Faculdade de Economia, Administração e Contabilidade de Ribeirão Preto
Universidade de São Paulo

Texto para Discussão

Série Economia

TD-E 10 / 2010

QUO VADIS REAL? ESTIMANDO A TAXA DE CÂMBIO REAL DE EQUILÍBRIO A PARTIR DE MODELOS VETORIAS COM CORREÇÃO DE ERROS E MUDANÇA ESTRUTURAL

Prof. Dr. Emerson Fernandes Marçal

Av. Bandeirantes, 3900 - Monte Alegre - CEP: 14040-900 - Ribeirão Preto-SP
Fone (16) 3602-4331/Fax (16) 3602-3884 - e-mail: cebelima@usp.br site:www.fearp.usp.br

Universidade de São Paulo

Faculdade de Economia, Administração e Contabilidade de Ribeirão Preto

Faculdade de Economia, Administração e Contabilidade de Ribeirão Preto
Avenida dos Bandeirantes,3900
14049-900 Ribeirão Preto – SP

A série TEXTO PARA DISCUSSÃO tem como objetivo divulgar: i) resultados de trabalhos em desenvolvimento na FEA-RP/USP; ii) trabalhos de pesquisadores de outras instituições considerados de relevância dadas as linhas de pesquisa da instituição. A série foi subdividida em função das principais áreas de atuação da FEA-RP/USP: Economia, Administração e Contabilidade. Veja o site da CPq na Home Page da FEA-RP: www.fearp.usp.br. Informações: e-mail: cpq@fearp.usp.br

'Quo Vadis Real?
Estimating the Brazilian Real Exchange Rate Misalignment in Vector Error Correction Model with Structural Change'

Emerson Fernandes Marçal
CCSA–Mackenzie Prebisterian University (efmarcal@gmail.com)
EESP - FGV

Fernando Barbi
EESP - FGV

Abstract:

This paper aims to estimate the equilibrium real exchange rate for the Brazilian economy. The equilibrium exchange rate is defined as the level of exchange rate that guarantees the stability of the net foreign asset position over time. An econometric model is estimated using a Vector Error Correction Model with structural breaks. The main conclusion of the paper is that the Brazilian exchange rate is below its long run values. The model also suggests that the improvement in fundamentals observed in the recent past is about to end. The level of misalignment is estimated at 18% in third quarter of 2009.

JEL codes: JEL codes: C32; C52; F31
Key-words: cointegration, structural change, real exchange rate, misaligment

Resumo:

O trabalho vista estimar a taxa de câmbio real de equilíbrio para a economia brasileira. A taxa de equilíbrio é definida como o nível de taxas de câmbio que garante a estabilidade da posição externa de ativos ao longo do tempo. Uma modelo econométrico é estimado utilizando um Modelo Vetorial com correção de erros e mudança estrutural. A principal conclusão do trabalho é que a taxa de câmbio real de equilíbrio está abaixo do seu valor de longo prazo. O modelo sugere que a melhoria dos fundamentos obsevadas no período recente está por terminar e que o nível estimado de desalinhamento estava na casa de 18% em terceiro trimestre de 2009.

Códigos JEL: C32; C52; F31
Palavras-chaves: cointegração, mudança estrutural, taxa de câmbio real e desalinhamento.

1. Introduction:

The level of Brazilian Exchange rate has changed dramatically in the recent past. At the same time, some economic fundamentals (such as terms of trade, productivity and net foreign asset) positions experienced vigorous movements. These facts brought to light the question of whether the fluctuation of the real exchange rate could be explained by those economic fundamentals movements. The Brazilian economy had very high and persistent inflation rates during the eighties and early nineties. In 1994 the Brazilian government launched a macroeconomic stabilization plan (Plan Real) that has achieved its main goal of lowering and stabilizing the inflation rate. In 1999, on the brink of an exchange rate crisis, Brazil moved from a fixed exchange rate regime to a "dirty float" one.

The main goal of this paper is to estimate the equilibrium real exchange rate for the Brazilian economy from 1980:1 to 2009:3 (third quarter). Besides discussing the concept of equilibrium exchange rate, the paper presents an econometric methodology that supports structural changes and accounts for heteroscedasticity.

This paper is organized in five parts. This introduction is followed by a literature review about the determinants of the real exchange rate. In the third section the econometric methodology is presented. In the fourth section the main results are shown, discussed and compared with those from the literature. Finally some conclusions are drawn.

2. Literature Review:

Many authors have discussed the determinants of the exchange rate. A classical and probably the most popular theory in this field is the Purchasing Power Parity (PPP). Recently many studies have tested the implications of PPP doctrine and shown some evidence in favor of this theory, particularly when tradable goods are considered. Yet, the speed of the adjustment towards equilibrium is very low (Froot, K. A. and K. Rogoff (1995)).

Williamson, J. (1994) was one of the pioneers in defining the equilibrium real exchange as a function of the fundamentals that affect the current account position of a country in order to guarantee its external solvency. The critics of this approach argue that the calculus of the equilibrium real exchange rate suggests a great degree of subjectivism over the 'correct' level of the exchange rate and that the stock-flow is inconsistent (Faruqee, H. (1995)).

Recently, many studies have searched for the determinants of the real exchange rate. Some examples are Goldfajn, I. and R. Valdes (1999), Edwards, S. (2000), Devarajan, S., J. D. Lewis and S. Robinson (1993), Williamson, J. (1994), MacDonald, R. (1999), Chand, S. (2005), Égert, B., A. Lahrèche-Révil and K. Lommatzsch (2004), Nilsson, K. (2004) and Badani, P. C. and Á B. Hidalgo (2005). All of them suggest that there is an equilibrium real exchange rate that can be calculated from a set of macroeconomic variables (the 'fundamentals').

