Real equilibrium exchange rates: A panel data approach for advanced and emerging economies

Antonia López Villavicencio[1]

Abstract. Based on a behavioral equilibrium exchange rate model, this paper examines the determinants of the real effective exchange rate and evaluates the degree of misalignment of a group of currencies since 1980. Within a panel cointegration setting, we estimate the relationship between the exchange rate and a set of economic fundamentals, such as traded-nontraded productivity differentials and the stock of foreign assets. After having ascertained that the variables are integrated and cointegrated, the long-run equilibrium values of the fundamentals are estimated and used to derive equilibrium exchange rates and misalignments. Although there is statistical homogeneity, some structural differences exist between advanced and emerging economies.

JEL Classification: C33; F31; F41.
Keywords: Equilibrium Exchange Rates; Panel Data; Cointegration; Emerging Economies; Misalignments; Error Correction Models.

Résumé. Cet article étudie les déterminants du taux de change effectif réel et estime le niveau de mésalignement d'un échantillon de devises depuis 1980, en s'appuyant sur un modèle de taux de change d'équilibre comportemental. À l'aide des techniques de cointégration en panel, nous estimons la relation entre le taux de change et certaines variables fondamentales, tels que les différentiels de productivité entre secteur marchand et non marchand et la position extérieure nette. Après s'être assuré que les variables sont intégrées et co-intégrées, les valeurs d'équilibre de long terme des fondamentaux sont estimées et utilisées pour en déduire les taux de change d'équilibre et les mésalignements. En dépit de l'homogénéité statistique, des différences structurelles apparaissent entre les économies avancées et émergentes.

Classification *JEL* : C33 ; F31 ; F41.
Mots-clefs : Taux de change d'équilibre ; données de panel ; cointégration ; économies émergentes ; mésalignements ; modèle à correction d'erreurs.

1. Antonia López Villavicencio, Economist, Departament d'Economía Aplicada, Universitat Autónoma de Barcelona and EconomiX, Université Paris X Nanterre (alopezv@selene.uab.es).

Introduction

The evolution of the Real Exchange Rate (RER) is a leading indicator of the strength of an economy. Foreign investment, capital flows or international trade are all deeply influenced by the modifications that the real exchange rate can bring upon the goods and capital markets. In addition, given its close link with competitiveness, it turns out to be a fundamental issue when dealing with economic crises and booms.

Indeed, the role of the real exchange rate in macroeconomic adjustments seems to be crucial. In particular, persistent exchange rate misalignments are believed to generate severe macroeconomic disequilibria often leading to costly external imbalances. Furthermore, nowadays RER appreciations are considered as early warning indicators of possible currency crises, a view that arises from the experiences of countries such as Argentina, Brazil or some Asian economies.

Therefore, any interventions to defend a parity should have in mind an approximation of the degree of real exchange rate misalignment and, of course, its consequences. It is unquestionable, then, that in order to understand the RER misalignment, a well defined point of reference of equilibrium is needed.

In spite of the extensive literature on the topic, the concepts of equilibrium exchange rate and misalignment remain subjective. For many years, the Purchasing Power Parity (PPP) doctrine was considered as the benchmark for measuring equilibrium exchange rates and a way of judging over or under-valuations. Still, whether the real exchange rate converges to a constant mean in the long-run, as the PPP doctrine proposes, is today a subject of controversy for many reasons.

For instance, given the mean reversion mechanism that the PPP proposes, nominal and real exchange rates cannot be misaligned for long periods of time. However, the observed movements of the exchange rates (long periods of high fluctuations, long-lasting misalignments with economic fundamentals, etc.) during the 1980s and 1990s, suggested that the real exchange rate may not be mean reverting.

Also, under the PPP, there are no explicit explanations for persistent foreign deficits. Yet, increasing external imbalances have been taking place in the world since the late 1990s. On the one hand, the U.S. has been running chronically large deficits; on the other hand, Japan and some other Asian countries, Russia and the Middle East, have undergone large surpluses. The euro area country members, somewhere in the middle, have also experienced important, although not very large, current account surpluses.[2]

2. According to IMF data from 2005, while in the major advanced economies the current account balance as percentage of GDP was –2.1%, in emerging markets and developing countries it was around 4.1%. In particular, the individual imbalances grew to -6.1% percent of GDP in the US, –2.2% in the U.K., –5.7% in Australia, +4.3% in Taiwan, +10.3% in Hong Kong, and +2.0% in South Korea. In the euro area growth of the current account was a moderate 0.5% of the GDP the same year.

These global imbalances can be explained by both the evolution of the trade balance and the international movements of capital. Indeed not only emerging economies have increased their trade surplus while the United States' and some other advanced countries' trade deficit have risen considerably, also the rapid integration of the international financial system during the past decade has played an important role in enabling these imbalances to persist and be easily financed. In addition, emerging market economies, traditionally recipients of foreign capital, have become a major source of net foreign capital outflows and, most notably, have been collectively important in financing the large and growing U.S. current account deficit (Lane and Milesi-Ferreti, 2006).

Given the shortcomings of the PPP approach (i.e., the impossibility to explain persistent misalignments and global imbalances), in this paper we adopt an alternative measure of exchange rate equilibrium, based on the economic fundamentals. As such, the equilibrium exchange rate is not a static indicator but rather moves over time as the economy's macrofundamentals do. Contrary to previous studies, in order to have a comprehensive understanding of real exchange rate misalignments, we try to take a global perspective by not disregarding macroeconomic imbalances in developing economies. Therefore, our estimation of equilibrium RER and the measure of misalignments include, apart from the major industrial nations, some emerging market economies.[3] This is an issue of special concern in a period characterized by increasing trade and financial integration.

In order to address these issues, we use a panel of medium income-level and emerging market economies together with high-income economies, arguing that these countries share common characteristics that justify the use of a panel data approach. First, we are particularly interested in these techniques because, by exploiting the cross-section as well as time series variability, we increase the power over univariate methods. Second, by estimating a single equilibrium exchange rate equation, we smooth the impact of individual countries' transitional dynamics. Third, given that macro-economic imbalances are increasingly linked between countries, it would be misleading to ignore emerging markets when assessing real exchange rate misalignments.

Therefore, we make a further step in the literature of equilibrium exchange rates by including some developing countries in our analysis. We are aware that, by doing so, we may introduce additional cross-section heterogeneity into the panel.[4] Yet, we test for homogeneity and split the sample between advanced and developing countries. Therefore, we are able to investigate if dropping the developing countries from the sample affects the main results.

The paper is organized as follows. In the next section we give a brief review of the equilibrium exchange rate theories. Then it describes the methodology implemented. In section 3 we report the empirical findings. Section 4 concludes.

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3. I will use here indistinctly the terms emerging market economies and developing countries.
4. As in any panel data study, there is a tradeoff between increasing the sample size and gaining power in the tests and introducing heterogeneity.

Modelling real equilibrium exchange rates

The purchasing power parity (PPP) is a simple and popular concept of long-run or equilibrium exchange rate in the literature that implies a constant equilibrium exchange rate. In other words, the PPP maintains that there exists a deterministic steady state level of RER (the equilibrium real exchange rate) towards which the current RER converges in the long run. Even though the PPP is at the core of many models for real exchange rate determination, many studies that test PPP during the recent float cannot reject the random walk hypothesis for the real exchange rates of the currencies of all the major industrialized countries against one another, suggesting that deviations from PPP are permanent (for example, Engle, 2000). Based on cointegration techniques, other works report the absence of significant mean reversion of the exchange rate toward PPP in major industrialized countries (Taylor, 1988), but are supportive of reversion toward PPP for exchange rates of high inflation countries (McNown and Wallace, 1989). Investigations using long-span data (Frankel, 1986; Lothian and Taylor, 1996) or panel data (Frankel and Rose, 1996) are more supportive of the mean reversion. Yet, since the speed of convergence to PPP is found to be extremely slow in many cases, whether PPP holds in the long-run remains contentious.

