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The short and long-run determinants of the real exchange rate in Mexico

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The short and long-run determinants of the real exchange rate in Mexico

Abstract

This paper explores the real exchange rate behavior in Mexico from 1960 until 2005. Since the empirical analysis reveals that the real exchange rate is not mean reverting, we propose that economic fundamental variables affect its evolution in the long-run. Therefore, based on equilibrium exchange rate paradigms, we propose a simple model of real exchange rate determination which includes the relative labor productivity, the real interest rates and the net foreign assets over a long period of time. Our analysis also considers the dynamic adjustment in response to shocks through impulse response functions derived from the multivariate VAR model.

Keywords: real exchange rate, purchasing power parity, Balassa-Samuelson effect, error correction models, bounds cointegration test.

JEL classification: C32, F31, F41, F49

Introduction

The evolution of the real exchange rate (RER) is a leading indicator of the strength of an economy. For instance, 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.

Even more, because a higher real exchange rate implies *ceteris paribus*- that a country's exports are more expensive and its imports relatively cheaper, it is a measure of relative competitiveness of imported goods among countries. Thus, given its close link with competitiveness, it turns out to be a fundamental issue when dealing with economic crises and booms.

Indeed, it has been for some time a question of important debate whether real devaluations are contractionary or expansionary. On the one hand, in the conventional textbook model, devaluations are supposed to increase competitiveness, increase production and exports of tradable goods, reduce imports, and thereby boost the trade gap, GDP and employment (assuming the Marshall-Lerner condition holds). On the other hand, Díaz-Alejandro (1963), Krugman and Taylor (1978) or Lizondo and Montiel (1989) showed that this positive effect could be offset by contractionary impacts in the non-tradable sector.

Even though it is not clear what are the effects of real devaluations in the economy, in the last years, many developing and emerging market economies have resisted devaluation, partly because of concerns that such a policy would be contractionary¹. This view arises from the experience of countries such as Mexico, where, as showed in figure 1, real depreciations (increases) of the peso have consistently been associated with declines in output, while real appreciations (decreases) have been linked to expansions.

In this sense, the Mexican case can result useful to understand some aspects of the financial crisis in some developing and emerging market economies for several reasons. First, the Mexican move toward flexible exchange rates implies the topic is of interest to other currency markets that did the same. Second, the debtor position of the Mexican economy is shared by other emerging economies such as Brazil or Argentina. Third, the exchange rate in Mexico, as in other emerging economies, is extremely volatile relative to developed countries. Finally, many developing countries have also experienced a series of external shocks, similar to the Mexican experience².

It is not our aim here to study whether a currency depreciation would have a favorable or negative effect on economic growth and employment. Whatever the association is, it is clear that the behavior in the real exchange rate has important and lasting effects on the economy as a whole. As such, whatever determines the real exchange rate has importance in itself. It is precisely the purpose of our investigation to find these determinants.

We show evidence below that, at first sight, the real exchange rate in Mexico does not converge to its purchasing power parity value. Therefore, the main proposition of our work is that it is determined by macroeconomic fundamentals. We study whether permanent (or persistent) changes in these factors can explain the lasting movements of Mexico's real exchange rate. The determinants are analyzed both in terms of their long-run and short-run impact on the real exchange rate. The empirical strategy will thus involve cointegration analysis and error-correction modelling between the real exchange rate and a set of selected macroeconomic factors, namely the real GDP per capita differential, the

¹However, the devaluation itself might be the result of, among others, incorrect policies and economic slowdowns as it was apparently the case in Argentina in 2001.

²In the 1980s, for example, these shocks included a steep rise in international interest rates, a slowdown of growth in the industrial world, and the debt crisis.

net foreign assets position and the interest rate.

The GDP and the capital account do not imply any problem for the cointegration approach, since they are usually found to be not stationary variables. However, most of the time, studies avoid including the real interest rate in the analysis (see Joyce and Kamas (2003), for instance), mainly because it is usually found to be a stationary variable. However, we believe that it would be a mistake not to include the interest rate differential in the analysis. In other words, if the chosen measure of real interest rate is $I(0)$, failure to incorporate it in the long-run cointegrating vector implicitly sets the interest rate influence on exchange rate to zero.

Hence, to take account of the statistical property of the interest rate we analyze the relationship between the RER and the fundamentals within a bounds cointegration procedure (Pesaran, Smith, and Shin (2001)). This approach has the advantage that it tests the existence of a level relationship between a dependent variable and a set of regressors, irrespective of whether the underlying regressors are purely $I(0)$, purely $I(1)$ or mutually cointegrated. Thus, we are able to present the definition and estimation of the fundamental (long-run) and short-run influences in a model for the real exchange rate in Mexico.

Another advantage of our paper is that, contrary to most of the studies that analyze the real exchange rate dynamics in Mexico, we go further than the 1994 collapse of the peso (i.e. the floating exchange rate regime). Indeed, if what we are trying to find are the long-run determinants of the real exchange rate, it would be a mistake to consider only a short period of time in the analysis. Thus, we explore Mexico's real exchange rate within an extended period of time (1960-2005).

The rest of the paper is organized as follows. In the following section we discuss some theoretical propositions for the empirical work. Section 2 deals with the evolution of the real exchange rates and the factors that, in principle, determine its evolution. In section 3 we present the econometric methodology and empirical results. Section 4 offers closing comments.

1 Modelling Real Exchange Rates

The literature that takes on to model and explain the real exchange rate (RER) behavior is very extensive. Nonetheless, even there are many propositions, there is no consensus on what are its major determinants. Broadly speaking, in accordance to how integrated the markets are supposed to be, we may think of two distinct approaches. Indeed, the exchange rate can be thought as a monetary phenomenon or, on the contrary, as a macroeconomic (real) phenomenon. It is, precisely, in this distinction where the two major approaches on exchange rate determination differ.

On one hand, the monetary approach assumes highly integrated goods and capital markets; therefore, it commonly expects the RER to meet the purchasing power parity (PPP) value as a long-run equilibrium value. Under this approach, the equilibrium real exchange rate for a given country remains constant overtime. Therefore, if any evidence the RER in a given country reaches its PPP value were to be found, then the PPP would turn out to be particularly useful because it could predict any over or under valuation. Otherwise, there would be no basis to state the RER is an equilibrium relationship that must be met in the long-run.

