Insper | Ibmec São Paulo

Empirical exchange rate models fit: Evidence from the Brazilian economy

Marcelo L. Moura

Adauto R. S. Lima

Insper Working Paper

WPE: 094/2007

Empirical exchange rate models fit: Evidence from the Brazilian economy

Marcelo L. Moura
Ibmec São Paulo
Rua Quatá 300, São Paulo-SP – Brazil – CEP:04546-042
Tel.: 4504-2435
marcelom@isp.edu.br

Adauto R. S. Lima
Ibmec São Paulo
Rua Quatá 300, São Paulo-SP – Brazil – CEP:04546-042
Tel.: 4504-2388
adautorsl@ isp.edu.br

THIS VERSION: APRIL 12, 2007

Empirical exchange rate models fit: Evidence from the Brazilian economy

ABSTRACT

In this article, we test the adequacy and forecasting performance of empirical exchange rate models for an emerging commodity exporter economy with independently floating regime. In particular, we study those models using data from the Brazilian economy. The tested economic models include the Flexible Price Monetary Model (FPMM) and its specification of the Asset Model, the Sticky Price Monetary Model (SPMM), the Portfolio Balance Model and the Market Model based on real-time information used in international trade desks. Our main result is to show that, opposed to the results shown in the classic literature, some of our specifications may forecast moves in the nominal exchange rate to a better result than that of a driftless random walk. In particular, the best specifications include variables that capture the monetary policy (M1 and interest rate), country risk (EMBI) and terms of trade.

Key-words: Empirical Models of Exchange Rate Determination, Out-of-sample forecasting, Emerging Economies.
JEL Codes: F31, F41, F47.

1 – Introduction

In the present study, we test the adequacy of the empirical exchange rate models for an emerging commodity-based economy with independently floating regime[1]. Our purpose is to assess the in-sample and out-of sample fit of those models. Our strategy consists of estimating the main empirical models of exchange rate determination, including controls for risk perception of economic agents, conditions of the external market, interventions of the Central Bank and other effects known in the literature. Our analysis replicates for an emerging economy the study carried out in the classic article by Meese and Rogoff (1983) but with a broader set of economic models. The original Meese and Rogoff work showed that a simple driftless random walk model would be more effective for the exchange rate forecasting than the models that involve macroeconomic fundamentals.

Meese and Rogoff's research has generated an extensive literature. Mark (1995) argues that the monetary fundamentals might obtain some success to explain the behavior of the exchange rate if the statistical tests were given more power. However, a host of authors, for example, Kilian (1999) and Giorgianni (2001) remained skeptics and suggested that the results obtained by Meese and Rogoff may still seem robust, even after all the data and intense academic investigation gathered for over twenty years.

Some exceptions to this skepticism are present in recent works. Chen (2004) analyzes commodities producers (Australia, Canada and New Zealand) for OCDE countries. The author concludes that for Australia and New Zealand the global price of their respective exported commodities is likely to have a meaningful and stable impact on their respective currencies. However, in the case of Canada, the evidence was less conclusive.

Guo e Savikcas (2006) make use of variables that reflect the agents' expectation towards the future behavior of the economic fundamentals, like the term structure of interest rates, credit risk, and the idiosyncratic risk of the United States' stock market, among others. Their analysis suggest that the idiosyncratic risk of those assets forecast the American dollar's behavior facing the G7's main currencies, and conclude that the exchange rate does not follow a driftless random walk..

Cheung, Chinn and Pascual (2003) added other models and elements to the 1970s traditional specifications, such as, the correlation between the external net asset and the differential of relative productivity in the tradable goods sector between countries (Balassa-Samuelson effect) at the determination of the exchange rate. The authors concluded that, in line with a great part of the existing literature, it is very difficult to find empirical estimations of structural models that may consistently outperform a random walk, having the MSE as basis of comparison. On the other hand, the structural models provide a better forecasting for exchange rate movements than that provided by the random walk.

Specific studies for Brazil, like Muinhos, Alves and Riella (2003), state that the random walk is not the best hypothesis to explain the behavior of the exchange rate in Brazil. Using data from May 1999 to December 2001, the authors conclude that a model derived from the theory of uncovered interest rate parity captures the Brazilian exchange rate's behavior better. This model takes into consideration the sovereign risk premium (in the study measured by the C-Bond spread, in relation to Treasury Bills, as a variable in the specification of the uncovered parity.

Summing up, the existing literature allows us to draw some important conclusions. First of all, it is difficult to find empirical economic models that consistently outperform a driftless random walk for the out-of-sample estimations. Second, the addition of specific variables of some

[1] This definition follows the exchange rate arrangements adopted by the IMF, and available at http://www.imf.org/external/np/mfd/er/index.asp

economies, such as export prices and country-risk premium improve the performance of the economic models. Finally, economic variables that have forward-looking components may improve the results of the models for the out-of-sample forecasting.

The purpose and contribution of this work is to carry out a detailed study about the empirical fit of these exchange rate models to an emerging economy like the Brazilian economy. The following section presents the economic models used in this work and the respective in-sample estimations. In the analysis of the in-sample results, we focus on the statistical significance of the estimated coefficients for the macroeconomic variables and whether their respective signs are in line with the ones expected by the economic theory. In Section 3, we analyze the forecasting performance of the estimated models against that of the driftless random walk. We follow the methodology suggested by Cheung, Chinn and Pascual (2003), in which the assessment criterion is the Mean Squared Error (MSE), and the statistic proposed by Diebold and Mariano (1995) measures its statistic significance. The last section presents the conclusion of the study.