The lack of empirical evidence supporting the PPP gave rise to alternative approaches. In particular, the macroeconomic approach, which focuses on the determinants of the real exchange rate based on the economic fundamentals, was introduced as a benchmark to check the possible misalignments of the actual exchange rate. That is, the "equilibrium exchange rate" is seen as an exchange rate consistent with long-run macroeconomic fundamentals. A clear advantage over the PPP (which can be thought as the monetary approach for the determination of the equilibrium real exchange rate) is the incorporation of real non-stationary sources. Two main lines of research are distinguished in this approach: the first one, known as the balance of payments approach, highlights the underlying net foreign asset position of a country. The second one, based on the Harrod (1933), Balassa (1964) and Samuelson (1964), centers its attention on the sectoral (tradable-nontradable) balance.

Following these propositions, Alberola, Cervero, López and Ubide (1999) and Alberola (2003) propose a theoretical model that encompasses both, the balance of payments and the Balassa-Samuelson approach to real exchange rate determination.[5] The starting point of the model is the decomposition of the exchange rate into two different relative prices: The first one, the price of domestic relative to foreign tradables, captures the competitiveness of the economy and determines the evolution of the foreign asset position. In contrast, the second one, which is the relative price of non-tradables relative to tradables within each country, plays a central role in adjusting excess demand across sectors in the economy.

Based on the previous theoretical approaches, several empirical studies have tried to measure equilibrium exchange rates and misalignments for major industrial countries. Yet, an impor-

5. We do not discuss this model in detail here but the reader may refer to Alberola *et al*. (1999) and Alberola (2003).

tant drawback of these studies is that they disregard valuable information by assuming that real exchange rate misalignment of major currencies only depends on macro-economic imbalances in the top group of industrialized countries (for example, Clostermann and Schnatz, 2000; Roeger and Hansen (2000); Alberola *et al.*, 1999; Maeso-Fernandez, Osbat and Schnatz, 2001). Therefore, they provide a guidance of the degree of misalignment for these currencies against each other, but they do not give any information regarding the misalignment with respect to the emerging economies.

On the contrary, the literature for developing countries is less abundant. In an attempt to study real equilibrium exchange rates in some Latin American currencies, Alberola (2003) estimates misalignments with annual data from 1960 to 2001. However, this paper considers only misalignments with respect for the dollar. Moreover, though the reported parameters of the cointegration vectors have the expected signs, the results are difficult to interpret since no information is given regarding their significance.

One of the few studies that estimate equilibrium exchange rates and misalignments for annual real exchange rates in both advanced and developing countries can be found in Bénassy-Quéré, Duran-Vigneron, Lahrèche-Revil and Mignon (2004). In this sense, our investigation follows theirs but we make a further step by testing for homogeneity of the sample. We also split the currencies into advanced and developing countries and therefore, we compare panel estimates for the two groups. Another advantage of our paper is that we do not assume that the real effective exchange rates were in equilibrium, on average, over the period under study.

Therefore, based on the notion of equilibrium exchange rates provided by Alberola *et al*. (1999) and Alberola (2003), we identify two main fundamentals for the evolution of the real exchange rate: the level of net foreign assets and a measure of relative sectoral productivity.

Methodology

The econometric methodology used in this paper is based on panel unit root and cointegration tests. First, we evaluate the PPP doctrine (i.e. we test for unit root in the RER). Second, we test for cointegration between the real effective exchange rate and the underlying macroeconomic fundamentals. Finally, we estimate the long-run parameters that we later use for computing the real equilibrium exchange rates (REER) and the misalignments.

There are several reasons that justify the use of these panel data unit root and cointegration techniques. First of all, it is well known that time series unit root and cointegration tests have limited power for finite samples against alternative hypotheses with highly persistent deviations from equilibrium. Thus, the use of panel data is usually seen as a way to generate more powerful tests. Second, countries may share common similarities usually lost in time series analysis. For instance, non-stationarity appears more as a general feature for macroeconomic series, characterizing an important number of developed and developing countries.

Hence, it is interesting to test the homogeneity of the unit root in a panel framework. In addition, a panel data framework not only allows to take into account the international dimension and the similarities of a group of countries, also some specifications consider possible cross-sectional dependence among them. Finally, a major advantage of panel cointegration techniques is that they allow to selectively pool the long run information contained in the panel while permitting the short-run dynamics to vary and heterogeneity among different members.

Panel unit root tests

Unit root tests can be classified into three groups depending on whether they allow for structural breaks and cross-sectional correlation, which are features very often found in time series and panel data models. Tests in the first group are based on a cross-sectional independence and no structural break assumptions. Examples of tests in this group are found in Im *et al*. (1997), which has unit root under the null hypothesis, and Hadri (2000) which, on the contrary, tests for stationarity. The second category of tests is characterized by not imposing the cross-sectional independence assumption but do not admit breaks (for instance, the z_e^c test proposed by Bai and Ng, 2004, the CIPS unit root test by Pesaran, 2003, and the nonlinear instrumental variables (IV) method by Chang, 2002).

Still, it is well known that structural breaks can be mistaken for non-stationarity (see Perron, 1989). Hence, we applied the *LM*(λ) panel unit root test proposed by Carrion-i Silvestre *et al.* (2005). This methodology test for stationarity in the presence of structural change has the advantage that it does not impose the absence of cross-correlation in the error terms and allows to up to five structural breaks.[6]

Panel cointegration

To test for cointegration in a panel setting, we follow the methodology proposed by Pedroni (1999), which has the advantage over others that it allows for considerable heterogeneous variances across countries at each point in time. Thus, it allows to pool the long-run information contained in the panel, while permitting the short-run dynamics to vary among different members. This "pooling" can be done across either the "within" or the "between" dimension. In Pedroni's panel cointegration tests, the null hypothesis is taken to be that for each member of the panel the variables of interest are not cointegrated. The alternative hypothesis is taken to be that for each member of the panel there exists a single cointegrating vector, although this cointegrating vector does not need to be the same for each member.

The long-run relationship

Having established that the variables are integrated and that a cointegration relation indeed exists, the long-run parameters can be estimated. For this, it is important to identify parameters that are likely to be similar across panel units while at the same time allowing for suffi-

6. The author gratefully acknowledges Carrion-i-Silvestre for providing the GAUSS codes to perform the *LM*(λ) test.

cient heterogeneity of other parameters. One approach that allows us to do that is the error correction pooled mean-group (PMG) estimators by Pesaran *et al*. (1999), PSS hereafter.

The PMG estimator combines two procedures that are commonly used in panels. The first one, known as the Mean Group (MG) estimate, consists of estimating separate regressions for each group (country) and calculating averages of the group specific coefficients. They show that the MG estimator will produce consistent estimates of the average of the parameters. This estimator, however, does not take into account the fact that certain parameters may be the same across groups. The second one involves the traditional pooled estimators (such as the fixed or random effects estimators) that allow only the intercepts to differ freely across groups while all the other coefficients and error variances are constrained to be the same.