On the other hand, by rejecting the PPP theory as an equilibrium reference, the macroeconomic approach centers its attention on the role played by the (real) economic

fundamentals in the determination of the exchange rate. So, this approach considers the equilibrium real exchange rate as a path on which an economy preserves both internal and external balance. As such, the equilibrium real exchange rate is not an immutable number; it is rather influenced by some real variables.

Under this approach, two main lines of research are distinguished. The first one, known as the balance of payments approach, highlight the underlying net foreign asset position of a country. The second one, based on the Balassa-Samuelson approach, centers its attention in the sectoral (tradable-nontradable) balance.

The balance of payment approach, introduced by Nurkse (1945), is based on the adequacy of the current account to keep notional or equilibrium capital flows and keep in check saving-investment balances. In this framework, several notions of equilibrium exchange rates have been suggested. For instance, Williamson (1985) suggested the notion of Fundamental Equilibrium Exchange Rate (FEER), which is defined as the exchange rate "which is expected to generate a current account surplus or deficit equal to the underlying capital flow over the cycle, given that the country is pursuing internal balance as best it can and not restricting trade for balance of payments reasons" (Williamson, p.14). A variant of the FEER is the Desirable Equilibrium Exchange Rate (DEER), proposed by Bayoumi, Clark, Symansky, and Taylor (1994) which assumes target values for the macroeconomic objectives, such as targeted current account surplus for each country.

Another approach to equilibrium exchange rate is the Behavioral Equilibrium Exchange Rate (BEER) by Clark and MacDonald (1998). The BEER relies on observed long-run relationships between the real exchange rate and a set of (long-run and medium term) economic fundamentals -derived from the determinants of saving, investment and the current account- and a set of transitory factors affecting the real exchange rate in the short run.

In the same line, the Macroeconomic Balance Framework, suggested by Faruquee, Isard, and Masson (1998) can be seen as a specification of the BEER approach since the macroeconomic fundamentals are derived from the determinants of saving, investment and current account. Similarly, the Natural Real Exchange Rate (NATREX), introduced by Stein (1994), falls between the FEER and the BEER approaches. The NATREX is the exchange rate that allows to attain of both internal and external equilibrium. However, the current account is modelled as the result of saving and investment behavior, as in the BEER approach.

The second line of research, based on the works by Balassa (1964) and Samuelson (1964) relates the long run behavior of the real exchange rate with the productivity performance of traded relative to non-traded goods. The idea is that if the productivity of the traded goods rises relative to that of non traded goods, the real exchange rate will appreciate. A Balassa-Samuelson effect can be introduced either in the FEER or in the BEER approach by assuming the existence of two sectors in the economy. The external equilibrium need then only applies to the tradable goods sector, whereas internal equilibrium must include a long-run productivity drift on top of short-to-medium-run demand effects (see Edwards (1989)).

Following the previous 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. The starting point of the model is to decompose 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 settles the evolution of the foreign asset position. On the

contrary, 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 sector in the economy.

1.1 The macroeconomic fundamentals

Based on the idea of equilibrium exchange rate, we propose a model that encompasses both, the external sector of the economy and the Balassa-Samuelson approach to real exchange rate determination. We identify three main fundamentals for the evolution of the real exchange rate: the productivity differentials (proxied by the real GDP differential), the net foreign assets position (proxied by the accumulated current account) and the real interest rate differential.

- **Productivity differentials:** The impact of productivity differentials is expected to follow the Balassa-Samuelson (BS) doctrine. That is, larger increases in productivity in the traded goods sector are associated with a real appreciation of the currency of a given country. The BS hypothesis may prove useful in a context like ours, since it tries to explain the recurrent deviations of the RER from a long-run value by relating the currency appreciation with the different states of productivity growth of the countries.
- **Net foreign assets:** Until recently, the appreciation of the real exchange rate in developing or transition countries was assigned to a Balassa-Samuelson effect affecting the sector of tradables. However, whether this effect is strong is today a subject of controversy. Indeed, the collapse of the Bretton Woods system in the 1970's, the following volatility of currency markets and the recent integration of international financial markets make the capital flows crucial to understand exchange rates, output, employment, etc.

Even more, the reform strategies conducted in Mexico, in particular, and in most of the developing countries, in general, were characterized by strengthening money and financial markets, the macroeconomic stabilization (about inflation, public finance and foreign debt) and the liberalization of the markets (that is, prices and trade). All these features lead to the idea that something else, besides the comparison of international levels of productivity, lies behind the recurrent deviations of the exchange rate from its PPP level.

Indeed, nowadays it is broadly accepted that trade and capital flows as well as imbalances between national savings and investment influence the exchange rate. Thus, a country's foreign balance is another commonly used variable to explain currency behavior. For instance, in the context of the equilibrium exchange rate models the current account imbalance is one of the motives that can drive the exchange rate away from its equilibrium level (i.e. the level compatible with the harmonious running of the economy).

In this sense, there are several channels through which the stock of foreign assets can influence the real exchange rate³. For instance, portfolio-balances considerations suggest that a deficit in the current account creates an increase in the net foreign

³Lane and Milesi-Ferreti (1999) explore the theoretical link between the real exchange rate and the net foreign assets, and provide evidence that the net foreign asset position is an important determinant of the real exchange rate for developing as well as developed countries.

debt of a country, which has to be financed by internationally investors which, 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 interest 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 (see Maeso-Fernandez, Osbat, and Schnatz (2001)).

Summing-up, an increase in the capital flows will finance greater absorption and a larger current account deficit. This is obtained through a real exchange rate appreciation, either through raising prices or an appreciation of the nominal exchange rate. That is, the real exchange rate is expected to fall (to appreciate) when the stock of foreign assets rises⁴. Thus, it is our belief that in developing and emerging economies in general, and in Mexico, in particular, the RER is susceptible to capital inflows and this is the case regardless of the exchange rate regime⁵.

- **Interest rates:** Perhaps one of the most widespread consensus across academic and policy-making cycles, is the solid relationship between interest rates and exchange rates. Conventional wisdom, based on the Mundell-Fleming tradition and Dornbusch (1979) contribution, but also in more recent papers with risk neutral investors, is that increases in any interest rate would appreciate the domestic currency⁶.

Theories based on portfolio balance suggest a close link between the exchange rate and the interest rates. The main idea is that the financial assets are not perfect substitutes among them. Then reducing the interest rate of one economy (domestic) in relation to another (foreign) creates an excess demand for foreign currency to profit from the interest-rate differential. If domestic authorities do not intervene in the exchange-rate market, that excess demand will turn into a weaker domestic currency (a rise of the exchange rate or depreciation)⁷. Contrariwise, a rise of domestic interest rates, *ceteris paribus*, makes domestic assets more attractive to investors (national or foreign). This leads to a domestic currency appreciation as investors adjust their portfolios. Thus, a line of causality between interest-rates and the exchange-rate is established not through the goods and services market but through the financial assets market⁸.