Faruqee, H. (1995) built up a formal economic model that exhibits an interaction among flows and stocks. There is a relationship between the real exchange rate and the net foreign asset position of a country. The model is extended by Alberola, E., S. Cervero, H. Lopez and A. Ubide (1999) in order to incorporate a non-tradable sector. This approach is used in this paper.

Kubota, M. (2009) develops a theoretical model for real exchange rate misalignment. His model yields the long-run relationship between real exchange rate and its fundamentals. This relationship was derived from an intertemporal social planner's problem for a small open economy in which the social planner chooses consumption and capital. Under this framework the level of real exchange is determined in the long-run by net-foreign asset position, tradable and non-tradable productivity differential and terms of trade.

2.1. Selected Fundamentals:

The literature offers some selected variables, the fundamentals, as possible candidates to explain the long-run behavior of the real exchange rate. They are briefly described here together with a discussion over the economic rationale.

2.1.1. Terms of Trade:

Terms of trade (TOT) is defined as the ratio of an export price index and an import price index. This variable is frequently listed as one of the long-run determinants of the real Exchange rate. Faruqee, H. (1995) is sceptic about the influence of this variable. The reason to accept it lies on the fact that an improvement in the terms of trade will positively influence the current account position. The country can therefore sustain a real appreciation of its currency without facing huge external imbalances.

2.1.2. Net foreign Asset Position:

Faruqee, H. (1995) argues that the net asset foreign (NFA) position of a country is the key fundament of the real exchange rate. He develops a stock-flow consistent model in order to investigate the determinants of the real exchange rate. An overvalued currency cannot be sustained indefinitely as it would result in an explosive trajectory for the net asset foreign position. There is a negative relationship between foreign asset position and real exchange in long-run (or a positive relationship when the foreign passive position is used instead of net foreign asset position) so that a deterioration of the former would be reverted by an appreciation of the latter.

2.1.3. Productivity difference in tradable and non-tradable sectors:

The difference in the productivity growth of tradable and non-tradable sectors was used by Balassa, B. (1964) and Samuelson, P. (1964) to explain the failure of the Purchasing Power Parity theory that explains the evolution of the prices a basket of tradable and non-tradable goods. This effect must be taken into account when the real exchange rate is analyzed. This variable was constructed following strictly Nilsson, K. (2004) methodology.

2.1.4. Ex-post Real Interest rate Parity:

The ex-post real interest rate can explain the movements of the exchange rate in an economy that is highly opened to the international financial markets. It's difficult to sustain a real interest rate level differential without attracting a huge inflow of capital (assuming risk aversion is stable). In an economy with floating exchange rate regime, a positive differential exerts pressure for an exchange rate appreciation. In an economy with fixed exchange rate regime the result will be the accumulation of reserves. The difference between domestic and international real interest rates, also known as the "Fisher equation", can be obtained by integrating the uncovered interest parity (UIP) and a relative version of the purchasing power parity as shown in Copeland, L. S. (1994).

2.1.5. Real Exchange rate: Definitions.

There are many alternative ways to define the real exchange rate in the literature. This work uses the same definition of Faruqee, H. (1995) and Nilsson, K. (2004). The exchange rate is deflated by Brazilian Consumer Price Index of Brazil and compared to a weight of average consumer price indexes of its trade partners. The Brazilian Price index is the IPCA calculated by IBGE, while the indexes for other countries, as well as the exchange rate, are collected at the IFS-IMF (*International Financial Statistics – International Monetary Fund*). Brief description of the econometric methodology:

This paper uses a cointegrated VAR econometric technique. The cointegration concept was first formulated in the classical paper of Engle, R. F. and C. W. J. Granger (1987) that also proposed a cointegration test. The cointegration tests were further generalized in the works of Johansen and Juselius (Johansen, S. (1988), Johansen, S. (1990), Johansen, S. (1995), Johansen, S. and K. Juselius (1992)). After that, a vast literature about the theme has emerged. Maddala, G. S. and I.-M. Kim (1998) contains an extensive review of the developments in this field during the nineties. Recently, new developments in the cointegration tests literature incorporate structural changes. This paper uses this recent developments by Hansen (Hansen, P. R. (2000), Hansen, P. R. (2002), Hansen, P. R. (2003)) to deal with structural changes in cointegrated models.

2.2. A cointegrated VAR with structural change:

The starting point of the analysis is a VAR with multiple regimes:

$$\Delta^2 X_t = \Gamma_{1,m}\Delta^2 X_t + \ldots + \Gamma_{k-2,m}\Delta^2 X_{t-k-2} + \Gamma\Delta X_{t-1} + \alpha\beta' X_{t-1} + \varepsilon_t \qquad (1)$$

where ε_t is a vector of random variable with zero mean and finite variance, m denotes the various regimes. The following matrices $(\Gamma_{1,1}, \Gamma_{2,1}, \ldots, \Gamma_{k-2,m}, \Gamma, \alpha\beta')$ contain the parameters of the model.