PSS suggest an intermediate estimator, called the Pooled Mean Group estimator because it involves both pooling and averaging. This estimator allows the intercepts, short-run coefficients and error variances to differ freely across groups, but the long-term coefficients are constrained to be the same. The PSS methodology has the benefit over other methodologies, such as the fully-modified OLS (FMOLS) by Pedroni (1997) or Phillips and Moon (1999), and the dynamic OLS (DOLS) by Pedroni (2000), Mark and Sul (2001) or Kao and Chiang (2000) that it is based on dynamic equations; so it does not only provide the cointegrating relationship, but also the short-run effects. Another advantage of this methodology is that it provides a way to test for homogeneity in the sample.

The starting point of the procedure is an autoregressive distributed lag (ARDL) model of order *(p, q, q, ...)* where p and q are the autoregressive orders of the dependent and independent variable(s), respectively. Reparameterized as a vector error correction mechanism (VECM) the system can be expressed as:

$$\Delta y_{it} = \theta_i y_{i,t-1} - \beta_i' x_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=1}^{q-1} \delta_{ij} \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (1)$$

where y_i is the dependent variable, x_i is the $(k \times 1)$ vector of explanatory variables for group (country) i, β_i are the long-run parameters, the θ_i are the equilibrium (or error) correction parameters, λ_{ij} and λ_{ij} include the country-specific coefficients of the short-term dynamics, μ_i represents the fixed effects and ε_{it} is a white noise process. In principle, the panel can be unbalanced and p and q may vary across countries. The pooled mean group restriction is that the parameters of β_i are common across countries; that is $\beta_i = \beta$ in equation (1).

Hence, if θ_i is significantly negative, there exists a long-run relationship between y_{it} and x_{it}. Estimation of (1) could proceed by OLS, imposing and testing the cross country restrictions on β. However, this will be inefficient since it ignores the contemporaneous residual covariance. Therefore, PSS suggest a maximum likelihood estimator.

Instead of assuming common long-run parameters, the estimation can also be done with individual specific β_i, which are then averaged over the N countries to obtain the MG estima-

tor. As can be expected, this is a natural background to test for the presence of slope homogeneity using a Hausman test. This test is based on the results that an estimate of the long-run parameters in the model can be derived from an average (MG estimation) of the country regressions and this is consistent even under heterogeneity. However, if the parameters are in fact homogenous, the PMG estimates are more efficient. That is, if the poolability assumption is invalid then the PMG estimates are no longer consistent.

Finally, an important assumption of the panel cointegration tests is the absence of cross-sectional correlation. The possible presence of contemporaneous correlation can be addressed either by using time dummies or by subtracting the cross-sectional mean from the data.

Real equilibrium exchange rates and misalignments

One of the reasons for finding the determinants of the real exchange rates is to be able to estimate their degree of misalignment. With this purpose, we use the long-run estimates of the economic fundamentals obtained from the PMG estimation to compute the fitted values of the equilibrium real exchange rates.

However, computing equilibrium exchange rates is not straightforward. Indeed, as mentioned by Arberola (2003), finding a long-run cointegration relationship between the real exchange rate and its fundamentals would yield an estimate of the equilibrium rate if we were able to observe the equilibrium level of the fundamentals. Unfortunately, we can observe only the actual values of these variables. Therefore, to calculate the long-run equilibrium RER we need to isolate the permanent values of the macro fundamentals from their short-run fluctuations.

There are several procedures to filter or decompose macroeconomic time series. Here, we use the Hodrick-Prescott (HP) methodology to obtain the permanent (equilibrium) components of the fundamental variables.[7] Thus, the estimates of the long-run equilibrium real exchange rate (REER) are obtained by substituting the values of the permanent component into the estimated cointegration equation. Finally, the misalignment in the real exchange rate corresponds to the difference between the observed and the equilibrium real exchange rate, both in logarithms.

Thus, the procedure characterizes the long-run equilibrium RER as a function of the sustainable values of the macroeconomic fundamentals. Consequently, this approach gives a good approximation of equilibrium exchange rates for each country, against which the level of the actual exchange rate can be assessed. As such, it helps to identify major exchange rate misalignments (i.e., over and undervaluations) and provides qualitative indication of the extend to which the exchange rates are in line with economic fundamentals.

7. In general, time series are viewed as the sum of transitory and permanent components, and the HP filter captures the smooth path of the trend component by minimizing the sum of squares of its second difference. Other alternative decomposition techniques are the propositions by Beveridge and Nelson (1981) or Gonzalo and Granger (1995), among others.

DATA SOURCES AND CONSTRUCTION OF THE VARIABLES

Our analysis considers quarterly data for the period 1980 Q1-2005 Q4 and includes the following seventeen currencies: Argentina, Australia, Brazil, Canada, the Euro-zone, Indonesia, India, Japan, South Korea, Mexico, Norway, New Zealand, Thailand, Turkey, South Africa, the United States and the United Kingdom.[8]

The main sources we have used in this paper are the IMF's *International Financial Statistics*, the OECD's *Analytical Database* and the European Commission's *AMECO Database*. Based on this information, we constructed the following variables.

The Real effective exchange rate, based on consumer prices, measures movements in the nominal exchange rate adjusted for the differential between the domestic price index and trade-weighted foreign price index. The *CPI*-based RER indicator, of a country *i* is:

$$RER_{it} = \frac{P_{it}S_{it}}{\prod_{j \neq i}^{N}(P_{jt}S_{jt})^{\omega_{ij}}}, \qquad (2)$$

where *j* is an index of country *i*'s trade partners; *N* is the number of countries, ω_{ij} is the competitiveness weight put by country *i* on country *j*, P_i and P_j are consumer price indices in countries *i* and *j*, and S_i and S_j represent the nominal exchange rates of countries *i* and *j*'s currencies in US dollars.[9] An increase (decrease) in a country's index indicates an appreciation (depreciation).

In (2) *i*'s *N* partners are exclusively the members of the panel which had a competitiveness weight, ω, in *i*'s trade equal or bigger than 2 percent, normalizing these weights to sum to one. The same criterion was used to compute the rest of the variables in multilateral terms.[10] We work with the logarithm of the real effective exchange rate, denoting this variable as q_t.

The impact of the **relative sectoral productivity** is expected to follow the Balassa-Samuelson doctrine, which states that relatively larger increases in productivity in the traded goods sector are associated with a real appreciation of the currency of a country. Given the fact that more of the components of the Producer Price Index (*PPI*) are tradable than those in the Consumer Price Index (*CPI*), to capture the diverging productivity trends we use the ratio of (*CPI*) to (*PPI*).[11] We obtained the ratio of this index for each country to its equivalent weighted foreign average:

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8. Given its growing importance in international trade, it would be interesting to include China in the analysis. However, for the period covered, no quarterly data exists for this country.
9. For the weights we used data from Durand, Madaschi, and Terribile (1998). This calculation of competitiveness considers the influence of emerging market economies, which is an advantage over other sources such as Zanello and Desruelle (1997). The weights correspond to the 1995 matrix.
10. If for some years, or for the whole period, a variable was missing for one or several of the *N* countries, we distributed the weights between the rest of the partners.
11. It would be desirable to count with a direct measure of productivity differential based, for instance, on output and hours worked or employment in the manufacturing sector. However, for several of the countries considered it is not possible to obtain these variables for a sufficiently long period of time.

$$PD_{it} = \frac{CPI_{it} \,/\, PPI_{it}}{\prod_{j \neq i}^{N} (CPI_{jt} \,/\, PPI_{jt})^{\omega_{i,j}}}, \tag{3}$$

We work with its logarithm and label the variable *pd*.

Finally, there are several channels through which the **stock of foreign assets** can influence the real exchange rate.[12] For instance, portfolio-balances considerations suggest that a deficit in the current account creates an increase in the net foreign debt of a country, which has to be financed by international investors which, in order to adjust their portfolio, demand a higher yield. At given interest rates, this can only be achieved through a depreciation of the currency of the debtor country.