⁴While theoretically, capital flows would equal zero in the long-run, most less developed countries are expected to be capital importers for the future, therefore most empirical studies of developing economies use a measure of sustainable capital flows rather than a zero capital account. Models of the RER in these countries often include capital flows as a determinant of the equilibrium real exchange rates (see Joyce and Kamas (2003)).

⁵Notice that if a country relies on foreign capital (or any other inward transfer) to keep high levels of domestic absorption, it is natural for the RER to appreciate, regardless of the exchange rate regime. The adjustment occurs either through an appreciation of the nominal exchange rate under a floating exchange rate system or through an increase in nominal prices of non-traded goods in a fixed exchange rate regime, or through a mixture of the two in an intermediate (fixed-but-adjustable) regime. Evidence also suggests that, contrary to conventional wisdom, misalignments and currency "crashes" are equally likely under pegged and flexible exchange rate regimes.

⁶See Ogaki and Santaella (1999) for an empirical study on Mexico.

⁷One could think of an expansive monetary policy where monetary authorities intervene in the market buying peso-denominated bonds.

⁸Although it is not our aim to analyze the relationship between the exchange rate and the term structure of interest rate, theory suggests that it can be complicated and counterintuitive when investors

2 Evolution of the real exchange rate and the macro-economic fundamentals in Mexico

The belief that a competitive exchange rate encourages exports and hence growth is a fundamental principle of the conventional wisdom of macroeconomic management (Kamin and Klau (1997)). Thus, for many years, policies were oriented towards keeping the real exchange rate highly competitive with the idea to prevent balance-of-payments crises and encourage output growth.

However, as we mentioned, many developing countries have resisted devaluations because of concerns that such a policy would be contractionary. In Mexico, during the last 45 years had a series of controlled (i.e. fixed, crawling, dual and target zone) exchange rate regimes, most of which ended in crisis and collapses. In the specific case of Mexico, each of the major crises over this period- August 1976, February and March 1982, July to November 1985, November 1987 and December 1994- was followed by a significant decline in economic growth (see figure 1).

[INSERT FIGURE 1]

Certainly, from 1960 until late 1970's, Mexico lived through a long period of economic growth in which GDP grew faster than the population, reducing the income gap *vis-à-vis* the U.S. However, due to a strong foreign shock, this period of fast economic growth fell apart by the early 1980's: From 1981 to 1986, GDP and GDP per capita fell 2% and 12% respectively. Thus, from that moment, any converging process on the income levels between the two countries came to halt and, once more, the gap widened while the Mexican economy growth rate stagnated.

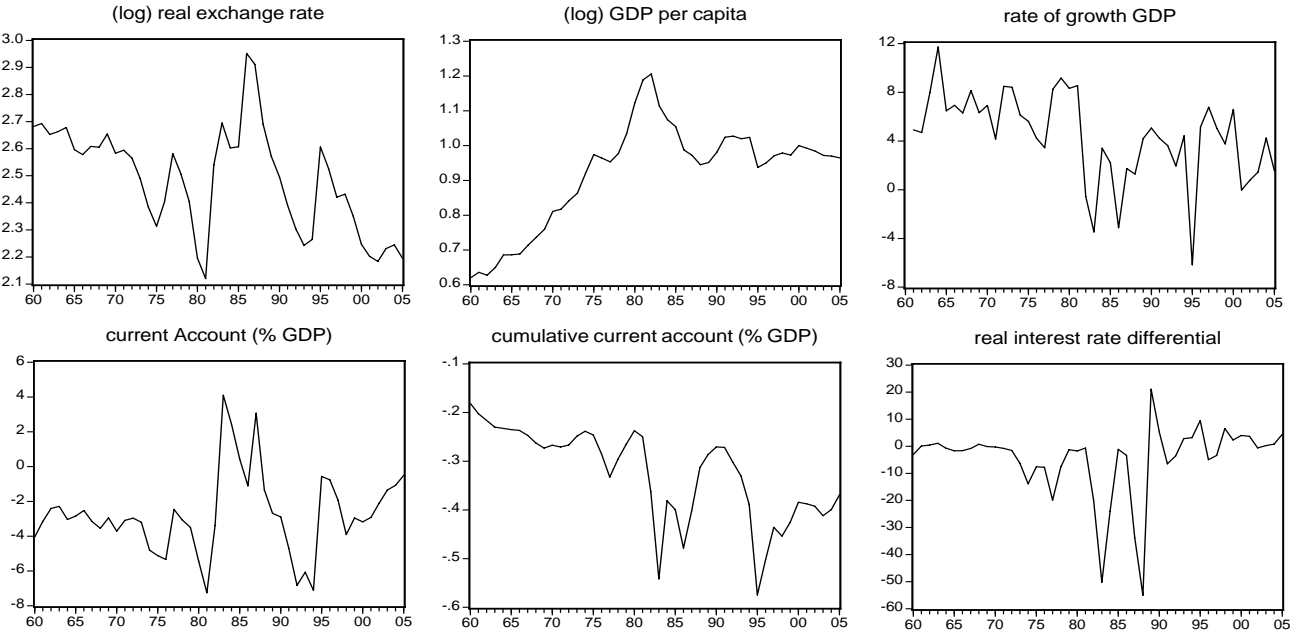
Indeed, as the figure shows, in 1981 Mexico had a cyclically high-level of output, a highly appreciated real exchange rate and a large capital account surplus⁹. The onset of the debt crisis in 1982 and the associated reversal of capital inflows led to a sharp real devaluation of the peso and a marked contraction in output by 1983. Following some recovering of the economy and a reversal of real depreciation in 1984 and 1985, additional shocks led to the extreme real depreciation of the peso and depression in economic activity registered in 1986-87 (Kamin and Rogers (1997)). After an exchange rate based stabilization program launched in 1988 and regained access to international capital markets, Mexico started to show a higher GDP, an appreciated peso and a large current account deficit. Following the devaluation in 1994, a new reversal of capital flows forced the economy back to where it had been in the early 1980's.