2 – Specification of the models and estimation

2.1 – Specification of the models

The Flexible-Price Monetary Model (FPMM)

The Flexible Price Monetary Model perspective was very representative in the 1970s when the floating exchange rates were adopted by the main industrialized economies, after the emergence of the Bretton Woods system in 1973. The FPMM assumes that, in each country, the equalization of currency supply and demand determines the price level in each country. Furthermore, relative prices in each country and exchange rates are related by the purchasing power parity relationship. In econometric terms, the FPMM to be estimated could be presented by:

$$s_t = \beta_0 + \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + \beta_4(i_t - i_t^*) + \mu_t \quad (1)$$

Where s_t is the exchange rate logarithm (R$/US$), m_t and m_t* the M1 logarithms in Brazil and in the United States, respectively; y_t and y_t* the industrial production logarithm in both countries and i_t and i_t* the logarithm for the swap interest rates for a year in Brazil and in the United States, respectively[2]. The variable μ_t is a random term.

The Sticky-Price Monetary Model (SPMM)

Despite the fact that the FPMM was the dominant approach to determine the exchange rate in the early 1970s, its weak empirical results led to the conception of models that took over frictions in the economy, inducing another form of convergence for long-run market equilibrium. Dornbusch (1976) introduces the idea of sticky prices in the short run to the exchange models, which enables jumps in the nominal and/or real exchange rate to beyond its long-run equilibrium value. The existence in the system of variables that jump, in this specific case, the exchange rate and the interest rate, would make up for the stickiness in other variables, that is, the prices of goods. Thus, the adjustment velocity in various markets would be different.

Consider π_t and π_t* logarithms for the inflation rates in Brazil and in the United States, which try to capture price stickiness in both economies, the Sticky-Price Monetary Model (SPMM) can be described by the following equation:

[2] (1+ pre swap interest rate logarithm) was used for the domestic rates and the USA rates.

$$s_t = \beta_0 + \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + \beta_4(i_t - i_t^*) + \beta_5(\pi_t - \pi_t^*) + \nu_t \quad (2)$$

Where ν_t is a random term.

In order to adapt the traditional models for an emerging economy in which commodities play an important role in exports, we included other variables that are specific to models (1) and (2). In other words, there will be the addition of some variables that capture the country-risk premium, the evolution of relevant prices for the trade balance, and a term that captures the relative evolution of productivity in the tradable goods sector between Brazil and the USA. Using these control variables[3], we can rewrite the above models:

$$s_t = \beta_0 + \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + \beta_4(i_t - i_t^*) + \Gamma_{j,t}^T \beta_j + \mu_t \quad (3)$$

$$s_t = \beta_0 + \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + \beta_4(i_t - i_t^*) + \beta_5(\pi_t - \pi_t^*) + \Gamma_{j,t}^T \beta_j + \nu_t \quad (4)$$

Where $\Gamma_{j,t}^T$ would be the transposed vector of the control variables.

The Portfolio Balance Model, Asset Model and Market Model

The monetary models formerly shown, flexible prices and sticky prices, assume the perfect substitution between home and external assets and their effects on the exchange rate. However, the existence of home-bias (home agents' preference for home assets), liquidity difference, solvency risk, tributary differences and even the currency-exchange risk can affect the presumed equilibrium in the monetary models, which makes the home assets and the external assets imperfect substitutes. The Portfolio Balance Model assesses how this flawed substitution between home and external assets can affect the agents' demand for home and external assets.

For the Portfolio Balance Model we made use of two specifications. The purpose is to capture the effects of the Portfolio Balance Models to changes in the agents' risk perception, the alterations in the international market country-risk premium credit conditions and the external price effects on the trade balance. In the case of the Brazilian economy, both the Central Bank of Brazil and the National Treasury act upon the exchange markets by means of dollar denominated domestic debt instruments or dollar-based derivatives, and that is why we added the evolution of the public sector foreign currency net domestic liabilities to capture the effect of those actions on the nominal exchange rate. The two specifications differ from the imposition or not of the PPP. Thus, the specification can be expressed as:

$$s_t = \beta_0 + (p_t - p_t^*) + \beta_1 z_t + \beta_2 CRB_t + \beta_3 FCL_t + \beta_4(i_t - i_t^*) + \beta_5 EM_t + \beta_6 DXR_t + \beta_7 VIX_t + \eta_t \quad (5)$$

Equation (5) represents the model that imposes PPP, while the specification that assumes price stickiness could be expressed as:

$$s_t = \beta_0 + \beta_1 z_t + \beta_2 CRB_t + \beta_3 FCL_t + \beta_4(i_t - i_t^*) + \beta_5 EM_t + \beta_6 DXR_t + \beta_7 VIX_t + \beta_8(\pi_t - \pi_t^*) + \eta_t \quad (6)$$

Where z_t is the logarithm of the productivity differential for the tradable goods sector, *CRB* is the CRB basket, *FCL* is the net foreign currency liabilities, herein measured by the monthly results of the current account, *EM* is the EMBI+ Brazil, *DXR* is the logarithm of the public sector dollar denominated net domestic liabilities and *VIX* is the volatility indicator which aims to capture the changes in the international investors' risk-aversion[4]. The term $(p_t - p_t^*)$ indicates that PPP is valid at

[3] The description of the data is shown in Appendix 1.
[4] See the definition of those indicators in the appendix.

every instant of time. All the variables are expressed in logarithm. Figure 1 shows the graphs of the variables used in the models.

One FPMM variant, the Asset Model, was also estimated, through the specification:

$$s_t = \beta_0 + \beta_1\left(m_t - m_t^*\right) + \beta_2\left(y_t - y_t^*\right) + \beta_3 EM_t + \beta_3 TT_t + \nu_t \qquad (7)$$

Where *TT,* is the Brazilian terms of trade.

Finally we use a specification, called Market Model, in which real time variables are used and whose access is immediate to the traders, and that somehow affect the market operators' decision when buying and selling currencies.

$$s_t = \beta_0 + \beta_1\left(i_t - i_t^*\right) + \beta_2 EM_t + \beta_3 CRB_t + \beta_4 VIX_t + \beta_5 HG_t + \nu_t \qquad (8)$$

Where, HG_t is the *CS High Yield Index II* that tries to capture changes in the credit scenario in the international markets. Again the variables are in logarithm.