The model represented by (1) restricts the structural change to the short run parameters $(\Gamma_{1,m}, \ldots, \Gamma_{k-2,m})$.[1] This fact guarantees that the trace and the maximum eigenvalue statistic have the same asymptotic distribution of Johansen, S. (1995) and these tests can be applied with minor modifications (Kurita, T. and B. Nielsen (2004)). The

[1] The model can be easily extended in order to contain structural changes in deterministic terms as well.

model given by (1) is estimated using the method of Generalized Reduced Rank Regression (GRRR) developed by Hansen, P. R. (2000).

2.3. Estimating a co-integrated VAR with structural change:

Hansen, P. R. (2000) generalizes the model proposed by Johansen, S. (1988):

(2) $$\Delta \mathbf{X_t} = \Gamma_{\mathbf{1}}(j)\Delta \mathbf{X_t} + \ldots + \Gamma_k(j)\Delta \mathbf{X_{t-k}} + \Phi(j)\mathbf{D_t} + \alpha(j)\beta'(j)\mathbf{X_{t-1}} + \varepsilon_t$$

$$t = 1,\ldots,T \;,\; j = 1,\ldots,m \,,\; m < T$$

where ε_t are random errors, $\Omega(j)$ is the covariance matrix of these errors in regime j. The first regimes starts when t equals zero and ends when t=T_1-1. The second regime starts in t=T_1 and ends in t=T_2-1, etc. There are m different regimes.

The parameters of the model are defined in the following equations:

(3)
$$\begin{aligned}
&\Gamma_i(j) = \Gamma_{1,i}1_{1,t} + \ldots + \Gamma_{m,i}1_{m,t}\\
&\Phi(j) = \Phi_{1,i}1_{1,t} + \ldots + \Phi_{m,i}1_{m,t}\\
&\Omega(j) = \Omega_{1,i}1_{1,t} + \ldots + \Omega_{m,i}1_{m,t}\\
&i = 1,\ldots,k-1\\
&1_{j,t} \equiv 1(T_{j-1} \le t \le T_j - 1)\\
&T_0 \equiv 0\\
&T_m \equiv T + 1
\end{aligned}$$

Where $i = 1,\ldots,k-1$, $1_{j,t} \equiv 1(T_{j-1} \le t \le T_j - 1)$, $T_0 \equiv 0$ and $T_m \equiv T + 1$.

Defining the following variables and matrices:

(4)
$$\begin{aligned}
&Z_{ot} = \Delta X_t\\
&Z_{1t} = (1_{1,t}X'_{t-1},\ldots,1_{m,t}X'_{t-1})'\\
&\tilde{Z}_{2t} = (\Delta X'_{t-1},\ldots,\Delta X'_{t-k},D'_t)'\\
&Z_{2t} = (1_{1,t}\tilde{Z}'_{2t},\ldots,1_{m,t}\tilde{Z}'_{2t})'
\end{aligned}$$

(5)
$$B = \begin{bmatrix} \beta_1 & 0 & \ldots & 0 & 0\\ 0 & \beta_2 & \ldots & \ldots & 0\\ \vdots & \ldots & \ddots & \ldots & \vdots\\ 0 & 0 & \ldots & \beta_{m-1} & 0\\ 0 & 0 & \ldots & 0 & \beta_m \end{bmatrix}$$

$$A = (\alpha_1,\ldots,\alpha_m)$$

(6)
$$\begin{aligned}
&C = (\psi_1,\ldots,\psi_1)\\
&\psi_j = (\Gamma_{j,1},\ldots,\Gamma_{j,k-1},\Phi_j)
\end{aligned}$$

Then the (2) can be rewritten as:

(7) $Z_{0t} = AB'Z_{1t} + CZ_{2t} + \varepsilon_t$

2.4. Generalized Reduced Rank Regression (GRRR):

Hansen, P. R. (2003) shows how to estimate the model given by (7). In order to do this, some definitions are necessary:

(8) $vec(B) = H\varphi + h$

where H is known, φ contains free (unrestricted) parameters and h is a tool to impose normalization and identifications restrictions in B.

(9) $vec(A, C) = G\psi$

where G is also know, and ψ contains free parameters.

By using (8), (9) and (10) to (13), it's possible to estimate the model by the following algorithm.

(10)
$$vec(\hat{A}, \hat{C}) = G\left[G'\sum_{t=1}^{T}\left[\begin{pmatrix} \hat{B}'Z_{1t}Z_{1t}^{'}\hat{B} & \hat{B}'Z_{1t}Z_{2t}^{'} \\ Z_{2t}Z_{1t}^{'}\hat{B} & Z_{2t}Z_{2t}^{'} \end{pmatrix} \otimes \hat{\Omega}(t)^{-1} \right] G \right]^{-1} x$$
$$xG'\sum_{t=1}^{T} vec(\hat{\Omega}(t)^{-1} Z_{ot}(Z_{1t}^{'}\hat{B}, Z_{2t}^{'}))$$

(11)
$$vec(\hat{B}) = H\left[H'\sum_{t=1}^{T}(\hat{A}'\hat{\Omega}(t)^{-1}\hat{A} \otimes Z_{1t}Z_{1t}^{'})H \right]^{-1} x$$
$$xH'\left[\sum_{t=1}^{T} vec(Z_{1t}(Z_{0t} - \hat{C}Z_{2t})'\hat{\Omega}(t)^{-1}\hat{A}) - \sum_{t=1}^{T} vec(\hat{A}'\hat{\Omega}(t)^{-1}\hat{A} \otimes Z_{1t}Z_{1t}^{'})h \right] + h$$

(12) $\hat{\Omega}(j) = (T_j - T_{j-1})^{-1} \sum_{t=T_{j-1}+1}^{T_j} \hat{\varepsilon}_t \hat{\varepsilon}'_t$

(13) $\hat{\varepsilon}_t = Z_{0t} - \hat{A}\hat{B}'Z_{1t} + \hat{C}Z_{2t}$

After an initial guess for the covariance matrices, the loading and short-run matrices, the cointegrated vector (B) is estimated. After this, an estimation of A and C can be done. Then a new covariance matrix and the residuals of the model are calculated. Finally the likelihood function is obtained. The procedure loops until it reaches convergence. See Hansen, P. R. (2003) for further details on the algorithm.