In addition, prior to the 1994 devaluation, supporters of Mexico's exchange rate strategy argued that the real exchange rate appreciation, and the associated widening of the current account deficits, were signs of economic health, reflecting rising productivity and improved prospects for the Mexican economy (Kamin and Rogers (1997)). The idea that the real appreciation could restrained economic growth was not an issue. However, after 1994, the crisis highlighted the danger of allowing the real exchange rate to appreciate substantially in a world of high capital mobility. Since early 1995, however, there has been a slow process of recovery and real appreciation.

are risk averse. Ogaki and Santaella (1999), for instance, analyzes the effect of the term structure of interest rates on the real exchange rate for the Mexican floating exchange rate regime, finding the term structure is indeed relevant. The one-month and the three-month interest rate differentials have the opposing effect on the exchange rate in Mexico.

⁹An increase (decrease) in the RER implies a depreciation.

Figure 1: Evolution of the real exchange rate, GDP growth, GDP per capita differentials, current account (as % of GD), cumulative current account (as % of GD) and real interest rate differential. 1960-2005



It is not our goal to describe in detail the reasons responsible for the Mexican collapses but rather to find the reasons for the appreciation of the Mexican peso, in the understanding that this issue influences the economy. Thus, we propose, firstly, that the appreciation is, to a big extent, result of the higher productivity growth in Mexico compared to its main economic partner, United States. Second, not only the BS effect is important to explain the misalignments of the exchange rate, but also the evolution of other economic fundamentals, especially those related to capital flows, and the sustainability of the external position of the economy are important.

Indeed, external shocks to the asset markets in the form of capital flow shifts or interest rate changes play key roles. In particular, the typical boom and bust cycle in Mexico over this period began with an external shock: a fall in world interest rates or a liberalization of trade or capital flows. This shock was normally followed by large capital inflows, increased fiscal expenditures (typically deficit financed), an expansion of the domestic money supply, higher inflation and an appreciation of the real exchange rate.

3 Modelling real exchange rates in Mexico

With the purpose of analyzing the evolution and the main determinants of the real exchange rate in Mexico from 1960 to 2005, we first examine the empirical evidence for the purchasing power parity hypothesis. Second, we propose an underlying relationship between the real exchange rate, the relative labor productivity (i.e. the Balassa-Samuelson effect), the capital flows (proxied by the Capital Account) and the relative interest rate. These fundamentals were determined by three considerations; theory, availability of data and whether the variable fits well in the model in statistical terms.

3.1 Data sources and construction of the variables

For the analysis we employed annual data for the period 1960-2005, collected from different sources. We used the average nominal exchange rate, S (expressed as domestic currency per US dollar) provided by the Banco de Mexico (Banxico) and the IMF International Financial Statistics (IFS). Both the Mexican and the U.S. GDP deflators (P and P^* respectively, 2000=100) were also provided by the IFS. The real exchange rate series was then built on the former data, and it was defined as the ratio between the U.S to the Mexican price index, expressed in Mexican pesos, i.e. $RER = S(P^*/P)$. We worked with its logarithm and name this variable as q ¹⁰.

To proxy the sectoral productivity differential (the BS effect) we constructed a series for the logarithm of the real GDP per capita differential between Mexico and the U.S. (labelled as $gdppc$) using the index of the GDP's volume (base year 2000) and the annual population available at IFS.

For the interest rate in Mexico, we averaged the monthly time deposit rate until 1978 and the 3-month *CETES* (Certificate of deposit) from that year on, both provided by Banxico. For the United States, we used the 10 years government bond yield. We adjusted for inflation in each case by the consumer price index (CPI). The real interest rate differential (RIR) was obtained as the difference between the Mexican and the U.S real interest rate.

¹⁰Under this definition, an increase (decrease) implies a depreciation (appreciation).

Finally, to give account of the net foreign asset position we used the accumulated current account position as a percentage of GDP, with the accumulation starting from 1950. This measurement of the stock of foreign assets is similar in definition and closely follows the trajectory of the *CUMCA* variable used by Lane and Milesi-Ferreti (1999). However, our definition ignores the initial value as well as the effects of debt reduction. Yet, since we have a sufficiently long period of accumulation for the current account, cumulative flows provide a reasonable estimate of the underlying net foreign asset position providing the best measure available for the longer term horizon analyzed in this paper.

3.2 Empirical Analysis

To study the purchasing power parity we limited ourselves to test the non-stationarity of the real exchange rate¹¹. Also, given that the PPP entail that in the long-run the real exchange rate converges to a constant mean, we propose that a simple test for structural change in the real exchange rate sets up an indirect way to examine for the PPP theory.

At this respect, it is worth mentioning that most of the empirical studies have focused on examining the presence or absence of PPP, so the null hypothesis has been either the stationarity or not-stationarity of the series. Nonetheless, these kinds of approaches, which reflect only one possibility, ignore valuable information, a fact that undermines their own outcomes.

Therefore, with the purpose to evaluate the presence (or absence) of PPP as a long-run equilibrium value, we have used two different kinds of tests based on the residuals. The first one, which includes the standard Dickey-Fuller (DF and ADF) and Phillips-Perron (PP) tests, have as the null hypothesis the non-stationarity of the RER. The second, on the contrary, proposed by Kwiatkowski, Phillips, Schmidt, and Shin (1992), the KPSS test, uses as the null hypothesis the stationarity of the series.

[INSERT table 1]

¹¹Surveys of the most important tests can be found in Froot and Rogoff (1995) and in Sarno and Taylor (2002).

Table 1: **Unit root test in q and Δq**

Test	Constant		Constant & Trend	
	q	Δq	q	Δq
<i>DF</i>	2.13	5.48	2.67	5.42
<i>DFA</i>	1.73	6.37	2.34	6.31
<i>PP</i>	2.18	5.38	2.77	5.30
<i>KPSS</i>	0.59**	0.04	0.18**	0.03

Note: (1) q : (log) real exchange rate; Δq : first difference of q ; (2) *,**,*** indicates the rejection of the null hypothesis at the 1%,5% and 10% significance level, respectively.

Table 1 present the results of the unit root tests in the logarithm of the RER (q) and its first difference (Δq). It is easy to verify that there is no evidence to reject the null hypothesis of one unit root in the real exchange rate (or reject the null hypothesis of stationarity in the KPSS test) both including a constant and a constant and a time trend.

In addition, given that under PPP the rate of currency depreciation is nearly equal to the difference between the domestic and foreign inflation rates, a fact that is reflected in the long-run in a stable real exchange rate, the simple presence of structural breaks in the RER could be taken as evidence against the PPP. In other words, we propose that testing for structural breaks in the real exchange rate sets up an indirect way to test for the purchasing power parity hypothesis.