2.2 - Model estimation

In order to avoid possible spurious regressions, the models were estimated assuming in first differences the dependent and independent variables[5]. A general expression for the relation with the exchange rate is:

$$s_t = \mathrm{X}_t \Pi + \varepsilon_t \qquad (9)$$

Where X, is the vector for the considered economic variables, ε_t is a random term, and Π is the vector for the estimated coefficients. The specification in first difference would involve the following regression:

$$\Delta s_t = \Delta \mathrm{X}_t \Pi + \upsilon_t \qquad (10)$$

Where υ_t is a random term.

Since in the exchange models there may be group determination of all variables present in the equation, it is justifiable to make use of instrumental variables that would lead to consistency gains in the estimated parameters. As the exchange rate variation, as well as the variation of some other variables present in the specifications, does not show a normal distribution, we used the Generalized Method of Moments (GMM) with the Time Series Weighting Matrix (HAC). The estimators generated by the GMM are robust, and opposite to those obtained by Maximum Likelihood, the GMM does not require the exact information from the distribution of errors of the specified models[6].

[5] According to Engle and Granger (1987), in case the non-stationary variables in their levels have a long-run equilibrium relation, that is, in case they co-integrate, when specifying the models in first difference, a specification mistake will be occurring. However, the sample limitation does not allow the use of the Vector of Error Correction (VEC).

[6] As instruments we used level variables with two and three lags for each estimation. In the Flexible and Sticky Prices Monetary Models, we have also included as instruments, the short-run interest rate differential between the countries and the CS high Yield Index II Spread to Worst (HG). We used those variables in level and with no lags and with, one, two and three lags. In the Portfolio Balance Model, besides the level variables with two and three lags, we included the short-run interest rate differential between the countries, using the same lags as in the monetary models. In the Market Model, the instruments used were the level variables with two and three lags and the short-run interest rate differential between countries with no lags and with, one, two and three lags.

Tables 1 through 5 contain the results from the various specifications taking into account the data from the whole sample (March 1999 to December 2005) for the estimations of the models[7]. As a whole, the specific variables seem meaningful to explain exchange rate in-sample changes, and their non-inclusion would generate specification problems of the models, in the case, problems with omitted variables, in line with Meese (1990).

FPMM Results

Table 1 presents the FPMM results. In the original specification, equation (1), monetary expansion and interest rate are significant while the industrial production is not. The inclusion of controls, specifications (2) through (8) tends not to alter those results.

The monetary expansion difference between the two countries is not significant in only one of the models being the positive sign of the estimated coefficients in line with the FPMM theory. An increase in the monetary expansion implies increase in the price levels, which leads to the nominal exchange rate devaluation since the model assumes that PPP is valid at every instant of time.

The interest rate differential between Brazil and the United States is positive and significant at a 99% confidence interval in six of the eight specifications tested. Despite the fact that these results are intuitively contradictory – an increase in the home interest rate, relatively to US international rates, would lead to the devaluation of the Brazilian Real – they are in line with what is expected by the economic theory that bases the model. In the FPMM, an increase in the home interest rate would induce to a fall in money demand; maintained the fixed money supply, the price level must go up to counterbalance the interest rate increase, given the PPP, the home price increase devaluates the exchange rate.

The inclusion of control variables improves the original model fit, according to the Akaike information criterion (AIC). The EMBI+ Brazil is strongly significant in all the specifications. The positive sign is in line with the expectations that the worsening in the solvency risk would induce to exchange rate devaluation, reflecting the deterioration of the economic agents' expectations about the future fundamentals of the economy.

The terms of trade variable is statistically significant in one of the two specifications in which it is included, and the negative sign came in line with what is expected. On the other hand, CRB commodities index is not statistically significant to the period in question. The productivity differential (Balassa-Samuelson) in the tradable goods sector is significant in two of the four specifications. The negative sign obtained is in line with the theory.

SPMM Results

The SPMM results are presented in Table 2. In the original model, specification (1), only the interest rate differentials and those of inflation between Brazil and the US are statistically significant. The addition of controls, specifications (1) through (8) alters these results, the inflation rate loses its statistic significance and the monetary expansion, M1, is positive and significant.

---

[7] In the estimation of the models we have also considered restrict models in which the short-run interest rate differential balanced with the risk premium is given by $\beta j\ (i - risk\ premium - i^*)$ and not as $\beta j\ (i - i^*) + \beta mEMBI$, presented in the shown models. To avoid the problem of constructing this variable because the EMBI+ Brazil could appear for over-one-year duration, we used the Brazil premium risk for a year. The restricted models, with interest differential balanced by EMBI+ Brazil both for in-sample and out-of-sample were also estimated, and the results obtained were similar to those obtained by the restricted models using the one-year premium. In both cases, the restricted models demonstrated results largely similar to the models presented in this article considering the sign and significance of the variables. Using the Akaike information criterion (AIC) to select the models, we verified that the same specifications for the unrestricted models generated better models than those obtained with the restrict specifications. The data are available upon request.

The positive and significant sign of the interest rate is not in line with what is expected in this model. Since the prices are sticky in the short run, an increase in the nominal interest rates implies the increase in the real interest rate, which, in turn, attracts external capitals and appreciates the exchange rate. The negative sign obtained for the inflation differential in specification (1) is in line with what is anticipated by the economic theory since the uncovered interest rate parity is valid. The differential in the expansion of monetary demand is significant in most of the estimated models (7 out of 8), with the positive sign for the coefficients, in line with the theory. However, the elasticity obtained is different from the unity, like some studies suggest.

As observed in the FPMM estimations, the inclusion of control variables improves the SPMM specification. The country-risk premium is again positive and statistically significant in all the specifications. The terms of trade variable is negative, as expected, and statistically significant. Variables that capture effects of the CRB index and the Balassa-Samuelson effect are not statistically significant in practically all the cases.

Portfolio Balance, Market and Asset Models Results

In relation to the variables that measure the risk perception (VIX and EMBI) and the interest rate, the results in terms of significance and sign are the same as those from FPMM and SPMM models; therefore, the same interpretation is valid here. Likewise, the CRB index and the Balassa-Samuelson effect do not show robust results in terms of statistical significance.

