)	(0.15786)	(0.68928)	(1.58888)
	[0.73803]	[-1.56474]	[-0.03784]	[-0.02934]
D(PRD(-7))	0.013822	0.042610	-0.237382	-0.000920
	(0.04769)	(0.03679)	(0.16064)	(0.37030)
	[0.28981]	[1.15819]	[-1.47771]	[-0.00249]

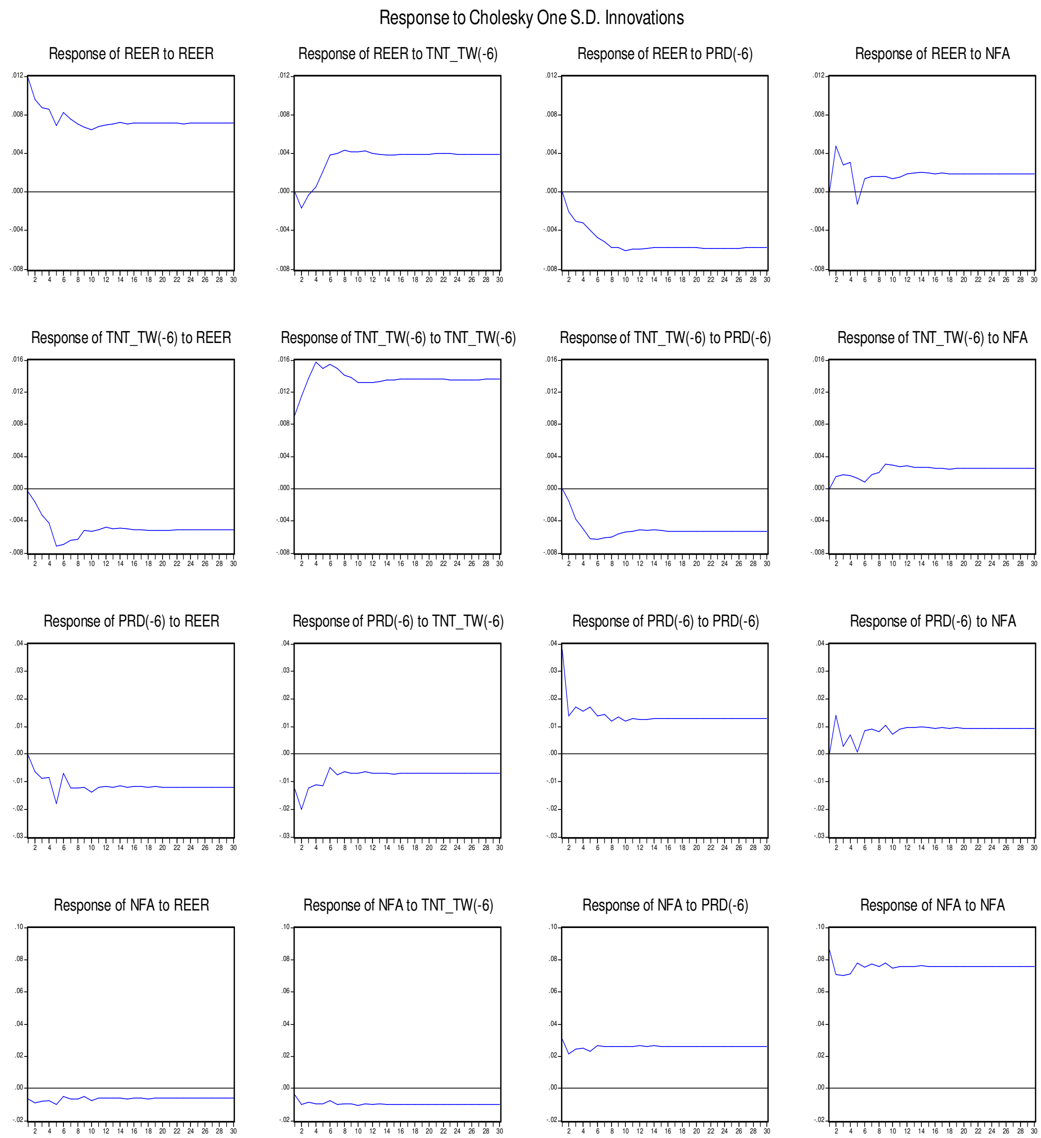
The Eviews output of the VEC model (continued)