At this respect, a quick inspection of the evolution of the RER (see figure 1) reveals abrupt changes, at least in the mean, of the series. However, to confirm that effect, we performed the test suggested by Bai and Perron (1998) to detect breaks. Briefly, this approach consists on detecting multiple structural changes in a linear regression model estimated by minimizing the sum of squares residuals. The tests allows the time series to have different numbers of breaks located at different dates. Given a maximum number of unknown break points (m^{max}), it consists in estimating their position for each $m \leq m^{max}$, testing for the significance of the breaks.

Once the dates for all possible $m \leq m^{max}$ are estimated, the point is to select the suitable number of structural breaks, if any. Bai and Perron (1998) suggest, among other procedures, to use the modified Schwarz Information Criteria (LWZ) and the Bayesian Information Criteria (BIC) to select the final number of breaks.

Following this approach, we applied the procedure with a constant and a time trend and account for potential serial correlation via non-parametric adjustment¹². By allowing up to 5 breaks and using a trimming of 0.15, both the LWZ and the BIC select three breaks in the real exchange rate¹³. The dates of the breaks are 1981, 1987 and 1994. Notice that the years coincide or precede the major economic crisis of the Mexican economy.

Therefore, the fact that the real exchange rate is not an immutable number has, at least two important implications. First, the PPP cannot be considered as an anchor to decide over or under valuations. Second, the real exchange rate is influenced by macroeconomic fundamental variables that determine its evolution in the long-run.

Thus, we identified three fundamentals for the evolution of the RER: the sectoral productivity differential (proxied by the relative GDP per capita), the movements of the international financial flows (proxied by the accumulated capital account) and the relative interest rate. The previous statement can be expressed as follows:

$$q_t = \beta_0 + \beta_1 gdppc_t + \beta_2 RIR_t + \beta_3 CCA_t + \varepsilon_t \quad (1)$$

Where ε_t is an *i.i.d* process, q_t is the logarithm of the real exchange rate, $gdppc_t$ is the logarithm of the ratio of the Mexican to U.S real GDP per capita, RIR_t is the real interest rate differential and CCA_t is the ratio of the accumulated current account to GDP.

The standard approach would be to test if there exists a cointegration relationship between the real exchange rate and the economic fundamentals. Nonetheless, the variables show different types of nonstationary behavior, not necessary corresponding to the unit root hypothesis. Indeed, the results of the ADF, PP and KPSS tests show that while the

¹²The heteroscedasticity and autocorrelation consistent covariance matrix is constructed following Andrews (1991) using a quadratic kernel with automatic bandwidth selection based on an AR(1) approximation.

¹³The trimming suggests the minimum distance between breaks

real exchange rate, the GDP differential and the capital account are $I(1)$ variables, the real interest rate is stationary¹⁴. In this case, the classical methods, such as the Johansen cointegration procedure, would yield misleading conclusions¹⁵.

Thus, since an alternative cointegration testing approach is needed, we employed the autoregressive distributed (ARDL) bounds test as proposed by Pesaran, Smith, and Shin (2001). The choice of this test (PSS from now on) is based on the following considerations. Firstly, unlike most of the conventional multivariate cointegration procedures, which are valid for large sample size, the bound test is suitable for a small sample size study. Secondly, the bound test does not impose restrictive assumptions that all the variables under study must be integrated of the same order. Its asymptotic distribution for the F -statistic is non-standard under the null hypothesis of no cointegration relationship between the examined variables, irrespective whether the explanatory variables are purely $I(0)$ or $I(1)$, or mutually cointegrated. As such, the order of integration is no more a sensitive issue and thus one could bypass the unit root test.

One interesting feature of the ARDL model is that it takes into account the error correction term in its lagged period. The analysis of error corrections and autoregressive lags fully covers both the long-run and short-run relationships of the variables tested. As the error correction term in the ARDL does not have restricted error corrections, the ARDL is an Unrestricted Error Correction Model.

The bound tests of proposed by PSS applies the fundamental principles of Johansen's five error correction multi-variance VAR models. Considering the presence of constant, time trend, and restricted condition, PSS distinguish five cases of interest delineated according to how the deterministic components are specified: **case I** implies no intercepts and no trend; **case II** restricts intercepts but allows no trends; **case III** allows unrestricted constant and no trends; **case IV** considers unrestricted intercepts and restricted trends and finally, **case V** involves unrestricted intercepts and trends.

For our particular purpose, the conditional equilibrium correction model (ECM) can be written:

$$\Delta q_t = c_o + c_1 t + \pi_{qq} q_{t-1} + \pi_{qxx} x_{t-1} + \sum_{i=1}^{p-1} \Psi'_i \Delta z_{t-i} + \delta' \Delta x_t + v_t \quad (2)$$

Where $z = (q_t, gdppc_t, RIR_t, CCA_t)' = (q_t, x_t)'$. We "bounds tested" for the presence of a long-run relationship between the real exchange rate and the GDP differential, the real interest rate and the capital account balance, using two separate statistics. The first involves an F-test on the joint null hypothesis that the coefficients on the level variables are jointly equal to zero. The second is a t-test on the lagged level dependent variable.

It is important to notice that instead of the conventional critical values, this test involves two asymptotic critical value bounds, depending on the dimension and cointegration rank, k and r , of the forcing variables x_t as well as on whether restrictions are placed upon the intercept and trend in (2). In particular, they show that the critical values take on lower and upper bounds when $r = k$ and $r = 0$ respectively. These two sets of critical values thus provide critical value bounds covering all possible classifications

¹⁴To save space, we do not report the results of these tests, but they are available upon request to the authors.

¹⁵A series of studies by Pesaran and Shin (1995b), Pesaran and Shin (1995a), Pesaran, Smith, and Shin (1996) and Pesaran, Smith, and Shin (2001) argued that as long as both $I(0)$ and $I(1)$ series exist in a system, conventional cointegration tests, i.e., Johansen's maximum likelihood approximation might bias the results of the long-run equilibrium interactions among variables.

of into $I(0)$, $I(1)$ and mutually cointegrated processes. The PSS test is then formulated as follows:

$$\begin{aligned}
 &H_0 : \pi_{qq} = 0 \quad \text{and} \quad H_0 : \pi_{qxx} = 0 \\
 &\qquad\qquad\qquad \text{against} \\
 &H_0 : \pi_{qq} \neq 0 \quad \text{and} \quad H_0 : \pi_{qxx} \neq 0
 \end{aligned}$$

If the computed statistic exceeds their respective upper critical values, then there is evidence of a long-run relationship regardless of the order of integration of the variables. If, on the contrary, it is below, it is not possible to reject the null hypothesis of no cointegration and if it lies between the bounds, any inference is inconclusive. If the test statistic exceeds its upper bound, then we reject the null of no cointegration. The procedure then amounts to test the assumption of no relationship (in levels) between the dependent variable q and the independent variables x_{t-1} in the regression.