In the case of the Portfolio Balance Model, it is worth noting that the PPP hypothesis, specification (2), differs little from the specification that does not assume the PPP, specification (1), providing non-conclusive answer whether one model is in fact better than the other. The Brazilian net external liabilities, herein measured by the current account variation, are significant and positive. Such result is expected by the theory given that the changes in the current account are associated with a relative transfer of wealth between countries with effects on the exchange rate risk premium. The inflation differential between countries is marginally significant and the negative sign is in line with what is expected by the theory. The dollar denominated government liability has a negative sign and is statistically significant at 99% confidence interval which implies that the hedge operations provided by the Central Bank of Brazil are effective in the exchange rate control[8].

In the Market Model (Table 4), which uses market real time variables, the High Yield Spread is not significant in any of the estimated models, very likely reflecting the high correlation of this variable with the EMBI+ Brazil (37%) and with the VIX (48%), suggesting the presence of multicolinearity in the specifications, which makes the individual identification of the effect of the variables difficult.

In the Asset Model, which assumes that today the exchange rate reflects the expected present discounted value of the economy's future fundamentals, only the product differential is not statistically significant and the signs estimated for the other variables were in line with what was anticipated by the economic theory.

4 – Out-of-sample forecasting

Our forecasting exercise used the out-of-sample estimation methodology adopted by Meese and Rogoff (1983a) as a way to assess the performance of the models for the exchange rate forecasting. Initially, we estimated the specifications for the period January 1999 through December 2001. Then, for each estimated model, we made one-, three-, six- and twelve-month projections

[8] These hedge operations are characterized by the sale of dollar denominated treasury bonds and swap operations – common policies adopted by the Central Bank of Brazil during the period studied, and mainly at moments of great turbulence and exchange rate speculation.

ahead for the exchange rate level. At a second moment, we displaced, using the rolling regression method, the estimation of the models one period ahead, keeping the size of the initial sample. We repeated the procedure to the exhaustion of the sample. This procedure is then compared with the forecasting of a model that assumes that the exchange rate follows a driftless random walk.

The out-of-sample forecasting analysis followed the methodology used by Cheung, Chinn e Pascual (2003). Firstly, we calculated the ratio between the Mean Squared Error[9] (MSE) of each specification and the MSE of the random walk. To test the statistic significance of this ratio, we used the statistic proposed by Diebold and Mariano (1995), in which, under null hypothesis, there is no difference between the two estimations forecasting performance, that is, the forecasting generated by the economic models is as good as the forecasting generated by a driftless random walk[10].

Table 4 presents the ratio between the MSE of the economic models and the estimations generated by a driftless random walk for the various out of sample periods: 1, 3, 6, and 12 months ahead. Thus, numbers inferior to one indicate that the economic models outperformed a driftless random walk for the out-of-sample forecasting of the exchange rate n-periods ahead; numbers superior to one indicate that the economic models underperformed a driftless random walk. Below the MSE ratio, we find the p-value of the Diebold Mariano test. Under the null, we test the equality between the loss functions of the economic and driftless random-walk models, and, under the alternative hypothesis, we test whether the loss function of the economic model is inferior to that generated by a driftless random walk[11].

For short-run forecasting, 1 and 3 months ahead, the Asset Model is the only one that outperforms a driftless random walk at a forecast horizon of 3 months. For long-run forecasting horizons, 6 and 12 months ahead, the economic models outperform the forecasts obtained by a random walk in 37,5% of the FPMM cases, 56% of the SPMM, 50% of the Market Model, and 100% of the Asset Model. The Portfolio Model, however, is always outperformed by the driftless random walk.

5 – Conclusions

The results of this study show that the economic variables may explain the behavior of an independently floating exchange rate in an emerging and commodity exporter economy like the Brazilian. The specifications herein estimated generated results consistent with those forecasted by the theoretical economic models, mainly when we considered monetary policy variables and used control variables that captured the economic agents' risk perception and the terms of trade conditions for the home market.

As a whole, the results of the in-sample estimations indicate that variables that measure the economic agents' risk perceptions, such as EMBI+, VIX, and Net External Liabilities are statistically significant and positive. As expected, the worsening (improvement) of the country risk perception leads to an exchange rate depreciation (appreciation).

---

9 $MSE = L(y_t) = E[(y\hat{}_t - y_t)^2]$where $y\hat{}_t$ is the estimated value and y_t is the observed value and E is the expected value operator.

10 Testing whether the economic models forecasting performance is different from the forecast generated by random walk is equivalent to testing whether the loss series sample average d_t, is zero, having: $d_t = L(y_t)-L(r_t)$. The statistic of Diebol-Mariano test is given by: $S = d/(LRV_d)^{1/2}$. Where $d = 1/T \sum_t d_t$ and LRV is a consistent estimator of the asymptotic variance $T^{1/2}d$. Diebold and Mariano (1995) show that under null hypothesis both models have the same forecasting power, $S^A \sim N(0,1)$.

11 For convenience, we have opted to present only at this moment the p-value of Test l. The complete results are available upon request

The interest rate is statistically significant and presents a positive sign whenever included, which shows that an increase in the interest rate does not attract external capital so as to induce the exchange rate appreciation. A possible intuition is that periods of increased interest rates are associated with moments of internal turbulence, and thus, correlated with the exchange rate devaluation. That is precisely what happened to the Brazilian economy in 1999, 2001 and 2002.

Terms of trade, when included in the specification, are always statistically significant and show a negative sign as expected by the theory, that is, improving the terms of trade tends to appreciate the exchange rate. However, in the case of the CRB index and the Balassa-Samuelson effect, they do not show robust results, they are not consistently significant, and the sign alternates.