Also, the balance of payments channel assumes that a current deficit accumulates net foreign debts, for which interests have to be paid. To service these higher interest payments, the debtor country needs to strengthen its international price competitiveness. Thus, to increase the attractiveness of its exports, the country needs to depreciate its currency. Therefore, we expect an increase of the net foreign assets position of a country (i.e., a reduction of the foreign debt) to have a positive effect on the currency.

Yet, it is not straightforward to compile a reliable measure for the *stock* of foreign assets and liabilities held by the countries. Usually, the proxies are based on an accumulation of current accounts over just the sample period and therefore ignore the initial levels. This, in principle, can create a potential significant bias in the estimated long-run relation.

Perhaps the most reliable measure for the net foreign asset position for several countries is given by Lane and Milesi-Ferretti (1999). This source provides annual estimates of foreign assets and liabilities using balance of payment data. The estimates are based on existing stock measures and, when available, supplemented by the cumulation of capital flows, with appropriate valuation adjustments.

In this paper, we computed the net foreign assets (*NFA*) as the accumulated current account (*CA*) position, taking into account the measure of the net foreign assets (*CUMCA*) provided by Lane and Milesi-Ferretti (1999).[13] We used the *CUMCA* variable to give an aproximation for the initial level. Thus, for the first year (1980) we used:

$$NFA_{i,1980} = CUMCA_{1979} + CA_{i,1980}, \tag{4}$$

For all the subsequent years, we computed the variable by adding the previous (*NFA*) to the contemporaneous current account:

$$NFA_{i\ldots t} = NFA_{i,t-1} + CA_{i,t}, \tag{5}$$

and considered the variable as percentage of GDP. This measurement of the stock of foreign assets is similar in definition and closely follows the trajectory of the (*CUMCA*) variable used

12. Lane and Milesi-Ferretti (1999) provide evidence that the net foreign asset position is an important determinant of the real exchange rate for developing as well as developed countries.

13. We could not use directly this information since the data is annual and it covers the period 1970-1997.

by Lane and Milesi-Ferretti (1999). Therefore, it provides the best measure available for the term horizon and countries analyzed in this paper.

Estimation results

Unit root and cointegration tests

To test for non-stationarity in the variables, we implemented the previously mentioned unit root tests. In all the specifications, we included fixed-effects because, *a priori*, there is no reason to believe that all the intercepts are the same across countries. Also, since the results of the tests are very sensitive to the specification of the individual dynamic structures, we allowed the models to have heterogeneous dynamic structure (i.e., the models have different autoregressive orders for individual cross-sectional units), ensuring uncorrelated residuals.

The results of the panel data unit root and stationarity tests applied to the (log) real exchange rate in levels are reported in Table 1. Assuming that the countries are both cross-section independent and dependent, most of the tests point to the rejection of the PPP hypothesis, since the unit root hypothesis cannot be rejected. Besides, the Hadri's (2000) test in strongly rejects the null hypothesis of stationarity. As seen in the last column of the table (the panel $LM(\lambda)$), these results are valid even when we allowed for structural changes. Additionally, when we split the sample between advanced (Australia, Canada, Euro-zone, Japan, Norway, New Zealand, UK and US) and emerging (Argentina, Brazil, India, Indonesia, Korea, Mexico, South Africa, Thailand and Turkey) countries, we are unable to reject unit roots.[14]

Table 1 - Panel unit root tests on the (log) real exchange rate in levels

	No correlation		Correlation		S. breaks	
	IPS	Hadri	Z_e^c	CIPS	*IV*	$LM(\lambda)$
Overall sample	–1.907** (–0.028)	12.556** (0.000)	0.0523 (–0.479)	–1.791 (–0.500)	–0.115 (–0.454)	7.359** (0.000)
Advanced countries	–2.266** (–0.011)	7.029** (0.000)	–1.065 (–0.856)	–2.56 (–0.010)	–0.786 (–0.216)	2.171 (–0.015)
Developing countries	–2.239** (–0.012)	10.557** (0.000)	–0.999 (–0.841)	–2.125 (–0.155)	–0.03 (–0.488)	8.579** (0.000)

Notes:
– IPS: IPS unit root test;
– Hadri: Hadri heteroskedasticity consistent unit root test;
– Z_e^c : Fisher's type statistic defined as in Choi (2002), by Bai and Ng (2004);
– CIPS: Pesaran (2003) test;
– *IV*: non-linear instrumental variable test by Chang (2002);
– $LM(\lambda)$: Carrion-i-Silvestre *et al*. (2005) test for heterogenous errors;
– lags selected according to the SIC and the Ljung-Box statistics, with a maximum lag length of 10;
– Specifications include fixed effects;
– *p*-values in parentheses;
– Hadri and $LM(\lambda)$ test for stationarity.
** indicates the rejection of the null hypothesis at the 5% significance level.

14. However, these results must be interpreted with some caution due to the small sample size in both groups.

In view of the non-stationarity characteristics of the data, we now test for the existence of a long-run relationship between the real exchange rate, the sectoral productivity differential and the net foreign assets using the cointegration tests proposed by Pedroni (1999). As can be seen in TABLE 2, with the exception of the parametric *t*-statistic, the results point to cointegration between the variables.[15]

Table 2 - Pedroni's panel cointegration tests

	Test statistic	p-value
Panel cointegration		
υ -stat	2.91598**	0.0030
ρ -stat	2.58457**	0.0085
t-stat (non parametric)	2.12663**	0.0216
t-stat (parametric)	0.62037	0.3472
Group mean cointegration		
ρ-stat	2.81223**	0.0020
t-stat (non parametric)	2.15530**	0.0088
t-stat (parametric)	0.97609	0.2781

Notes:
– ** *Idem* table (1);
– Data are cross-section demeaned.

With these preliminary findings in mind, we now turn to the estimation of the long-run relationship between the variables. For this purpose, the coefficients were derived using the Pooled Mean Group (PMG) estimates as proposed by PSS. As a starting point, diagnostic tests were applied to an ARDL (4,4,4) with the Bayesian Information Criterion (BIC) used to select lags and imposing long-run homogeneity to both the sectoral productivity differential and the net foreign assets. TABLE 3 presents the estimates of the long-run relationship.

Table 3 - Pooled mean group estimates

	Overall		Advanced		Developing	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
pd	0.867	5.387	0.816	3.210	0.764	2.430
NFA	0.526	8.577	0.308	2.785	0.691	7.155
Error correction coef.	–0.106	–6.164	–0.065	–4.474	–0.110	–4.981
	h-test	*p*-value	*h*-test	*p*-value	*h*-test	*p*-value
Joint Hausman test	4.30	0.13	1.40	0.47	3.05	0.22

Notes:
– Data are cross-section demeaned;
– BIC was used to select the lag orders for each group;
– The long-run parameters were restricted to be the same across groups;
– The mean group estimate(s) was used as initial estimate(s);
– The Newton-Raphson method was used to compute the log-likelihood function;
– Under the slope homogeneity hypothesis the Hausman's statistic is asymptotically distributed as a χ^2 variante.

15. Note that the panel statistics impose common or pooled coefficients across individual panel units in deriving the corresponding test statistics, whereas the group statistics corresponds to the group mean of individual test statistics.