2.5. Permanent and transitory decomposition:

The literature offers many techniques to decompose macroeconomic variables in their permanent and transitory components. In general the decompositions take the form given in the following equations (P for permanent, T for transitory):

(14) $X_t = \beta_\perp (c'\beta_\perp)^{-1} c' X_t + c_\perp (\beta' c_\perp)^{-1} \beta' X_t$

(15) $P_t \equiv \beta_\perp (c'\beta_\perp)^{-1} c' X_t = A_1 c' X_t = A_1 f_t$

(16) $T_t \equiv c_\perp (\beta' c_\perp)^{-1} \beta' X_t = A_2 \beta' X_t = A_2 z_t$

Different decompositions imply different choices for the vector c. One condition for a valuable choice of c is that the matrix $(\beta' c_\perp)$ must have full rank. This condition is not necessarily fulfilled by most decompositions proposed in the literature. The $f_t = cX_t$ contains the permanent factors whereas the term $z_t = \beta' z_t$ contains the transitory factors.

Gonzalo, J. and C. W. J. Granger (1995) proposed to make c equal to $\alpha_\perp$. This decomposition always exists for a VAR of order one but not always for VAR of a higher order. Johansen, S. (1995) proposed that c equals $\alpha_\perp \Gamma$. This decomposition always exists for a VAR of any order if it contains only variables that are at most integrated of order one I(1). Another choice is made by Kasa, K. (1992) where c= $\beta_\perp$. Finally in order to obtain the long-run components of the systems one can generate forecasts from the model at each point in time for a very long horizon. The values to which the system eventually converges are interpreted as the permanent (long-run) components. The transitory component is obtained by difference between the variable value and the permanent component.[2] Paruolo, P. (2006) discusses theses decompositions and formally tests the rank of matrix $(\beta' c_\perp)$ for any choice for c. In this paper it will be use the Gonzalo & Granger decomposition.

3. Results:

In this section it will be discussed and shown a sequence of tests and models that were estimated in order to build up an estimation of the Brazilian equilibrium real exchange rate.

3.1. Database Description:

The data to construct the real exchange rate (RER) indexes were collected next to IBGE and the IFS-IMF (*International Monetary Fund*) databases. The weights of each Brazilian international trade partners were collected at the Brazilian Ministry of

---

2 In this case the deterministic terms must be restricted to cointegrated space. If this is not the case the variable will converge to a long-run trend.

Development. The terms of trade indexes were obtained at FUNCEX (Fundação Centro de Estudos de Comércio Exterior). The interest rate data was also collected next to IFS-IMF. The net asset foreign position was constructed from IMF data from 2000 to 2009. From 1980 to 1999 the data was collected from Milesi-Ferretti, G. M. and P. Lane (2007). The data is reported on a quarterly basis and the period covered by the sample goes from first quarter of 1980 to the third quarter of 2009. The nominal position was divided by the nominal GDP in current dollars and the sign was changed in order to work with the net liabilities position instead of net asset position. Finally the data to calculate an indicator of relative difference in productivity between tradable and non-tradable sectors to Brazilian partners was collected at IFS-IMF. The methodology to build up the index follows Nilsson, K. (2004).

3.2. Obtained Results from cointegration analysis:

Johansen, S., R. Mosconi and B. Nielsen (2000) have tabulated the critical values of the trace statistics when there is a structural change in the determinist components of the VAR. Under these circumstances, the value of the trace statistics depends on the moment of the change and the dimension of the cointegration space. The critical values under structural change tend to be bigger that the traditional ones.

Table 1 shows the trace statistics for the model that contains 4 regimes. The first starts at the beginning of the sample (first quarter of 1980) and ends in the last quarter of 1985. The second regime starts at the first quarter of 1986 and ends in the second quarter of 1994. The third regime starts at the third quarter of 1994 and goes until the fourth quarter of 1998. The last regime starts on the first quarter of 1999 and ends by the third quarter of 2009. The first regime deals with the events prior to the sequence of macroeconomic stabilizations plans that started in first quarter of 1986 with the announcement of 'Plano Cruzado'. The last stabilization Plan was launched in 1993 and Brazil has adopted a new currency (Real) in July of 1994. Since then, Brazil has shown lower rates of inflation compared to previous period in its History. The analysis of the results is shown in Table 1. There is evidence of two co-integrated relations among the variables included in the VAR: real exchange rate, net foreign passive position, terms of trade, relative tradable and non-tradable productivity index and ex-post uncovered interest parity (Table 1).

[Table 1]

3.3. *Testing hypothesis on the estimated system:*

In this section it's reported the results of tests in order to identify the two estimated relations and also test the hypothesis about the loading matrix (α).

3.3.1. A structural change really happened?

In order to evaluate whether there is evidence of structural change it is tested if the short run parameters in all four regimes are equal. If this is not rejected then it is possible to work with one structure for all the periods. This hypothesis can be tested by a likelihood ratio test that has a chi-square distribution with 75 degree of freedom. The hypothesis is clearly rejected (line 2 of Table 3).