In line with the arguments presented by Meese and Rogoff (1983a), in the sense that the out-of-sample forecasting would be one of the important criteria for the assessment of the empirical exchange models, we also estimated the forecasting performance of those models for short-run horizons, 1 and 3 months, and long-run, 6 and 12 months.

The specifications which have the best forecasting performance for both 6- and 12-month horizons are the FPMM (2), SPMM (2), (6), and (7), and finally the Asset Model. Considering only the statistically significant variables, the EMBI+ Brazil variable and M1 differential are always present in these specifications, and the interest rate differential and terms of trade are present in most cases. These results indicate that the exchange rate in Brazil is linked with economic factors and does not follow a random walk, corroborating the analysis carried out by Muinhos, Alves and Riella (2003).

Our study indicates that forecasting the future behavior of the exchange rate for an emerging commodity exporter economy with independently floating regime like Brazil must include macroeconomic fundamentals. In particular, monetary policy variables, like interest rates and M1, variables that measure the risk perception of the economic agents, like EMBI+ Brazil and VIX, and variables that measure the exporting market conditions, like terms of trade. In line with the analysis carried out by Obstfeld and Rogoff (1996), the exchange rate as well as the price of any asset reflects the agents' expectations towards the behavior of other variables. Future studies should try to test these results in other emerging economies.

References

BALASSA, B. The purchasing power parity doctrine: a reappraisal. **Journal of Political Economy**, v.72, p. 584-596, 1964.

BERKOWITZ, J.; GIORGIANNI, L. Long-horizon exchange rate predictability? **Review of Economics and Statistics**, v. 83, p. 81-91, 2001.

BILSON, J.F.O. The monetary approach to the exchange rate: some empirical evidence, **International Monetary Fund Staff Papers**, v. 25, p. 48-75, 1978.

BUITER, W.H.; MILLER. M. Monetary policy and international competitiveness: the problems of adjustment. **Oxford Economic Papers**, v. 33, Supplement, p. 143-175, 1981.

CHEN, Y. Exchange rates and fundamentals: evidence from commodity economies. **Job Paper,** University of Washington, Nov. 2004. Available at: <http://faculty.washington.edu/yuchin/Papers/ner.pdf>. Accessed in: March 10 2006.

CHEUNG, Y; CHINN, M.D.; PASCUAL, A.G. Empirical exchange rate models of the nineties: are any fit to survive?. Santa Cruz Department of Economics, **Working Paper Series,** 1333, 2003.

Available at:: <http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1033&context=ucscecon>. Assessed in: December 15 2005.

CLARIDA, R.; TAYLOR, M. The term structure of forward exchange premiums and the forecastability of spot exchange rates: correcting the errors. **Review of Economics and Statistics**, v. 79, p. 353-361, 1997.

DIEBOLD, F. X.; MARIANO, M. Comparing Predictive Accuracy. **Journal of Business and Economic Statistics**, v. 13, p. 253-65, 1995.

DORNBUSCH, R. Expectation and exchange rate dynamics. **Journal of Political Economy**, v. 84, p. 1161-76, 1976.

______. Exchange rate economics: where do we stand? **Brooking Papers on Economic Activity**, 1, p. 143-85, 1980.

______. Monetary policy under exchange rate flexibility. In: BIGMAN, D.; TAYA, T. (eds.). **Floating exchange rates and the state of World trade payments**. Cambridge, Massachusetts: Harper & Row, Ballinger, 1984, p. 3-31.

ENGEL, D.; GRANGER, C.W.J. Co-integration and error correction: representation estimation and testing. **Econometrica**, v.55, p. 251-276, 1987.

FRANKEL, J. A.; ENGEL, C.M. Do asset demand functions optimize over the mean and variance of real returns? A six-currency test. **NBER Working Paper**, n. 1051, 1982.

FRENKEL, J. A. A Monetary approach to the exchange rate: doctrinal aspects and empirical evidence. **Scandinavian Journal of Economics**, v. 78, p. 200-224, 1976.

GRANGER, C.W.J.; NEWBOLD, P. Spurious regression in econometrics. **Journal of Econometrics**, v.2, p. 111-120, July 1974.

GUO, H.; SAVICKAS, R. Idiosyncratic volatility, economic fundamentals, and foreign exchange rates. **Federal Reserve Bank of St. Louis Working Paper Series**, n. 2005-025B, May 2006.

HANSEN, L. P. Large Sample Properties of Generalized Method of Moments Estimators. **Econometrica**, v. 50, p. 1029-54, 1982.

HONG, Y.; LEE, T. Inference on predictability of foreign exchange rates via generalized spectrum an nonlinear time series models. **Review of Economic and Statistics**, v. 85, p. 1048-62, 2003.

HOOPER, P.; MORTON, J. Fluctuations in the Dollar: A Model of Nominal and Real Exchange Rate Determination. **Journal of International Money and Finance**, v. 1, p. 39-56, 1982.

KILIAN, L. Exchange rates and monetary fundamentals: evidence on long-horizon predictability. **Journal of Applied Econometrics**, v. 14, p. 491-510, 1999.

LEWIS, K.K. Are foreign exchange intervention and monetary policy related and does it really matter?. **Journal of Business**, v. 68, p. 109-127, 1995.

MACKNINNON, J. G. Numerical Distribution Function for Unit Root Tests. **Journal of Applied Econometrics**, v. 11, p. 601-618, 1996.

MARK, N. C. Exchange rates and fundamentals: evidence on long-horizon predicatability. **American Economic Review**, v. 85, p. 201-218, 1995.

______. **International macroeconomics and finance:** theory and econometric methods. Malden, Massachusetts: Blackwell Publishers Inc., 2001, 67-70 p.

MARTIN, J. P.; MASSON, P. R. Exchange rate and portfolio balance. **NBER Working Paper**, n. 377, 1979.

MEESE, R. Currency fluctuations in the Post-Bretton Woods era. **The Journal of Economic Perspective**, v. 4, n. 1, p. 117-134, 1990.