From these results, we can highlight some interesting points. First, the variables are significant and correctly signed: a rise in the *NFA* position (an improvement in the current account or a reduction in the net foreign liabilities) or in the *CPI* to *PPI* ratio (a rise in the relative productivity) leads to a real exchange rate appreciation.[16]

Second, we found a negative and statistically significant error correction term (*ECT*) implying that, if the fundamentals in the last period dictate a lower RER than that observed, then the RER will strictly depreciate in the current period. The (average) error correction coefficients reported show that adjustment is substantial (about 11% taking place within a quarter of a year).

Third, according to the Hausman tests, the long-run parameters are homogeneous, implying that pooling leads to more efficient estimates than simple averaging of the coefficients. Note that this criterion for (slope) homogeneity does not imply that the parameters are exactly the same across countries but rather that the pooled estimator provides an acceptable estimate of the mean of the parameter distribution.[17]

To confirm that homogeneity was not incorrectly imposed, we split the sample between smaller and more homogenous groups: advanced countries and emerging or developing countries. We found again that all the variables enter significantly in the long-run vector. The *NFA* and the sectoral productivity differential have the same positive effect upon the real exchange rate in both groups. Furthermore, adjustment is also substantial in the two subsamples.

Yet, one important difference between the two groups is the higher speed of adjustment (the error correction coefficient) in the group of the developing countries. This result is not surprising, since these countries are often further from the equilibrium values, relative to advanced countries. When misalignment (overvaluation in particular) was severe, most of the emerging economies had strong devaluations with dramatic currency crises.

The second difference is the higher value of the coefficient of the *NFA* in emerging economies. There are several reasons that can explain this. For instance, asset holders may react more abruptly at the first sign of trouble in developing economies. Conversely, countries with stronger economic fundamentals are more stable and, therefore, less affected by movements in the capital markets. Second, several emerging markets are often subject to liability dollarization. In this case, exchange rate depreciations will have negative valuation impact on the ratio of debt to GDP.[18] Since we identified the ratio of net foreign assets as a

16. The fact that the value of the coefficient of the *CPI*-to-*PPI* ratio is close to the theoretical one, leads us to suggest that it proxies well the relative productivity and it seems to be a good substitute for the Balassa-Samuelson effect.
17. Even though the Hausman tests support pooling across all countries, it is highly plausible that economies have structural differences, even if this test is insufficiently powerful to pick this up.
18. Indeed, a surprise exchange rate depreciation has conflicting effects for a typical emerging market economy: although its trade balance will eventually improve, its net foreign asset position may deteriorate if it is a net debtor in terms of foreign currency instruments.

fundamental variable, movements in it will have further effects on the RER. Therefore, the real exchange rate may overshoot its equilibrium level[19].

Real equilibrium exchange rates and misalignments

The fact that we were able to find homogeneity in the panel of countries implies that our calculations of real equilibrium exchange rates and misalignments can be derived from the pooled estimates presented before. In FIGURES A1.1 and A1.2 (APPENDIX 1) the real exchange rate, the equilibrium real exchange rate and the misalignments for the seventeen currencies are plotted.[20]

Several interesting facts come out upon inspection of the graphs. First, the real equilibrium exchange rate clearly depreciated in most of the countries, with the exception of Korea, Japan, Turkey and the Euro-zone. Of course, a sizeable difference exists among the countries, with Argentina and Brazil being the countries with the highest rate of depreciation. In the United States, on the other hand, even though a real appreciation did occur, we observe different episodes of appreciation and depreciation, and a clear appreciation over the last stage.

The sources of the movements in the REER also differ among countries. For instance, in Argentina, Australia, Brazil, Canada and the UK, the significant depreciation was most likely due to both a deterioration in their external position and a fall in the *CPI* to *PPI* to ratio.[21] In the USA, the effect of the persistent deterioration of the current account, that should induce a depreciation, was offset by periods of growing productivity (especially during most of the 1990's). Yet, at the beginning of 2002, both, the net foreign liabilities increased and the productivity fell considerably, resulting in an important depreciation in real terms.[22] Quite the opposite, the appreciation in the Euro, Japan and Korea was the result of a rising productivity and a strong net asset position.

Second, using the equilibrium exchange rates and the actual exchange rates, we derived the misalignments of the currencies. As such, we have a more reasonable way to judge currency misalignments than simple calculations based on PPP. Our results show that, although most of the countries went through important periods of over or under valuations, average misalignment in emerging economies was substantially higher than in advanced countries. Also, whenever the RER was away from its fundamental value, the adjustment to equilibrium seemed to be smoother in advanced economies. These findings imply, above all, that the real exchange rates in major industrial countries have been, in average, closer to macroeconomic fundamentals.

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19. Alberola (2003) analyzes the overshooting process for some Latin American countries.
20. In the graphs, values above (below) zero imply an overvaluation (undervaluation) of the real effective exchange rates.
21. The graphs showing the evolution of the fundamentals are available upon request.
22. Note the resemblance between the actual US situation and that of some developing countries such as Argentina, Brazil and Mexico, where also capital flows financed large current account deficits. Furthermore, the level of net foreign debt to GDP is quite similar in these countries.

Regarding the particular countries, in the USA the currency was overvalued from 1982 to the end of 1986, when the overvaluation reached almost 13%. These years coincide with a period of an important productivity rise of the United States *vis-à-vis* its major trade partners. A slight undervaluation followed since 1987 for about ten years and then, again, the currency was overvalued. At the end of the period of analysis, the dollar was estimated to be considerably overvalued.

In contrast, and congruent with conventional wisdom, after an initial period of a minor overvaluation, the Euro undervaluation at the beginning of the eighties coincided with the period of extraordinary dollar strength and real overvaluation in the USA. Later, after a large period of overvaluation usually reflecting episodes of dollar weakness, at the beginning of 1999 the euro started to slightly under-valuate.[23] This phase of slight undervaluation, that lasted until 2002, coincides with the launch of the euro and the moment when the European Central Bank took over responsibility for the monetary policy of the EMU member states.[24] Still, during these years, deviations from the fundamentals were not very high compared to other periods or countries. Later, during 2002, when the Euro-area countries started to circulate euro-denominated notes and coins, the euro was close to its equilibrium value. Finally, in the last few years, the RER departed from its fundamentals to an overvaluation reaching levels similar to the ones observed during the nineties.

Regarding the yen, although it strongly appreciated in real terms over the whole period, the crises incited persistent misalignments, placing the yen far below its long-run estimated value. At the end of the year 2005, the estimated undervaluation of the yen was around 14 percent with no tendency to approach equilibrium. Likewise, for most of the period, the pound sterling was strongly misaligned, the undervaluation reaching levels of almost 15 percent at the end of 1986. However, in the case of the U.K., the real exchange rate has approached gradually its equilibrium value, placing the estimated undervaluation in about 2 percent at the end of the period.

The case of the Latin American and Asian currencies is very interesting for several reasons. Among others, because these countries were characterized for having a rigid – *de facto*, pegged or quasi pegged – exchange rate system with respect to the US dollar. The movement to more flexible exchange rate regimes was, in many occasions, driven by crises. Also, deviations from equilibrium have been considerably high. Furthermore, it is still a question of important debate to establish whether these exchange rate misalignments were one of the major causes for their crises. If this was the case, this would underline the need to avoid

23. While most of the models coincide with the overvaluation of the euro during must of the 1990's, most of them find different results after 1997 depending on the specification of the model. For example Maeso-Fernandez, Osbat and Schnatz (2001) suggest that according to a Behavioural Equilibrium Exchange Rate (BEER) model, the euro was overvalued in the last quarter of 1998, but it was undervalued according to a Permanent Equilibrium Exchange Rate (PEER) specification.