Some important issues in the specification are whether to include a deterministic trend in the ECM, and the number of lags, p , to include in the regression. Since the test is based on the assumption that the disturbances are serially uncorrelated, this is not a trivial issue. Thus, as noted by Pesaran, Smith, and Shin (2001), for the bound test to be valid, it is especially important to ensure that there is no serial correlation.

It is clear from figure 1 that only the real exchange rate shows a declining trend. This suggests, at least initially, that a restricted linear trend should be included in the equation. To determine the appropriate lag length, we estimated the conditional model (2) by LS, with and without a linear time trend and a constant. Allowing for a maximum lag length of two, we selected the ARDL model based on the Schwartz's Bayesian Information Criteria (SBC) and Lagrange Multiplier (LM) statistics for testing the hypothesis of no serial correlation against orders 1 and 2.

Given that neither the constant nor the trend (unrestricted or restricted to the real exchange rate) were significant, our relevant model is case I in PSS. However, we also present the results from the ARDL model when a constant and the restricted trend are included (case IV). Based on the different criteria, the final model selected is an ARDL(0,0,2,1) and an ARDL(1,0,1,0) for case I and case IV, respectively. Although the noticeably inconsistent results when mixing $I(0)$ and $I(1)$ series, we also used Johansen's methodology to test for cointegration among the variables. We present the λ (test of the maximum eigenvalue) and the trace statistic of the cointegration test among the variables. Table 2 summarizes the results.

[INSERT table 2]

Table 2: **Bounds cointegration and Johansen cointegration tests between the (log) real exchange rate and fundamentals**

Bounds cointegration tests	F_I	t_I	$\chi_{BG}^2(2)$
Case I: no constant or trend	4.122**	3.491**	0.244 (0.784)
Case IV: constant & restricted trend	4.475**		1.581 (0.220)
Johansen cointegration tests	Trace	λ	
r=0	57.100*	36.805*	
r \leq 1	20.294	12.488	
r \leq 2	7.806	6.613	
r \leq 3	1.192	3.841	

Note: (1) F_I and F_{IV} are the F -statistic for testing $H_0 : \pi_{qq} = 0$ and $H_0 : \pi_{qxx} = 0$ in eq. (2) when no linear trend and constant and restricted trend, respectively, are included in the equation; (2) t_I is the t-ratios for testing $H_0 : \pi_{qq} = 0$ in eq. (2) without a linear trend; (3) ** indicates that the statistic is above the 5% upper bound; (4) Critical values from Pesaran, Smith, and Shin (2001); (6) $\chi_{BG}^2(2)$ is the Breusch and Godfrey statistics for serial correlation at order 2 and its p -values is in parenthesis; (7) In Johansen test, $H_0 = rango(\Sigma) = r$; (8) λ : test of the maximum eigenvalue; (9) * denotes rejection of the hypothesis at the 0.05 level.

As it can be seen, the results from the PSS test indicate the presence of a valid long-run relationship between the real exchange rate and the explanatory variables, as the F -test statistics, exceed the respective upper critical values both, when no trend or constant are included and when the trend is restricted. The result from the application of the bounds t -test to the real exchange rate equation is also clear, since the value of the test statistic lies above the 5% critical values. Hence, based on both, the F -test and the t -test, we can reject the null hypothesis of no cointegration, regardless of whether the variables are $I(0)$, $I(1)$ or a mix of both. Care should be, however, be taken with respect to the interpretation of the output obtained with these, the Johansen tests confirm the presence of the long-run relationship.

In the previous specifications, it is important that the coefficients of lagged changes remain unrestricted, otherwise these tests could be subject to a pre-testing problem. Nonetheless, following PSS, for the subsequent estimation of level effects and short-run dynamics of the real exchange rate, we use of a more parsimonious specification. The estimated error correction model is presented in table (3)¹⁶.

[INSERT table 3]

¹⁶We introduced a dummy variable for the years 1986 and 1987 (d8687) to account for the effects of some economic events that took place in those years. In particular, at the end of 1986 there was an important reduction in the oil international prices and, therefore in the value of the Mexican exports. Second, both, interest rates and the inflation increased considerably. As a result, the economic activity was reduced about 3% in 1987.

Table 3: **Equilibrium Correction Model for the (log) real exchange rate**

Dependent variable:	Coefficient	<i>t</i> -value
$\Delta(q)$		
Long-run terms:		
Equilibrium error	-0.397	-3.106
Constant	0.716	2.506
$gdppc_{t-1}$	-1.171	-4.756
CCA_{t-1}	-1.307	-2.123
RIR_{t-1}	-0.016	-4.074
Dynamic terms:		
$\Delta gdppc_t$	0.699	0.227
ΔCCA_t	-1.350	-5.197
ΔRIR_t	-0.002	-2.111
ΔRIR_{t-1}	0.001	1.793
$d8687$	0.2420	3.627
R^2 : 0.767		
$\chi^2_{BG}(2)$: 1.123(0.337)		

Note: (1) q is the (log) real exchange rate, $gdppc$ is the (log) constant GDP per capita differential, CCA is the cumulative current account (as % of GDP), RIR is the real interest rate differential and $d8687$ is a dummy variable that takes value 1 over the years 1986 and 1987, 0 elsewhere; (2) Δ is the first difference operator; (3) $\chi^2_{BG}(2)$ is the Breusch and Godfrey statistics for serial correlation at order 2 and its p -value is in parenthesis.

The short and long-run dynamics of the real exchange rate are then fully captured by the specification presented in table 3. Several aspects are important about this model. As it can be seen, all level estimates are significant and have the expected signs, indicating first, that in the long-run a rise in the relative GDP per capita (or productivity) leads to a real exchange rate appreciation, as suggested by the Balassa-Samuelson hypothesis. Second, an improve of the net foreign asset position (i.e. lower indebtedness) is also associated with a real appreciation in the long-run. Third, a higher interest rate in relation to the world interest rate generates an excess demand for foreign currency that will turn into a weaker domestic currency.