MEESE, R.; ROGOFF, K. The out-of-sample failure of empirical exchange rate models: sampling error or misspecification?. In: FRENKEL, J., (ed.), **Exchange Rates and International Macroeconomics**. Chicago: University of Chicago Press, 1983b, p. 67-105.

______. Empirical exchange rate models of the seventies: do they fit out of the sample?. **Journal of Finance**, v. 43, p. 933-948, 1983.

______. Was it real? The exchange rate-interest differential relation over the modern floating-rate period. **Journal of Finance**, v. 43, p. 933-948, 1988.

MEGALE, C. **Fatores externos e o risco-país**. Rio de Janeiro, 2003. 96 f. Dissertação (Mestrado em Economia) – PUC-Rio.

MUINHOS, M. K.; ALVES, S. A. L.; RIELLA, G. Modelo macroeconômico com setor externo: endogeneização do prêmio de risco e do câmbio. **Pesquisa e Planejamento Econômico**, v. 33, iss. 1, p. 61-89, abr. 2003.

OBSTFELD, M.; ROGOFF, K. **Foundations of international macroeconomics**. Cambridge, Massachusetts: MIT Press, 1996, cap. 8, 9, p. 529, 625.

ROSSI, J. **O modelo monetário de determinação da taxa de câmbio**: Testes para o Brasil. Brasília: IPEA, 1995. p. 28, (Working Paper, n. 393).

SAMUELSON, P.A. Theoretical Notes on Trade Problems. **Review of Economics and Statistics**, v. 46 (May), p. 145-146, 1964.

SARNO, L.; TAYLOR, M.P. **The economics of exchange rates**. Cambridge: Cambridge University Press, 2002, cap. 4, p. 104-107, 115-118.

TABLES

Table 1 – In-sample results: exchange rate changes – Flexible Price Monetary Model and controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	**0,010*** **	**0,006** **	**0,005* **	**0,007** **	**0,011*** **	**0,004**	**0,001**	**0,004**
Product	**0,039**	**0,023**	**0,089**	**0,038**	**0,023**	**-0,025**	**-0,063**	**-0,030**
M1	**0,246** **	**0,291*** **	**0,383*** **	**0,274*** **	**0,170**	**0,238** **	**0,239** **	**0,208** **
Interest Rates	**1,726*** **	**0,961*** **	**1,097*** **	**1,081*** **	**1,671*** **	**-0,166**	**-0,380**	**1,053*** **
EMBI+ Brazil	..	**0,223*** **	**0,150*** **	**0,215*** **	..	**0,302*** **	**0,295*** **	**0,249*** **
Terms of Trade	..	..	**-1,167*** **	..	..	..	**-0,118**	..
Commodities Index - CRB	..	..	..	**0,081**	..	..	..	**0,233**
Balassa–Samuelson Effect	..	..	..	..	**0,212**	**-0,457**	**-0,631** **	**-0,605*** **
Statistic J (1)	**0,105**	**0,088**	**0,063**	**0,091**	**0,112**	**0,094**	**0,107**	**0,098**
AIC	**-6.187**	**-6.589**	**-6.139**	**-6.622**	**-6.189**	**-6.355**	**-6.229**	**-6.521**

Notes: ***, ** and * denote significance levels at 1%, 5% e 10%, respectively.
(1) H0: the over identification of the instruments is satisfied.

Table 2 – In-sample results: exchange rate changes – Sticky Price Monetary Model and controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	0,000	0,004	0,005*	0,005	0,014***	0,004	0,010*	0,004
Inflation	-1,209**	-0,564	-0,180	-0,525	0,551	-0,272	0,531	-0,006
Product	-0,013	0,052	0,079	0,032	0,084	0,069	0,121	0,054
M1	0,202	0,312***	0,363***	0,296***	0,259**	0,349***	0,430***	0,366***
Interest Rates	1,486***	1,028***	1,077***	1,018***	1,616***	0,846***	1,257***	0,913***
EMBI+ Brazil	..	0,219***	0,153***	0,215***	..	0,250***	0,121**	0,248***
Terms of Trade	..	..	-1,038***	..	..	..	-1,096***	..
Commodities Index - CRB	..	..	..	0,010	..	..	..	0,096
Balassa–Samuelson Effect	..	..	..	..	1,059***	0,255	0,355	0,203
Statistic J (1)	0,129	0,105	0,083	0,104	0,113	0,137	0,082	0,129
AIC	-6.146	-6.591	-6.190	-6.562	-6.034	-6.512	-6.051	-6.477

Notes: ***, ** and * denote significance levels at 1%, 5% e 10%, respectively.
(1) H0: the over identification of the instruments is satisfied.

Table 3 – In-sample results: exchange rate changes – Composite Models

	Portfolio Model (1)	Portfolio Model (2)	Market Model	Asset Model
Constant	-0,001	-0,007*	0,013***	-0.001
M1				0.444***
Product				0.071
Balassa-Samuelson Effect	-0,746***	0,001		
Commodities Index - CRB	0,119	0,170	-0,357*	
Terms of Trade				-0.677*
Interest Rates	1,491***	1,234***	0,899***	
Inflation	-1,257**	..		
Dollar Denominated Government Liability	-0,064**	-0,081***		
Net External Liabilities (Current Account adjusted)	1,246**	1,945***		
VIX	0,060*	0,107***	0,191***	
EMBI+ Brazil	0,123***	0,166***	0,147**	0.228***
High Yield Spread			-0,016	
PPP	..	1		
Statistic J (1)	0,103	0,148	0,082	0,104
AIC	-6.711	-6.585	-6,090	-6,103

Notes: ***, ** and * denote significance levels at 1%, 5% e 10%, respectively.
(1) (1) H0: the over identification of the instruments is satisfied.

Table 4 – Out-of-sample forecasts.