It was tested if there is a change in the volatility of the errors. The null of homocedasticity is strongly rejected (**Erro! Fonte de referência não encontrada.** lines 1). It's also tested whether or not there is a change in the deterministic components of the model. In the homoscedastic environment if the null is true then the trace statistic has Johansen's traditional critical value (Kurita, T. and B. Nielsen (2004)). If not, these critical value must be adjusted as described in Johansen, S., R. Mosconi and B. Nielsen (2000).

It's tested whether there is structural change in the deterministic components. These elements are restricted to the cointegrated space. This hypothesis can be tested by a likelihood ratio test. The statistics is 207,9 with p-value of 0,00% (Table 3 at line 15). However there is evidence of heteroscedasticity in the errors and the Johansen procedure might have some size distortions under this enviroment. Cavaliere, G., A. Rahbek and A. M. R. Taylor (2008) propose a procedure to test for cointegration in an environment with no structural change in mean but with structural change in the variance. Their results apply to this paper due to the structural change in the first moment equations. The Johansen statistics suggests two cointegration relationships (Table 1).

[Table 1]

3.3.2. Stationarity of Uncovered interest rate parity.

It was assumed that the system has two cointegration vectors. It was tested whether or not one of these cointegration vectors is the UIP. This hypothesis can be tested using a likelihood ratio test with asymptotical chi-square distribution. The statistic is 8,9 with three of freedom and p-value of 3,0% line 4 of Table 3.

3.3.3. Restrictions on the deterministic terms:

Since one of the cointegration vectors obeys the UIP restrictions, it was tested hypothesis on the deterministic terms of both vectors. The constant in the UIP vector can be interpreted as a term premium. It was tested whether the premium in the second and fourth regime are equal. The change in the constant term of the fundamental cointegration vector can be interpreted as a change in the equilibrium RER not explained by the variables of the model. It was tested whether or not the equilibrium level of RER of the second regime equals the third regime. These hypotheses are tested in line 7 of Table 3 and accepted at 5% level.

3.3.4. Identifying the cointegration space?

Faruqee, H. (1995) suggests that in the long-run the real exchange rate are not linked to the terms of trade but only to the net foreign asset position. This hypothesis can be tested in the estimated model by imposing that both the cointegration vectors do not contain the terms of trade. Since the UIP is valid, this hypothesis requires one further restriction on the other vector. This hypothesis is tested jointly with the previous restrictions. They are rejected at 1% line 9 of Table 3.

The same test was performed but instead of excluding terms of trade from the cointegration space it was opt to exclude the net foreign position. The hypothesis is rejected at 5% level (line 10 of Table 3.). When the productivity differential is excluded a rejection below 1% level is obtained (line 11 of Table 3.). Finally when the real exchange rate is excluded, there is also a rejection at 5% level (line 8 of Table 3.).

These results endorse the conclusion that the first cointegration vector is related to fundamentals of the real exchange rate whereas the second vector can be associated to the uncovered interest rate premium and that there is a clear long run relation between real exchange rate and the fundamentals.

3.4. Estimation results:

In the long run a fall of 1% in the net foreign asset position will cause a permanent depreciation of the real Exchange rate in 1,3052%. The effect of one percent change in tradeable and nontradeable productivity index (PROD) will require a appreciation of to

0,90% in the long-run due to the Ballassa-Samuelson effect. The effect for terms of trade is 0,1756%. The magnitudes and signs of the parameters in the first cointegrated relation are quite reasonable and very similar to those report in Nilsson, K. (2004) and Alberola, E., S. Cervero, H. Lopez and A. Ubide (1999) (Table 2).

The second relationship shows that the average risk premium measured from the ex-post Uncovered interest parity gets the highest value at the third regime (from 1994:3 to 1998:4). (Table 2)

The dynamics towards adjustment of the estimated model is a very appealing one and it's similar to Nilsson, K. (2004). A negative misalignment – real exchange rate below fundamentals – generates an increase in the net foreign asset position. This initial effect enlarges the disequilibrium. Then movements in the real exchange rate and productivity differentials put the economy towards the equilibrium. Since the estimated model is stable, the second effect dominates the first in the long-run (Table 2).

[Table 2]

Figure 1 shows the evolution of the real Exchange rate and the estimated fundamentals line (using Gonzalo & Granger decomposition). After the Real Plan (macroeconomic stabilization Plan launched in 1994) until 1999 (the adoption of floating exchange rate regime) it has prevailed a high and increasing overvaluation of Brazilian currency. After that the Brazilian currency started a period of continuous overdepreciation that was reverted only at the end of 2004. At the end of the sample the Brazilian currency seems to be overvalued at the level of 16% at the third quarter of 2009.

[Figure 1]

Figure 2 shows the evolution of the estimated fundamentals and the actual RER these throughout the sample. A large persistence in misalignment can be seen by visual inspections.

[Figure 2]

3.4.1. Does the magnitude and the endless misalignment matters?

The analysis of the model dynamics suggests that the level of the exchange rate depends on not just of the net foreign asset position but also on how long the misalignment will last. If the misalignment takes too much time to revert due to some reason then the net foreign passive position will deteriorate and the adjustment that will eventually occur but a higher level of exchange rate will be required. Periods of high undervaluation will cause a worsening of the fundamentals whereas periods of high over devaluation tends to improve the fundamentals. (See loading parameters of the second cointegration relationship in Table 2)

4. Comparison with the Literature:

Faruqee, H. (1995) develops a model where an explicit relationship between net foreign asset position and real exchange rate is derived. Alberola, E., S. Cervero, H. Lopez and A. Ubide (1999) estimate the equilibrium real exchange rate for a sample of developed countries with a similar methodology. The net foreign asset position is highly significant for most of the countries. The results of the following work are quite similar to those obtained in this paper.