24. On January 1, 1999 although the euro did not yet exist as a physical currency (bank notes and coins were introduced in 2002), the euro was traded in financial markets and new issues of securities were already denominated in euros.

over-valuated exchange rates (i.e. a RER that is incompatible with maintaining sustainable external accounts).

For example, the Argentinean peso was over-valuated during the previous years of the crisis in 2001, when the peso was abruptly devaluated. The undervaluation that followed reached levels of 30% during 2002 and even though the misalignment has been reduced, at the end of 2005 it was still the currency with the highest deviation from equilibrium (around 20%). Similarly, Brazil's real exchange rate was also over-valuated from 1994 until the currency crisis at the beginning of 1999. While the depreciation was enough to keep the currency around its equilibrium level for a short period, a new episode of overvaluation can be seen at the end of the period (estimated to be more than 13 percent at the end of 2005). Regarding Mexico, excluding the minor periods of slight undervaluation, the Mexican peso displayed two decades of strong overvaluation.

In Indonesia, Korea and Thailand, periods of overvaluation preceded the currency crisis at the end of 1997. Subsequently, real exchange rate overshot the long-run fundamental exchange rates by large margins during the first quarter of 1998. Although the RER rebounded steeply afterwards, it took several quarters for most of the misalignment to be eliminated. Yet, an important difference with the Latin American real exchange rates is that in Asia the movements before the crisis were significantly closer to equilibrium. As a result, by the end of the period, estimated misalignments in Korea, Thailand and Indonesia are quite insignificant compared with other countries.

Summary and conclusions

This paper provides evidence that the Purchasing Power Parity cannot be considered as a way to judge currency over or undervaluation in a set of industrialized and emerging economies. On the contrary, we support the idea that, in the long-run, the real exchange rate depends on the evolution of macroeconomic fundamental variables. As such, there is an equilibrium real exchange rate that varies in time as a function of the stock of foreign assets and the evolution of sectoral prices.

Thus, an important finding in this paper is that the real appreciations are due to significant net capital inflows and productivity shocks. Equally important is the fact that this is not only the case when we consider advanced and developing countries together in a panel setting, but also that these results remain when the whole sample is divided into smaller and more homogenous groups.

We also estimated the equilibrium exchange rates. Since this is a value to which the RER tends to return in the long-run, if there is an important exchange rate misalignment, a later reversal is foreseeable. Still, this transition was found to have different characteristics depending on the country. For instance, the convergence to equilibrium is quicker in emerging economies than in advanced countries. Also, we found that most of the currency crises

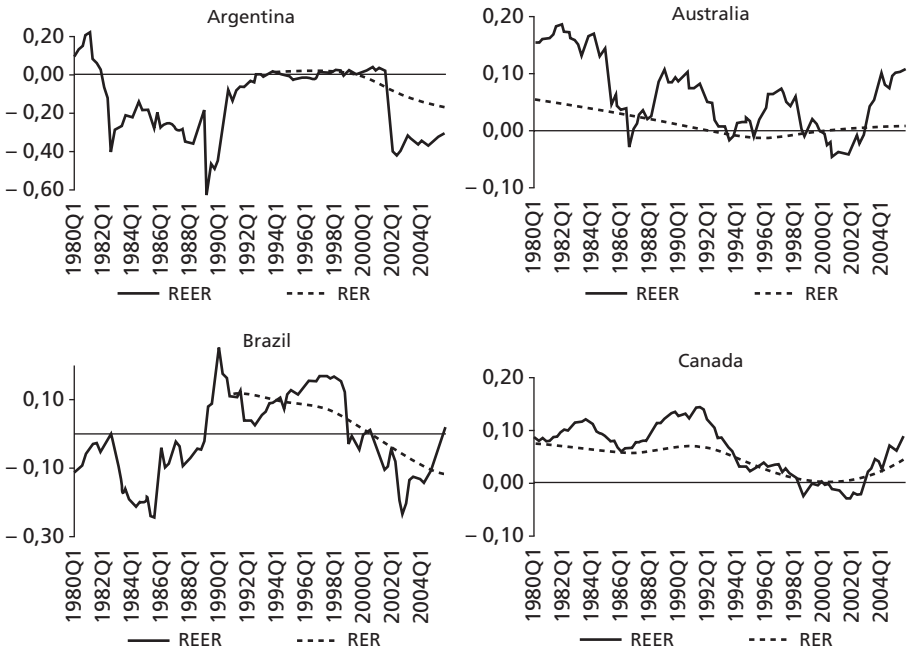
that characterized emerging markets in the second half of 1990's and beginning of the present decade were preceded by important episodes of overvaluation, followed in many cases by overshooting of the RER. Of course, misalignments were also found to exist in advanced economies, though in these cases the convergence to equilibrium seemed to be smoother.

Thus, persistent misalignments in the real exchange rates sometimes can be considered as an indicator of potential crisis, with disastrous consequences on the economy. For this reason, development strategies should include efforts to preserve as long as possible the RER at or near the equilibrium regardless of the exchange rate regime. Our results also suggest the importance of promoting local currency debt markets (instead of having debt denominated in terms of foreign currency), particularly in emerging market countries.

A. L. V.[25]

Appendix 1

Graph A1.1 - Real exchange rates (plain line) and real equilibrium exchange rates (dotted line), 1980:Q1-2005:Q4



Note: An increase (decrease) indicates appreciation (depreciation).

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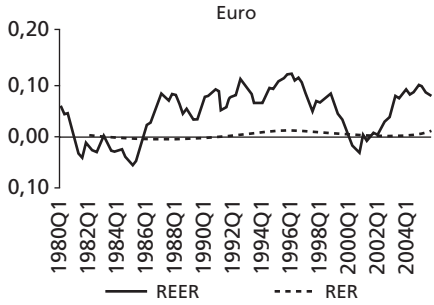
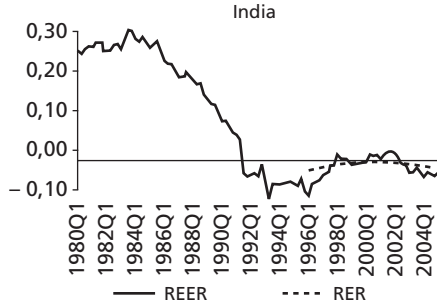
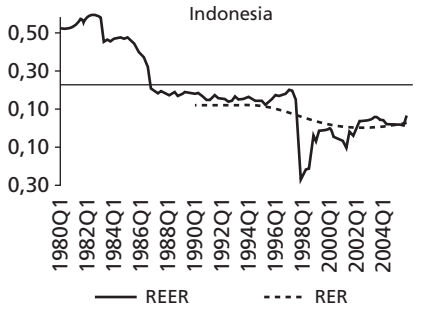
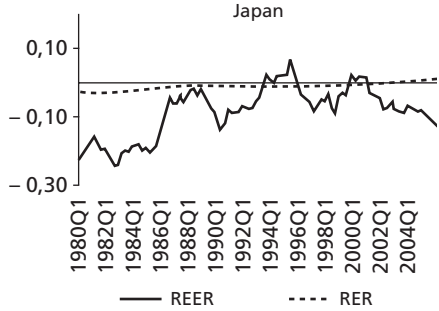
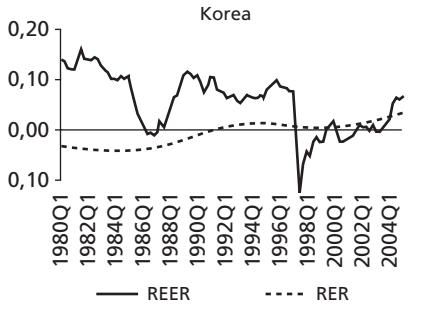
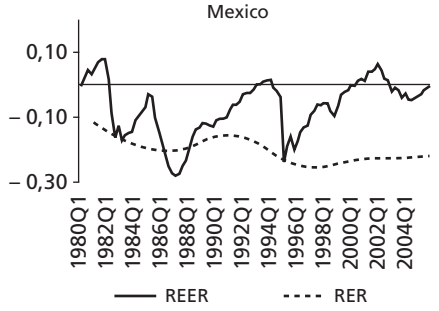