Models / Periods ahead[(1)]	1 month	3 months	6 months	12 months
FPMM – original specification	1,089 0,646	0,987 0,485	0,944 0,434	1,127 0,700
+ EMBI+ Brazil	1,115 0,679	0,863 0,374	0,733 0,168	0,705 0,053
+ Terms of Trade	1,032 0,540	0,654 0,170	0,678 0,099	0,648 0,021
+ CRB commodities index	0,972 0,476	0,741 0,309	0,838 0,369	1,086 0,591
+ Balassa-Samuelson effect	1,273 0,903	0,963 0,458	1,025 0,530	1,216 0,846
+ Balassa + EMBI	0,895 0,408	0,719 0,284	0,647 0,144	0,601 0,008
+ Balassa + EMBI + TT	0,756 0,254	0,724 0,285	0,805 0,292	0,667 0,023
+ Balassa + EMBI + CRB	0,889 0,403	0,506 0,125	0,567 0,068	0,722 0,142
SPMM – original specification	2,220 0,941	1,160 0,734	0,925 0,398	0,964 0,443
+ EMBI+ Brazil	0,937 0,393	0,764 0,244	0,642 0,096	0,675 0,019
+ Terms of Trade	0,968 0,452	0,612 0,120	0,670 0,124	0,721 0,041
+ CRB commodities index	0,870 0,366	0,718 0,261	0,630 0,081	0,978 0,453
+ Balassa-Samuelson effect	1,050 0,588	0,850 0,326	0,909 0,384	1,191 0,697
+ Balassa + EMBI	1,137 0,672	0,762 0,269	0,566 0,049	0,580 0,050
+ Balassa + EMBI + TT	0,782 0,261	0,616 0,197	0,486 0,045	0,612 0,076
+ Balassa + EMBI + CRB	1,045 0,540	0,843 0,379	0,563 0,076	0,804 0,276

Table 4 – *Continuation* – Out-of-sample forecasts.

Models / Periods ahead[1]	1 month	3 months	6 months	12 months
Portfolio Model – without PPP	1,315	1,523	2,429	6,129
	0,700	0,778	0,962	0,993
Portfolio Model – with PPP	1,639	1,569	2,032	4,390
	0,861	0,826	0,943	0,995
Market Model	1,019	0,855	0,679	0,784
	0,526	0,336	0,124	0,062
Asset Model	0.807	0.529	0.525	0.531
	0,298	0,083	0,037	0,001

Notes: The table presents the out-of-sample MSE ratio between the economic models forecast and the driftless random walk forecasts. Values below unity indicate that the economic models had a better forecast performance than the driftless random walk. The gray numbers below the ratios indicate H0 p-values for the Diebold-Mariano test (DIEBOLD; MARIANO, 1995, p. 4). Shadowed boxes indicate that the economic model has outperformed the driftless random walk at a confidence interval level of 90% or higher.

(1) H0: MSE of the economic model = MSE of a driftless random-walk;
H1: MSE of the economic model < MSE of a driftless random-walk.

Appendix – Data Description

The data cover the period from January 1999 to December 2005.

The following series for the Brazilian price indexes were used: the IPCA, calculated by IBGE was used as consumer inflation rate measure, the IPA-DI, estimated by FGV, as tradable inflation rate indicator, and the IPCA non-tradable inflation rate series (IPCAnt), calculated by MCM (a Brazilian consulting firm), as non-tradable inflation rate proxy for Brazil. For the United States, the Consumer Price Index was used as the consumer price index, the Service CPI Less Energy Services (CPInt), as non-tradable inflation rate measure, and the Producer Price Index (PPI), as tradable goods inflation rate measure. The Bureau of Labor Statistics calculated the US series. In all the cases, we used the original series without seasonal balance.

The inflation rate for both countries was calculated by the 12-month log-difference in the consumer price index (IPCA and CPI).

As product proxy, given the absence of GDP monthly series in both countries, the industrial production original series for Brazil and the United States, calculated by IBGE and by the Bureau of Labor Statistics were respectively, used.

The exchange rate (R$/US$) used refers to the last market price at the end of the month closing rate, obtained at Bloomberg.

The SELIC Rate and the FED Fund Rate were used as short-run interest rates for Brazil and the United States, respectively. However, given the different basis for calculus between rates in Brazil and in the United States, the following transformation was made in the SELIC rate series so that it would be made linear and comparable to the FED Fund:

$$SELICn = \left[(1 + SELIC/100)^{(1/252)} - 1\right] \times 252$$

As long-run rate, the 1-year Pre-DI swap rate and the US Swap semi 30/360 1Y were used – both series obtained at Bloomberg[13]. The same procedure used for SELIC was replicated at the Pre-DI swap so that it would become linear.

The Gross Government Debt data about the Brazilian GDP are provided by the Central Bank of Brazil (BCB); for the United States, the data were obtained at Bloomberg[12].

The risk premium used was EMBI+ Brazil (Emerging Market Bond Index – Brazil) calculated by JP Morgan, which measures the risk spread of the Brazilian sovereign external debt over a general risk-free bond, in the case, the United States Treasury.

The CS High Yield Index II Spread to Worst (HG) was used and calculated by Bank Credit Suisse[13]. The HG includes corporate bonds considered below investment grade and reflects the risk perception of the market credit.

The VIX measures the implicit volatility of the prices in a basket of options in the S&P 100 index, and shows the market expectations for the 30-day volatility. It is

[12] Bloomberg Code: *.DBT%GDP Index*
[13] Bloomberg Code: *DLJHSTW Index*

published by the Chicago Board Options Exchange (CBOE), and widely used as market risk measure[14].

The net external liabilities is not published monthly by the Central Bank of Brazil; thus, a June-2005 net external liabilities based series was built and updated with June-2005 monthly current account liquidity, which is also provided by the BCB.

The domestic dollar denominated government debt data, which also include the position in USD-SELIC swap of the Central Bank, are released by the Central Bank of Brazil and by the National Treasury. It's worth noting that despite being measured in dollars, the dollar-dominated bonds are issued and settled in national currency, in this case, the Brazilian Real. The USD-SELIC swap is settled by the differential of returns between the dollar Ptax[19] and the SELIC Rate.