Chand, S. (2001) calculates the misalignment of Australian currency using the methodology similar to this paper, but uses a different set of fundamentals.Égert, B. (2002) and Égert, B., A. Lahrèche-Révil and K. Lommatzsch (2004) estimates the relationship between real exchange rate and net asset foreign position for transition economies. Some results are not intuitive but the authors suggest these results are due to the period covered by the sample.

5. Main conclusions:

The evidence obtained in this paper also suggests that the terms of trade, net foreign asset position and productivity differential explain the evolution of the real exchange rate in the long run.

The level of estimated misalignment shows a high degree of persistence throughout the time. In the period from 1996 to 1999 the Brazilian currency was below its fundamentals value whereas in the period from 1999 to 2004 the Brazilian currency was above its fundamentals and collapsed towards the fundamentals in the end of 2004. The estimated level of misalignment at the end of sample suggests that the Brazilian currency is overvalued.

6. References:

ALBEROLA, E., S. CERVERO, H. LOPEZ, and A. UBIDE (1999): "Global Equilibrium Exchange Rate: Euro, Dolar, 'Ins', 'Outs' and Other Major Currencies in a Panel Cointegration Framework," Washington: IMF.

BADANI, P. C., and Á. B. HIDALGO (2005): "A Taxa De Câmbio Real De Equilíbrio No Brasil," *Economia Aplicada*, 9, 543-55.

BALASSA, B. (1964): "The Purchasing Power Doctrine: A Reappraisal," *Journal of Political Economy*, 72, 584-596.

CAVALIERE, G., A. RAHBEK, and A. M. R. TAYLOR (2008): "Testing for Co-Integration in Vector Autoregressions with Non-Stationary Volatility " Copenhagen: CREATES.

CHAND, S. (2001): "How Misaligned Is the Australian Real Exchange Rate?," Sidney: East Asian Bureau of Economic Research.

— (2005): "How Misaligned Is the Australian Real Exchange Rate?," Sidney: East Asian Bureau of Economic Research i.

COPELAND, L. S. (1994): *Exchange Rates and International Finance*. Londres: Addison-Wesley Publishers.

DEVARAJAN, S., J. D. LEWIS, and S. ROBINSON (1993): "External Shocks, Purchasing Power Parity and the Equilibrium Real Exchange Rate," *The World Banck Economic Review*, 7, 45-63.

EDWARDS, S. (2000): "Exchange Rates Systems in Emerging Market Economies," Washington: NBER.

ÉGERT, B. (2002): "Equilibrium Real Exchange Rates in Central Europe's Transition Economies: Knocking on Heaven's Door," Paris: University of Paris.

ÉGERT, B., A. LAHRÈCHE-RÉVIL, and K. LOMMATZSCH (2004): "The Stock-Flow Approach to the Real Exchange Rate of Cee Transition Economies," Paris: CEPII, 42.

ENGLE, R. F., and C. W. J. GRANGER (1987): "Co-Integration and Error Correction: Representation, Estimation and Testing," *Econometrica*, 55, 251-276.

FARUQEE, H. (1995): "Long-Run Determinants of the Real Exchange Rate: A Stock Flow Perspective," *IMF Staff Paper*, 42, 80-107.

FROOT, K. A., and K. ROGOFF (1995): "Perspectives on Ppp and Long-Run Real Exchange Rates," Amsterdam: North-Holland.

GOLDFAJN, I., and R. VALDES (1999): "The Aftermath of Appreciations," *Quartely Journal of Economics*, 114, 229-262.

GONZALO, J., and C. W. J. GRANGER (1995): "Estimation of Common Long-Memory Components in Cointegrated Systems," *Journal of business and Economics Statistics*, 13.

HANSEN, P. R. (2000): "Structural Changes in Cointegrated Processes," San Diego: University of California.

— (2002): *Generalized Reduced Rank Regression*. SSRN.

— (2003): "Structural Changes in the Cointegrated Vector Autoregressive Model," *Journal of Econometrics*, 114, 261-295.

JOHANSEN, S. (1988): "Statistical Analysis of Cointegration Vectors," *Journal of Economic Dynamics and Control*, 12, 231-254.

—(1990): "Maximum Likelihood Estimation and Inferences on Cointegration - with Applications to the Demand for Money," *Oxford Bulletin of Economics and Statistics*, 52, 169-210.

—(1995): *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford: Oxford University Press.

JOHANSEN, S., and K. JUSELIUS (1992): "Testing Structural Hypothesis in a Multivariate Cointegration Analisys of the Ppp and Uip for Uk," *Journal of Econometrics*, 53, 211-224.

JOHANSEN, S., R. MOSCONI, and B. NIELSEN (2000): "Cointegration in the Presence of Structural Breaks in Deterministic Trends," *Econometric Journal*, 1(3).

KASA, K. (1992): "Common Stochastic Trends in International Stock Markets," *Journal of Monetary Economics*, 29.

KUBOTA, M. (2009): "Real Exchange Rate Misalignments: Theoretical Modelling and Empirical Evidence," York: University of York.