D(PRD(-10))	0.031306	-0.003145	0.118077	-0.125401
	(0.04872)	(0.03759)	(0.16412)	(0.37832)
	[0.64251]	[-0.08366]	[0.71946]	[-0.33147]
D(NFA(-1))	0.037538	0.002081	0.078563	-0.191155
	(0.02665)	(0.02056)	(0.08976)	(0.20692)
	[1.40859]	[0.10123]	[0.87522]	[-0.92383]
D(NFA(-4))	-0.051437	-0.005410	-0.064425	0.076442
	(0.02171)	(0.01674)	(0.07312)	(0.16854)
	[-2.36959]	[-0.32308]	[-0.88114]	[0.45356]
C	-0.001475	0.000117	-0.002844	0.026250
	(0.00210)	(0.00162)	(0.00706)	(0.01628)
	[-0.70328]	[0.07205]	[-0.40254]	[1.61203]
IRD_TW_12	-9.51E-05	-8.98E-05	0.000289	-0.001212
	(0.00011)	(8.7E-05)	(0.00038)	(0.00087)
	[-0.84640]	[-1.03566]	[0.76465]	[-1.38926]
D9_98	0.044174	-0.002839	0.068836	-0.221438
	(0.01444)	(0.01114)	(0.04863)	(0.11209)
	[3.05978]	[-0.25492]	[1.41558]	[-1.97548]
R-squared	0.453517	0.423655	0.428581	0.189748
Adj. R-squared	0.303234	0.265160	0.271440	-0.033071
Sum sq. resids	0.005569	0.003314	0.063186	0.335744
S.E. equation	0.011800	0.009102	0.039745	0.091617
F-statistic	3.017754	2.672987	2.727374	0.851578
Log likelihood	163.9002	177.3961	100.7512	57.32410
Akaike AIC	-5.842315	-6.361388	-3.413508	-1.743235
Schwarz SC	-5.392028	-5.911101	-2.963221	-1.292948
Mean dependent	-0.001260	-0.000717	0.003202	0.007754
S.D. dependent	0.014136	0.010618	0.046564	0.090138

Determinant Residual Covariance	1.21E-13
Log Likelihood	505.5376
Log Likelihood (d.f. adjusted)	478.2517
Akaike Information Criteria	-16.39430
Schwarz Criteria	-14.44305

APPENDIX 3

Diagram 3.1 Impulse-response functions for VECM specification



APPENDIX 4

Table 4.1 Roots of Characteristic Polynomial

Endogenous variables: REER TNT_TW(-6) PRD(-6) NFA
Exogenous variables: IRD_TW_12 D9_98
Lag specification: 1 1 4 4
Date: 05/26/03 Time: 06:14

Root	Modulus
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
-0.593128 - 0.493536i	0.771608
-0.593128 + 0.493536i	0.771608
0.675803 - 0.360942i	0.766152
0.675803 + 0.360942i	0.766152
0.335788 - 0.651786i	0.733197
0.335788 + 0.651786i	0.733197
-0.695157 + 0.104994i	0.703041
-0.695157 - 0.104994i	0.703041
-0.371350 + 0.524962i	0.643028
-0.371350 - 0.524962i	0.643028
-0.205289 + 0.571624i	0.607370
-0.205289 - 0.571624i	0.607370
0.028571 + 0.603436i	0.604112
0.028571 - 0.603436i	0.604112
0.593736	0.593736
0.569432 - 0.136353i	0.585529
0.569432 + 0.136353i	0.585529

VEC specification imposes 3 unit root(s).

APPENDIX 5

Diagram 5.1 Inverse roots of characteristic polynomial