Instead of using directly the CRB15 as reference for the commodities prices in the international market, a series was built from the CRB segmented indexes, using differentiated considerations in order to approach this series to the Brazilian Export basket. The following series were used: CRB Energy (10%), CRB Metal (30%), CRB Grains (40%), CRB Raw Industrial (10%) e CRB Industrial (10%)16. Data related to terms of trade, constructed and released by FUNCEX were also used.

For data concerning the SELIC rate and FED Fund, Brazil 1-year Pre-DI swap rate and the US Swap, CRB and its segments, CS High Yield Index II e EMBI+ Brazil, we used market quotation at the end of period (monthly).

Given the inexistence of monthly productivity data both in Brazil and in the United States, the following productivity proxy related to the tradable goods sector between the two countries was applied (Z)17:

---

[14] The VIX index can be obtained at Bloomberg through the code VIX Index. Further details on VIX can be obtained at http://www.stricknet.com/vix.htm

[15] The CRB is calculated daily by the Commodity Research Bureau, in USA, and comprises the price of 22 commodities. CRB data is available at http://www.crbtrader.com/crbindex/spot_background.asp.

[16] The Bloomberg codes are respectively CRBFENRG Index, CRB METL Index, CRBFGRNS Index, CRBFINDU Index e CRB RIND Index.

[17] We assume that the tradable goods sector productivity index can be expressed by inverting the tradable goods price index in each country ((1/IPA-DI e 1/PPI); the same procedure is used to obtain the sector productivity index of non-tradables (1/IPCAnt e 1/CPInt). Denominating Zbr and Zus the relative productivity between the tradable goods and the non-tradable goods in Brazil and in the United States, respectively, we have: $Zbr = (IPCAnt / IPA - DI)$

$Zus = (CPInt / PPI)$

Balassa-Samuelson assume similar productivity for the non-tradable goods for the sector, which leads to:
$Zbr / Zus = (IPCAnt / IPA - DI)/(CPInt / PPI)$

in logarithm, the above expression can be rewritten as:
$Zbr / Zus = \log(IPCAnt / IPA - DI) - \log(CPInt / PPI) = Z$

Figure 1 – Data

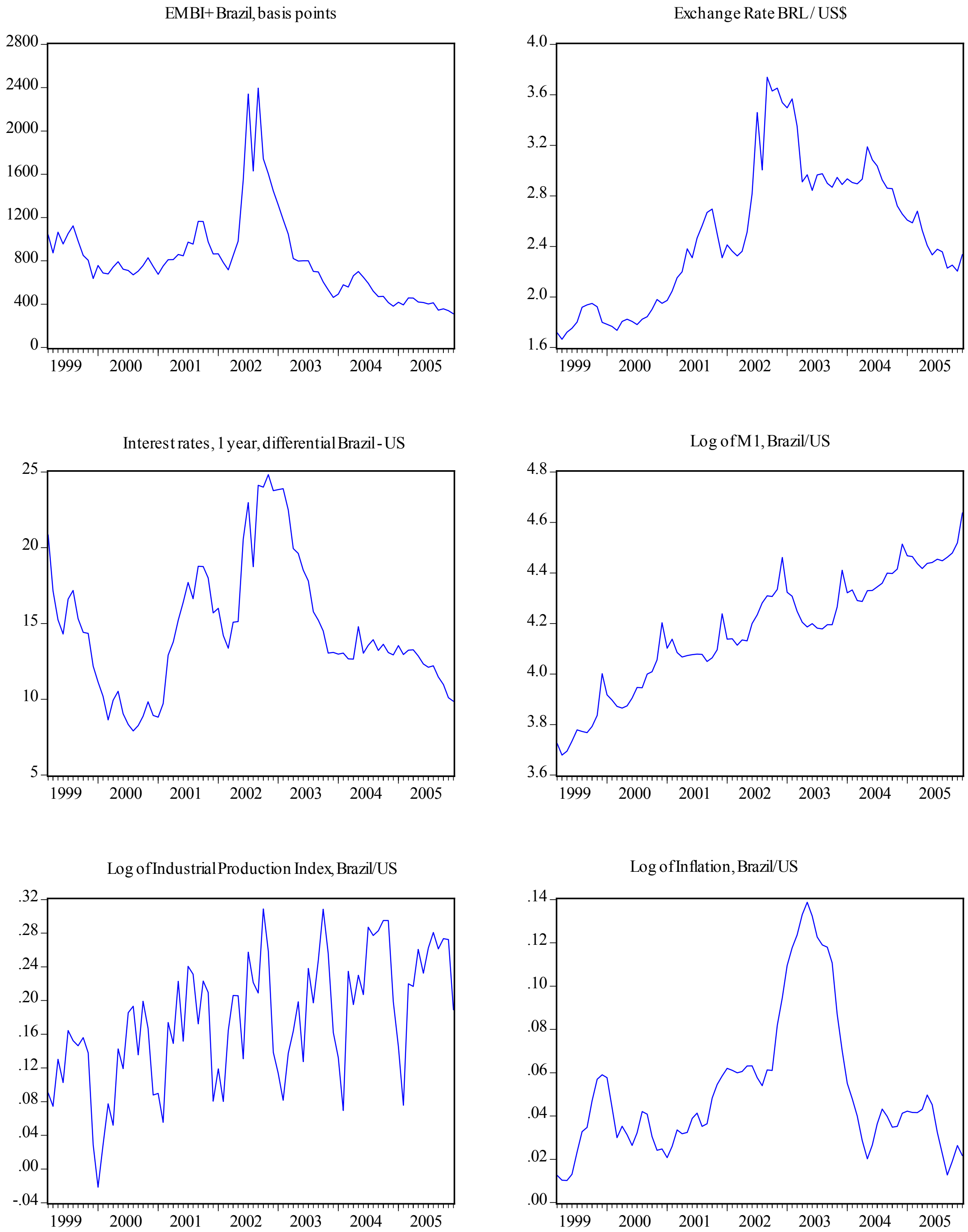

Figure 2 – Data