KURITA, T., and B. NIELSEN (2004): "Short-Run Parameter Changes in a Cointegrated Vector Autoregressive Model," Oxford: University of Oxford.

MACDONALD, R. (1999): "What Determines Real Exchange Rate? The Long and Short of It," in *Equilibrium Exchange Rates*, ed. by R. MacDonald, and J. Stein. Dordrecht.

MADDALA, G. S., and I.-M. KIM (1998): *Unit Roots, Cointegration and Structural Change*. Cambridge: Cambridge University Press.

MILESI-FERRETTI, G. M., and P. LANE (2007): "The External Wealth of Nations Mark Ii: Revised and Extended Estimates of Foreign Assets an Liabilities," *Journal Of International Economics*, 73, 223-250.

NILSSON, K. (2004): "Do Fundamentals Explain the Behaviour of the Swedish Real Effective Exchange Rate?," *Scandinavian Journal of Economics*, 106, 603-622.

PARUOLO, P. (2006): "The Likelihood Ratio Test for the Rank of a Cointegration Submatrix," *Oxford Bulletin of Economics and Statistics*, 68.

SAMUELSON, P. (1964): "Theoretical Notes on Trade Problems," *The Review of Economics and Statistics*, 46, 145-154.

WILLIAMSON, J. (1994): *Estimating Equilibrium Exchange Rates*. Washington D.C.: IIE.

Table 1: Kurita & Nielsen version of Johansen cointegration test.

Trace		90%	95%	99%
132.49	**	**93.9**	**98,8**	**108,3**
70.57	a	**67.9**	**72,1**	**80,5**
34.71		45.8	49,4	56,6
10,90		27.4	30,4	36,5
3.53		12.7	15	20

Critical value are tabulated following Johansen, S., R. Mosconi and B. Nielsen (2000).

[a] indicates significance at 10% nominal level

[*] indicates significance at 5% nominal level

[**] indicates significance at 1% nominal level

Source: The author.

Table 2: Estimated cointegration relations.

Variable-Equation	CR	PEL	TOT	TNT	UIP	Intercept	Dummy 1	Dummy 2	Dummy 3
Model - Brazil									
First Relation									
Adjustment coefficient	0.0077	-0.0076	0.0024	-0.0320	-1.3539				
Vector coefficient	0	0	0	0	1	3.3%	-13.2%	-21.4%	-13.2%
Second Relation									
Adjustment coefficient	-0.2288	-0.0679	0.0297	-0.0398	0.9051	-1.3517			
Vector coefficient	1	-1.3052	-0.1756	0.9044	0	-6.8110	-41.2%	-41.2%	-93.5%
Model for Sweeden - Nilsson (2004)									
Adjustment coefficient	-0.1906	-0.1732	-0.0295	0.0589					
Vector coefficient	1	-0.1034	0.6516	-0.4591	0	-5.5050	0	0	0

Dummy 1 assumes value 1 from 1986(1) to 1994(2).
Dummy 2 assumes value 1 from 1994(3) to 1998(4).
Dummy 3 assumes value 1 from 1999(1) to the end of the sample.

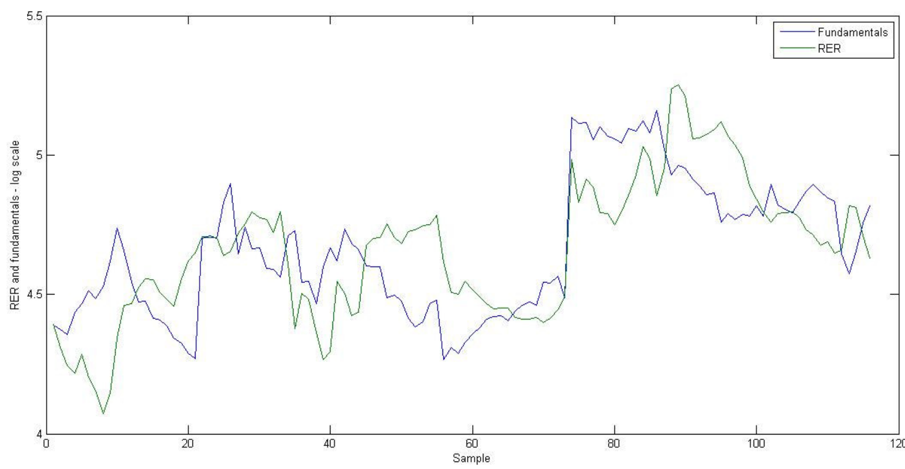
Source: The author.

Table 3: General to specific modeling– Results of the tests.