In addition to the long-run effects, temporary changes in the fundamentals also have short-run effects. This becomes evident by the negative effect that both, the contemporaneous stock of foreign assets and the real interest rate, have on the real exchange rate. Indeed, capital inflows are important in the immediate short-run via the influence of the short-run flows, which lead to a real appreciation. Surprises, however, the positive sign of the lagged change in the interest rate. Yet, the associated t -statistic fails to meet the five-percent criterion, preventing any meaningful conclusion. On the contrary, while the level effect of productivity differential is important, the short-run effect of this variable is not significant.

Finally, a key parameter in the previous estimation is the associated with the equilibrium correction term, since it measures the degree of adjustment of the actual real exchange rate with its equilibrium level. We found that the speed of adjustment is significant, indicating that about 40% of the adjustment takes place within a year¹⁷.

¹⁷Notice, however, that in a specification as the one presented in table (3) there might be simultaneous feed-back effects from $\Delta(lgdp_t)$, $\Delta(KAB_t)$ and (RIR_t) so that the OLS estimates might suffer from simultaneity bias. To overcome this, we tried to estimate the equation with instrumental variables, but we failed to obtain reliable results from this methodology.

3.3 Impulse response function

We presented evidence earlier that the real exchange rate is cointegrated with the economic fundamentals and that, as a results of the variability in these factors, the exchange rate is subject to permanent changes. Yet, a sensible way to gain a full insight into the relative importance and persistence that shocks in the shocks in the productivity, the interest rate and the current account have in the real exchange rate is through impulse response functions.

The idea of impulse response functions is to examine the effects of one standard deviation shock on the contemporaneous and future values of the endogenous variables in a model. For construction, the results of the impulse response function are subject to the "orthogonality" assumption and might differ markedly depending on the ordering of the variables in the VAR. Yet, a simple way to overcome this is to employ the generalized impulse response function (*GI*), suggested by Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998).

The *GI* does not require the orthogonalization of the innovations and does not depend of the ordering of the variables in the model. Briefly, the idea is to obtain a media of the future shocks in a way that the response is an average of what could happened given the present and the past. Given an actual arbitrary shock, δ_k , in the k variable, the *GI* is defined as:

$$GI[n, \delta_k, \Omega_{t-1}] = E[y_{t+n} | \varepsilon_{kt}, \Omega_{t-1}] - E[y_{t+n} | \bar{\Omega}_{t-1}] \quad (3)$$

Where n is the number of periods ahead, $\delta_k = (\sigma_{kk})^{1/2}$ denotes one standard error shock, Ω_{t-1} is all the information available in the moment of the shock (*i.e.* the known history of the economy up to the moment $t - 1$), $E[\cdot | \cdot]$ is the conditional mathematical expectation taken with respect to the VAR model and ε_{kt} are the original innovations in the VAR. In opposition to the standard impulse response function, in the *GI* all contemporaneous and future shocks are integrated out. Thus, the generalized impulse response function for the y vector n periods ahead is the difference between the expected value of y_{t+n} when the δ_k shock is taken into account and the expected value without the shock. Assuming Gaussian errors, Koop, Pesaran, and Potter (1996) show that the conditional expectation of the shock is equal to:

$$E[\varepsilon_t | \varepsilon_{kt} = \delta_k] = (\sigma_{1k}, \sigma_{2k}, \dots, \sigma_{mk})' - \sigma_{kk}^{-1} \delta_k = \sum e_j \sigma_{jj}^{-1} \delta_j \quad (4)$$

where e_k is the selected vector with the k -th element equal to one and all other elements equal to zero and $\Sigma = E(\varepsilon_t \varepsilon_t')$. Then, the *GI* for a one standard deviation shock, $\delta_k = 1$, to the k variable is:

$$\gamma_k(n) = \psi_n \Sigma e_k \sigma_{kk}^{-1} \quad (5)$$

Thus, given the historic distribution in the residuals, it is important to notice that a one shock in the k -th equation implies shocks in the other equations as well. In this way, the generalized impulse response does not pretend to answer what would happened if there is one shock with "all other thing remaining equal". It is rather the historical distribution of residuals (as expressed in the variance and covariance matrix) which determines the effects of the impact of other variables.

Figure 2 displays the results of the generalized impulse response function for ten different forecasting horizon obtained from a VAR that includes the (log) real exchange

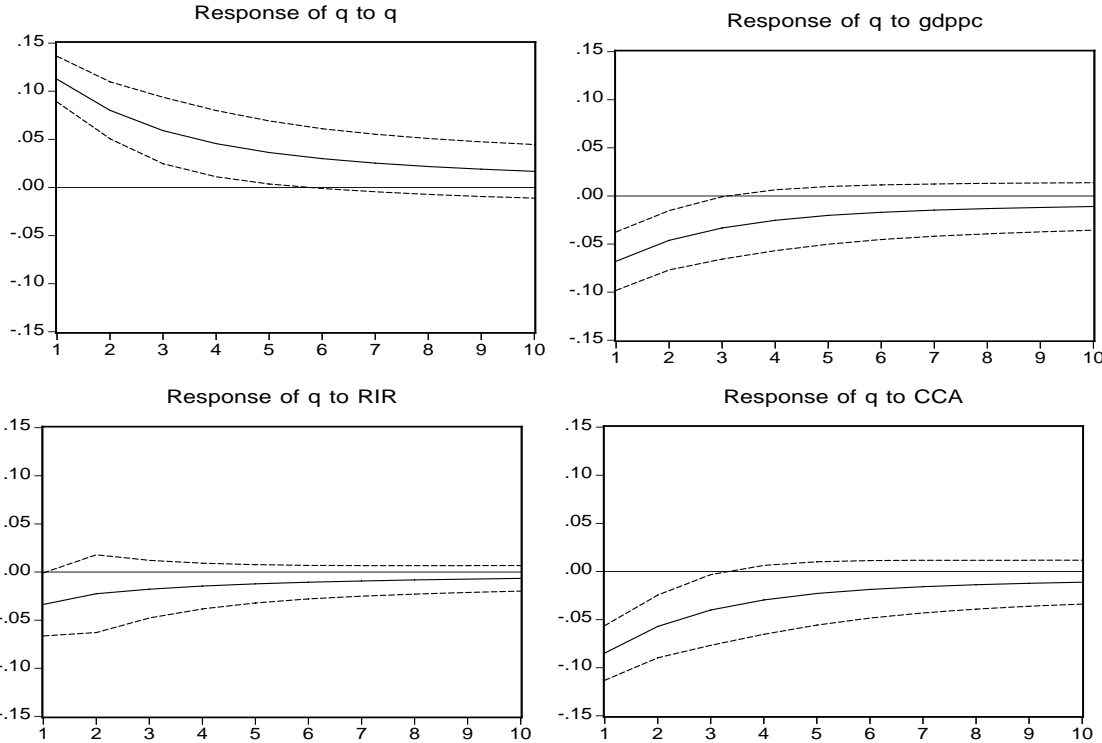
rate, the (log) GDP per capita differential, the accumulated capital account (as %of GDP) and the real interest rate differential¹⁸. In all specifications, the VAR includes one lag and a constant as the only exogenous variable.