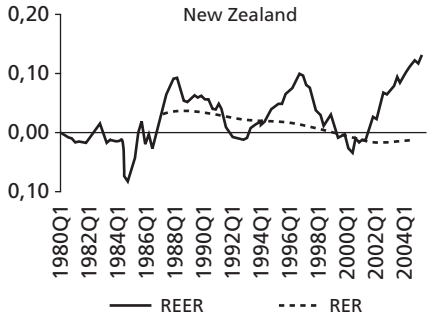


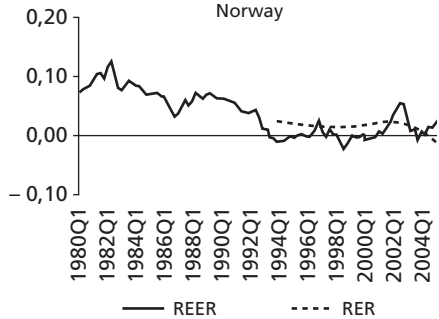




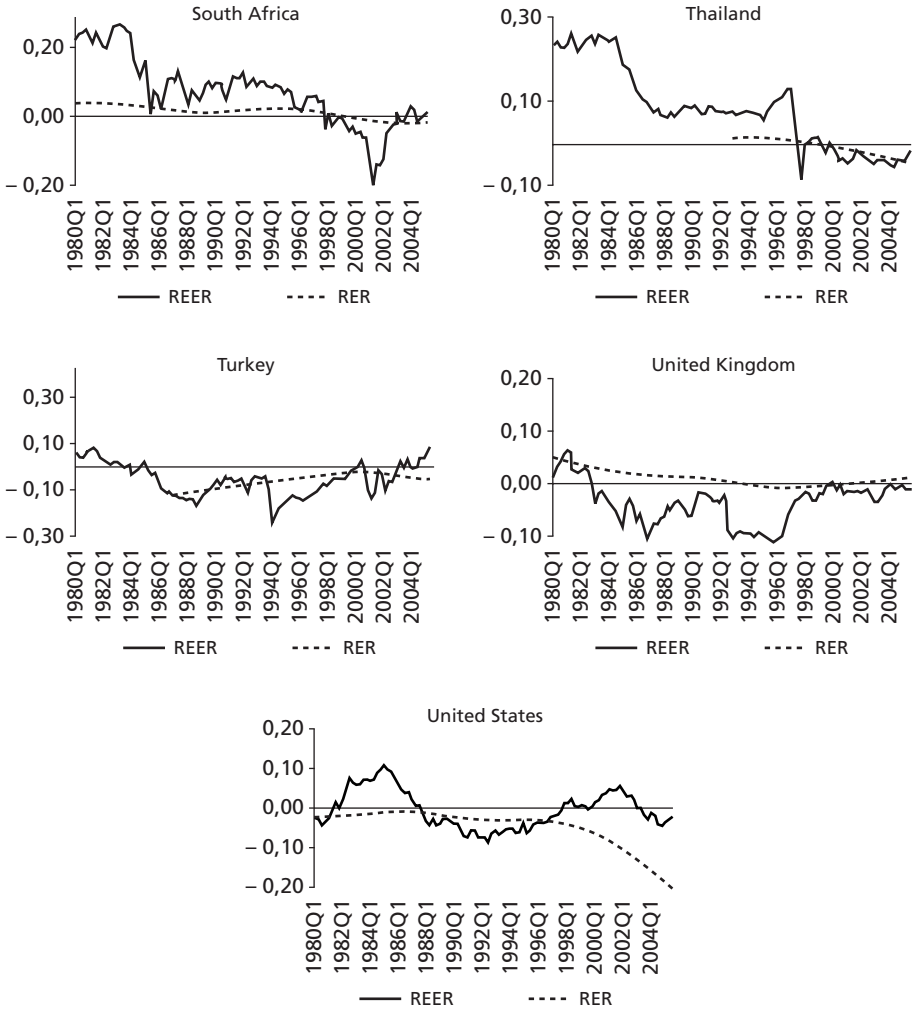






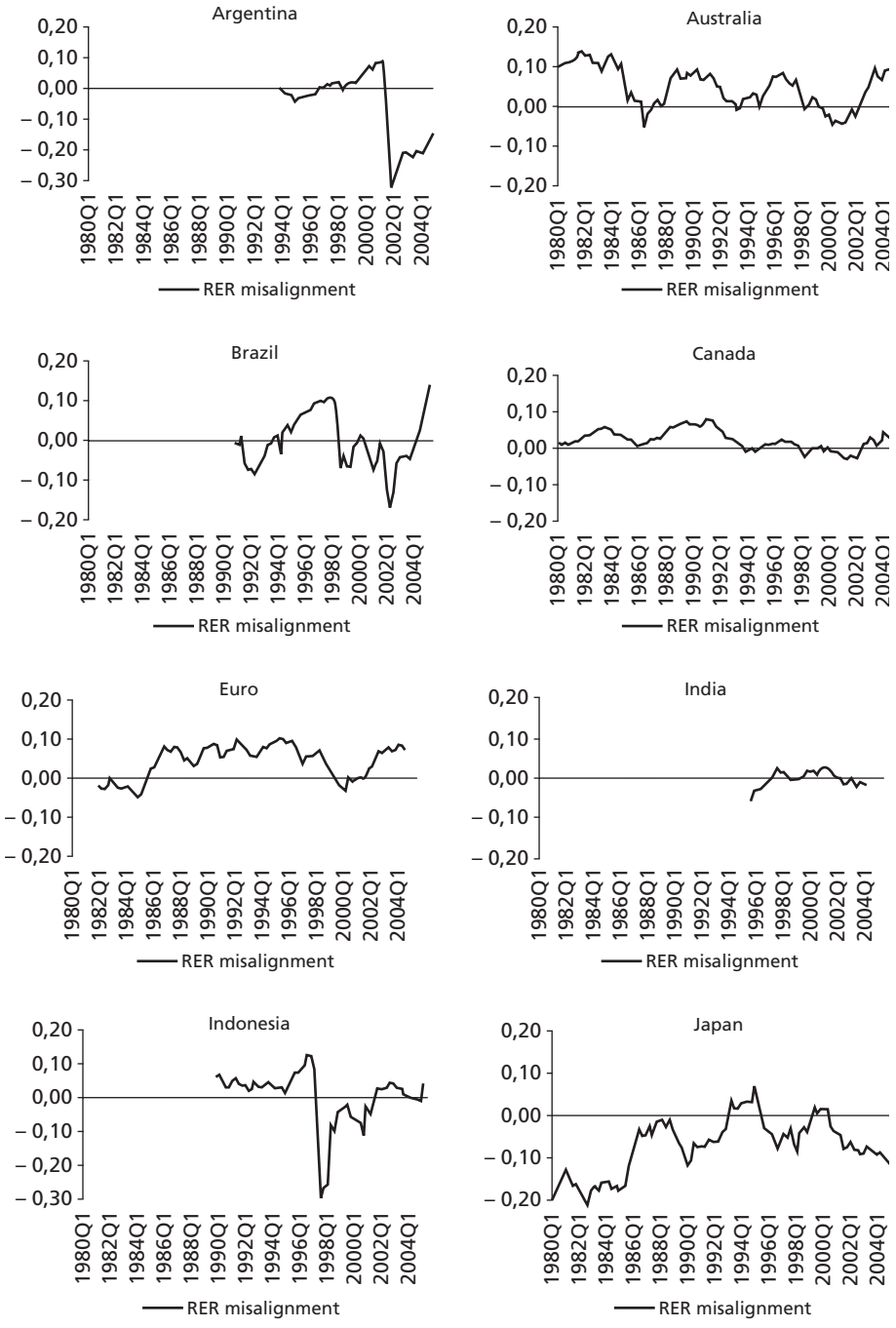


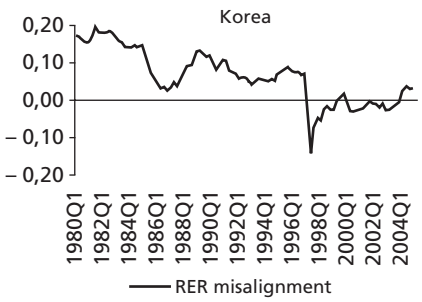
Note: An increase (decrease) indicates appreciation (depreciation).

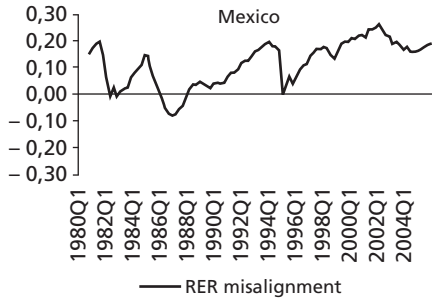


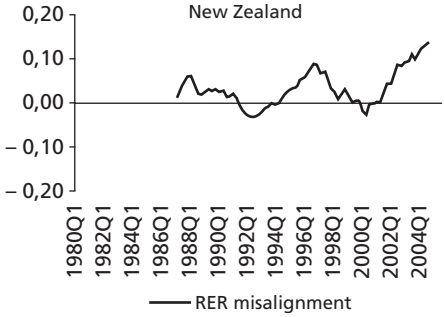
Note: An increase (decrease) indicates appreciation (depreciation).

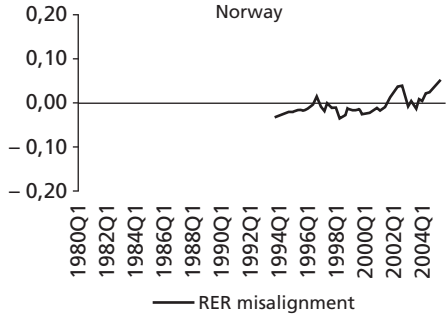
Graph A1.2 - Real exchange rate misalignments, 1980:Q1-2005:Q4

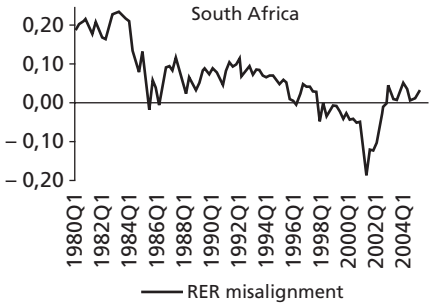


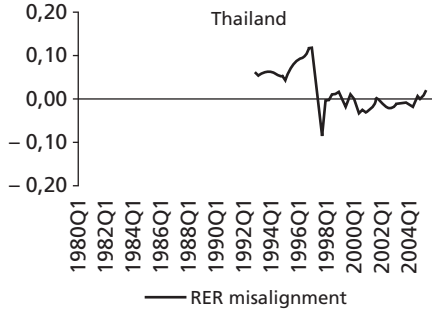

Korea
0,20
0,10
0,00
– 0,10
– 0,20
1980Q1
1982Q1
1984Q1
1986Q1
1988Q1
1990Q1
1992Q1
1994Q1
1996Q1
1998Q1
2000Q1
2002Q1
2004Q1
RER misalignment

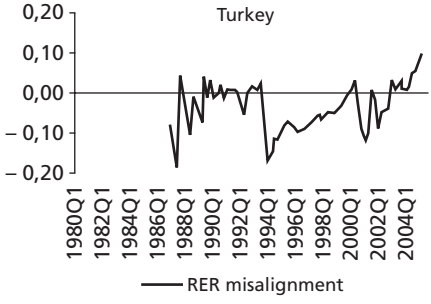

Mexico
0,30
0,20
0,10
0,00
– 0,10
– 0,20
– 0,30
1980Q1
1982Q1
1984Q1
1986Q1
1988Q1
1990Q1
1992Q1
1994Q1
1996Q1
1998Q1
2000Q1
2002Q1
2004Q1
RER misalignment


New Zealand
0,20
0,10
0,00
– 0,10
– 0,20
1980Q1
1982Q1
1984Q1
1986Q1
1988Q1
1990Q1
1992Q1
1994Q1
1996Q1
1998Q1
2000Q1
2002Q1