Line	Models - General - Specific	Restrictions [1]: Short Run Restrictions	Restrictions [1]: Long run Vector	Restrictions [1]: Deterministic Terms: Restricted constant	Restrictions [1]: Errors	Likelihood Function	Number of parameters	M1: Likelihood Ratio Statistic	M1: Degree of freedom	M1: p-value
0	M1	None	None	None	Heteroscedastic	1,537.8	209			
1	M2	None	None	None	Homocedastic	1,398.3	164	279.0	45	0.0%
2	M3	Only one regime	None	None	Heteroscedastic	1,465.1	134	145.3	75	0.0%
3	M4	None	No change in deterministic constant	None	Heteroscedastic	1,514.0	203	47.5	6	0.0%
4	M5	None	First vector is the UIP	None	Heteroscedastic	1,533.3	206	8.9	3	3.0%
5	M6	None	First vector is the UIP	All regimes are equal	Heteroscedastic	1,510.7	200	54.1	9	0.0%
6	M7	None	First vector is the UIP	second regime equals the third	Heteroscedastic	1,531.2	204	13.1	5	2.2%
7	M8	None	First vector is the UIP	second regime equals the third in the fundamental relationship and second regime equals the fourth	Heteroscedastic	1,533.2	204	9.1	5	10.3%
8	M9	None	First vector is the RIP and second vector does not have RER	second regime equals the third in the fundamental relationship and second regime equals the fourth regime in UIP vector	Heteroscedastic	1,531.3	205	12.9	4	1.2%
9	M10	None	First vector is the UIP and second vector does not have net foreign asset position	second regime equals the third in the fundamental relationship and second regime equals the fourth regime in UIP vector	Heteroscedastic	1,528.9	205	17.7	4	0.1%
10	M11	None	First vector is the RIP and second vector does not have terms of trade	second regime equals the third in the fundamental relationship and second regime equals the fourth regime in UIP vector	Heteroscedastic	1,515.0	205	45.5	4	0.0%
11	M12	None	First vector is the RIP and second vector does not have productivity	second regime equals the third in the fundamental relationship and second regime equals the fourth regime in UIP vector	Heteroscedastic	1,516.5	205	42.5	4	0.0%
12	M13	None	None	All regimes are equal	Heteroscedastic	1,433.8	203	207.9	6	0.0%

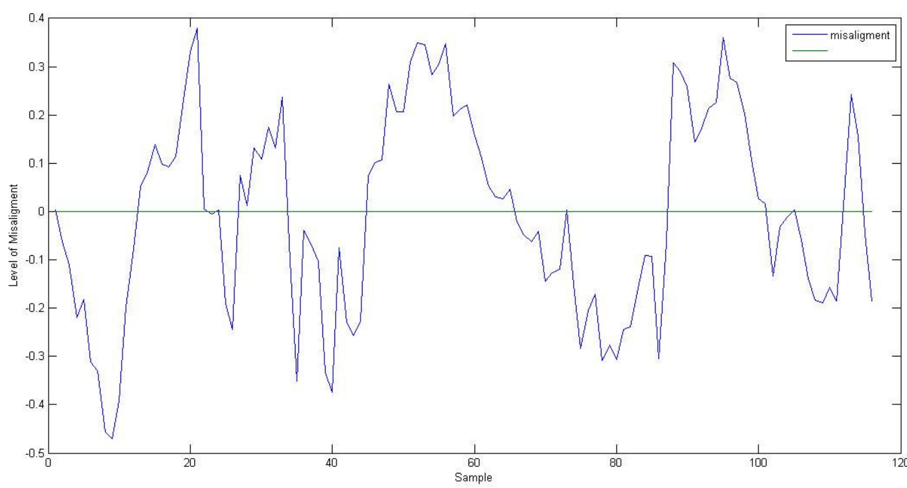
[1] No restriction is imposed in the loading matrix.

Figure 1: Fundamentals versus Real Exchange rate.



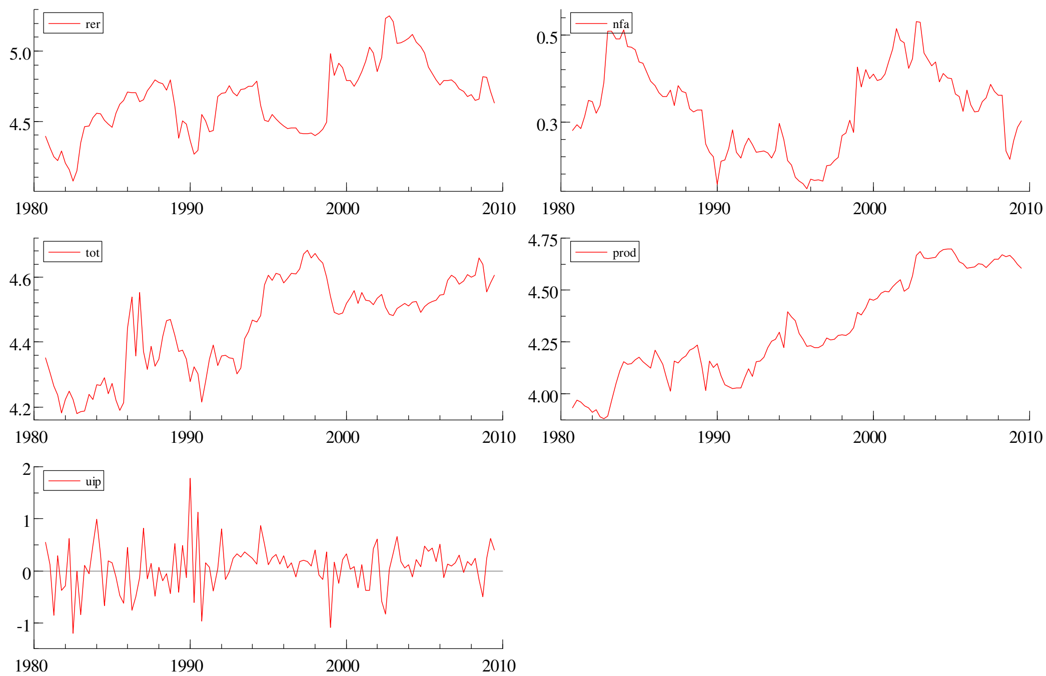
Source: The author.

Figure 2: Level of Misalignment using Gonzalo & Granger decomposition.



Source: The author

Figure 3: Plot of the series.



Source: The author