[INSERT figure 2]

¹⁸Because we are focussing on the fluctuations in the real exchange rate, we only report the results for the real exchange rate and analyze the relative importance of the different factors in the model.

Figure 2: Generalized impulse response function of the (log) real exchange rate to an innovation in the (log) real GDP per capita differential, cumulative current account (%GDP) and real interest rate differential

Response to Generalized One S.D. Innovations ± 2 S.E.



Notes: (1) q is the (log) real exchange rate, $gdppc$ is the (log) constant GDP per capita differential, CCA is the cumulative current account (as % of GDP) and RIR is the real interest rate differential; (2) VAR includes constant and one lag.; (3) the dotted line indicates one standard deviation ± 2 standard errors

As it can be seen, a one standard deviation impulse in the GDP per capita differential has a negative effect on the real exchange rate. That is, one shock in the productivity induces a real appreciation that tends to diminish gradually. Also, an increase in the stock of net foreign assets has a lasting negative effect on the real exchange rate. Finally, a one shock in the real interest rate has a minor effect on the real exchange rate.

4 Concluding remarks

Conventional models assume the real exchange rate is determined by a certain form of the purchasing power parity condition. According to PPP, a country has an overvalued currency when its domestic inflation exceeds that of its trade partners. It is precisely this what produces a loss in price competitiveness and, as a result, a trade deficit in the balance of payments. Therefore, to correct this deficit, the nominal exchange rate must adjust.

Therefore, under the PPP doctrine, and given the mean reversion mechanism, real and nominal exchange rates cannot be misaligned for long periods of time. However, the empirical evidence, not only in Mexico, but in most of the countries, shows that this is not the case. The challenge in this case would be to explain the long periods of currency appreciation or depreciation as well as the long-lasting misalignments of the real exchange rates.

According to this, we analyzed the short and long-run determinants of the real exchange rate in Mexico between 1960 and 2005, finding, first, that the purchasing power parity cannot be taken as a long-run equilibrium relationship. In addition, we found that the real exchange rate, far from converging to a constant mean overtime, was subject to several structural breaks which correspond to the main economic crisis in Mexico.

The fact the exchange rate does not adjust to achieve and maintain competitiveness has to be explained within a broader context. Thus, based on equilibrium exchange rate paradigms, we found out that the real exchange rate in Mexico is connected to macroeconomic variables such as the relative productivity, the real interest rate and the stock of debt of a country. We provided an analysis of the long and short-run co-movements between the real exchange rate and these set of economic fundamentals finding a reasonable explanation for the real exchange rate appreciation.

So, as revealed by the VAR approximation and the estimation of impulse-response function, productivity differentials are important. Indeed, the differences in the economic growth between Mexico and United States resulted in an appreciation of the currency of the faster-growing country, Mexico.

However, at least two things are clear. First, the higher evolution of the productivity in Mexico *vis-à-vis* USA in some years contributed to the appreciation of the Mexican currency. However, it is likely that such an effect had a stronger influence between 1960 and late 1970's, when the income gap between both countries shrank. This catching-up ended with the 1982 economic crisis, from whence the BS impact might have declined.

Nowadays, more crucial for the exchange rates movements in Mexico and in other developing economies are the effects of the interest rates and the size of the net foreign assets, especially in a period driven by the twin forces of globalization and liberalization of markets and trade. First, in recent years, many emerging economies have gradually relaxed or removed capital controls. Second, many of these economies have accumulated net foreign liabilities. In general, in these countries, upward pressure on the exchange rate has stemmed largely from the increased in capital movements¹⁹.

Indeed, we found evidence first, that a higher interest rate generates an inflow of capitals which, in turns, appreciates the real exchange rate. Second, the size of net foreign assets is associated with a more appreciated exchange rate. That is, reaching a higher level of net foreign assets can afford to finance a worse current account balance

¹⁹The vulnerability of the small open economies to capital flows reversal is highlighted by, for example, the Mexican peso crisis of 1994-95.

and therefore can sustain a loss in competitiveness associated with a more appreciated real exchange rate.

In addition, the link between exchange rates and foreign sector imbalances and interest rates is also important in the short-run and when one considers the expectations of the exchange-rate market participants. Indeed, changes in the expectations, usually caused by current account imbalances (triggered either by trade flows or domestic saving-investment disequilibrium) can bring sudden and frequent adjustments in portfolios, which lead to exchange rate movements. For instance, when a country runs an unsustainable current account deficit (surplus) it loses (accumulates) foreign bonds and reduces its international reserves. In this case, agents anticipate a currency depreciation that will, eventually, take place if doubt amounts to a relevant level²⁰.

The fact that the real exchange rate will change in response to a set of economic fundamentals have several policy implications. For example, given the link between the exchange rate and the capital flows, managing of the capital transactions will have permanent effects on the real exchange rate. Since there is much room for policy intervention, attention must be given to productivity, interest rates and capital movements, when considering exchange rate objectives. Our analysis suggests that, whatever exchange rate regime a country follows, long-term success depends on a commitment to sound economic fundamentals. This is not only the case for Mexico but also for other developing countries.

Finally, we want to address that failure to reject the unit root hypothesis by a linear autoregressive process for the real exchange rate does not necessarily invalidate the purchasing power parity hypothesis. Indeed, a necessary condition for the weak form of PPP to hold in the long-run is that the real exchange rate, without any parameter restriction, is stationary. However, failure to reject the unit root hypothesis might imply that the true process for the exchange rate is given by a nonlinear model. This might open a very interesting field for future research.

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²⁰Nonetheless, some theoretical approaches argue that changes in expectations can come up independently of how the economy may be performing. That is, expectations may change even if the current account is in equilibrium: it is enough to think that an asset price is due to rise to create an immediate demand boost for it, increasing its price, fact that feedbacks expectations.

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