2004Q1
RER misalignment


Norway
0,20
0,10
0,00
– 0,10
– 0,20
1980Q1
1982Q1
1984Q1
1986Q1
1988Q1
1990Q1
1992Q1
1994Q1
1996Q1
1998Q1
2000Q1
2002Q1
2004Q1
RER misalignment


South Africa
0,20
0,10
0,00
– 0,10
– 0,20
1980Q1
1982Q1
1984Q1
1986Q1
1988Q1
1990Q1
1992Q1
1994Q1
1996Q1
1998Q1
2000Q1
2002Q1
2004Q1
RER misalignment


Thailand
0,20
0,10
0,00
– 0,10
– 0,20
1980Q1
1982Q1
1984Q1
1986Q1
1988Q1
1990Q1
1992Q1
1994Q1
1996Q1
1998Q1
2000Q1
2002Q1
2004Q1
RER misalignment


Turkey
0,20
0,10
0,00
– 0,10
– 0,20
1980Q1
1982Q1
1984Q1
1986Q1
1988Q1
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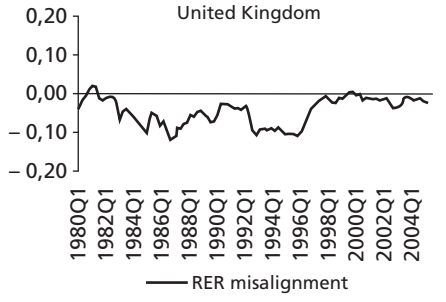
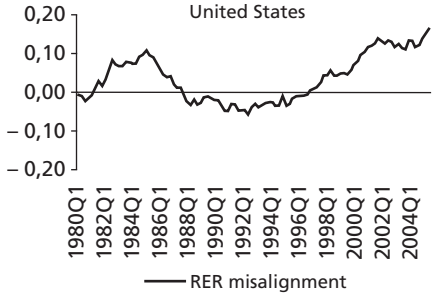
1992Q1
1994Q1
1996Q1
1998Q1
2000Q1
2002Q1
2004Q1
RER misalignment


United Kingdom
0,20
0,10
0,00
– 0,10
– 0,20
1980Q1
1982Q1
1984Q1
1986Q1
1988Q1
1990Q1
1992Q1
1994Q1
1996Q1
1998Q1
2000Q1
2002Q1
2004Q1
RER misalignment


United States
0,20
0,10
0,00
– 0,10
– 0,20
1980Q1
1982Q1
1984Q1
1986Q1
1988Q1
1990Q1
1992Q1
1994Q1
1996Q1
1998Q1
2000Q1
2002Q1
2004Q1
RER misalignment

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