A unified approach to testing for mean reversion of exchange rates and prices: The OECD and Latin American cases

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A UNIFIED APPROACH TO TESTING FOR MEAN REVERSION OF EXCHANGE RATES AND PRICES:
THE OECD AND LATIN AMERICAN CASES

BY

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DEDICATION

This dissertation is dedicated first and foremost to my mother, Eliana, for her support and unconditional love throughout my entire life. I would also like to thank my brother (Fernando) and his kids (Luis Renato and Tatiana), my sister (Silvana), my father (Vasco), and my grandparents (Pedro and Geralda), they have been a great family.
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ABSTRACT

A UNIFIED APPROACH TO TESTING FOR MEAN REVERSION OF EXCHANGE RATES AND PRICES: THE OECD AND LATIN AMERICAN CASES

BY

Flavio Vilela Vieira

University of New Hampshire, May, 2002

The present dissertation is a theoretical and empirical investigation regarding the existence of a long-run relationship between exchange rates and prices. It develops a unified approach to test for mean reversion of exchange rates and prices, bringing together the disequilibrium view and the long-run real exchange rate literatures in such a way that not only exchange rates and relative prices are considered, but also the role played by real factors in explaining long-run behavior of exchange rates and prices. In chapters 2 and 3 we developed some empirical tests for mean reversion of exchange rates and prices for OECD and Latin American countries from 1957 to 1997, while in chapter 4 we have restricted our attention to the floating period for selected OECD countries when we have included some real factors into the analysis.
Introduction

The main goal of the dissertation is to develop an empirical investigation into the determinants of long-run nominal exchange rate. One of the crucial points proposed by the dissertation is the argument that the findings of the long-run real exchange rate literature imply that the specifications used in testing for mean reversion in the PPP literature are incorrect.

The central question for the thesis is to know to what extent, if it all, do nominal exchange rate and relative prices mean revert to some long-run equilibrium levels? In order to answer this question we offer a novel approach, which takes into account some results from two distinct literatures on long-run exchange rates, the PPP literature and the real exchange rate literature.

On the one hand, there is a voluminous literature spanning decades on testing whether the “theory” of purchasing power parity (PPP) is consistent with the movements of exchange rates and relative prices in the long-run. The idea behind this literature is that because of sticky-prices and disequilibrium in the goods markets, exchange rates and prices can deviate from long-run PPP. The implicit assumption behind the PPP literature is that the determinants of the long-run nominal exchange rate are relative prices (P and P*), in a way that keeps the long-run real exchange rate constant.

The empirical results on testing the PPP theory are mixed at best, with the difficulty arising during periods of floating rates, when evidence on mean reversion between nominal exchange rates and relative prices is meager. Even for those studies that find evidence of mean reversion, the rate is too slow to be reconciled with standard theory.
One of the conclusions we can draw from the PPP literature is that the long-run real exchange rate appears to be non-constant so that some deviations from PPP are permanent. Since demand-side shocks such as monetary policy actions are invariably modeled as having no long-run implications, the empirical literature on PPP literature suggests that long-run real factors such as rates of thrift and productivity are part of the story behind exchange rate movements. But this leaves an open question. Do temporary monetary shocks and overshooting behavior play any role for nominal exchange rates and relative prices and if they do, what is their importance relative to long-run real factors. This is the question to be empirically tested in chapter 4 of the dissertation.

On the other hand, there is a second literature, which has been developed independently from the PPP literature that examines the determinants of the long-run real exchange rate. The premise behind this literature is that the long-run real exchange rate is not constant, i.e., the PPP model does not provide a useful explanation of the long-run movements of nominal exchange rates and relative prices. Rather, a real model of resource allocation can explain long-run real exchange rates. The idea is to examine whether the real exchange rate is cointegrated with a set of real factors.

One of the main objectives of this thesis is to explore the idea that both the disequilibrium view of Dornbusch [1976] and others and the long-run equilibrium view of Balassa [1964] and others are both relevant in explaining the movement of nominal exchange rates and relative prices over the long-run. We argue that these two views can be seen as comprising two components of one model.

The new empirical framework developed in chapter 4 provides a way to address the question concerning the relative importance of temporary demand-side factors (and thus the disequilibrium view) and long-run real factors (the long-run equilibrium view) for the nominal exchange rate and relative prices.
The final message to be captured after all of the above considerations is that the findings of the long-run real exchange rate literature imply that the specifications used in the PPP literature for testing the extent of mean reversion of nominal exchange rates and relative prices (which omit long-run real factors) are incorrect. Once this argument is understood we still have some open questions to be answered.

The first one is the difficulty of finding evidence of cointegration and mean reversion during floating rate periods is due to the omission of long-run real factors? Second, is the problem of finding slow mean reversion, when mean reversion is found, also connected to the omission of long-run real factors, thereby providing some explanation of the PPP puzzle? Finally, if long-run real factors are included in the cointegrating regression, then will the estimated coefficients on goods prices become more consistent with the predictions of symmetry and proportionality?

A final contribution of the thesis is to develop an empirical investigation on long-run exchange rates for Latin America using a broader number of countries and a longer period of time when compared to previous studies. This empirical research is developed in chapter 3 of the dissertation and the main goal is to test for cointegration between nominal exchange rates and relative prices in Latin America, and calculate the half-lives and compare them with the half-lives of developed countries.
Chapter One

A Literature Review on Long-Run Exchange Rates: Recent Developments and Prospects

I - Introduction

This chapter reviews the work on long-run exchange rates, by comparing the theory and empirical results from two competing literatures, the purchasing power parity (PPP) literature and the long-run real exchange rate literature (including the Balassa-Samuelson tradition and the NATREX model). The purpose of this review is to shed light on the following question: to what extent, if it all, do nominal exchange rates and relative prices mean revert to some long-run equilibrium levels? This chapter will argue that the findings of the long-run real exchange rate literature imply that the specifications used in testing for mean reversion in the PPP literature are incorrect. An open question, which we explore in later chapters, is the extent to which this misspecification can explain...
the difficulty in finding mean reversion in nominal exchange rates and relative prices.

The PPP literature is based on the assumption that the long-run real exchange rate is constant and the determinants of long-run nominal exchange rates are relative prices. No one maintains that PPP holds at every point in time, but rather over long periods, movements in nominal exchange rates and relative prices should be proportionate. There is no consensus in the literature concerning why deviations from PPP occur in the short-run, especially deviations that are long lasting and persistent (see Rogoff [1996]). However, the model to which most economists adhere in explaining short-run deviations is the disequilibrium, overshooting model of Dornbusch [1976]. The Dornbusch model is designed to explain the implications of temporary demand-side shocks (such as monetary shocks) for the short-run movement of nominal exchange rates and relative prices, given that goods prices are sticky in the short-run. In the long-run, the model assumes PPP, i.e., a constant long-run real exchange rate. The implicit assumption here is that long-run real factors such as rates of thrift and productivity, which would cause movements in the long-run real exchange rate, are unimportant for exchange rate movements.

One of the ways for testing PPP as a long-run relationship has been to test the extent to which real exchange rates mean revert to constant long-run levels, i.e., testing to see if real exchange rates are integrated of order zero ($I(0)$). Such tests are called stage two tests in the literature, and the idea behind
them is that deviations from PPP, due to sticky prices and overshooting, are not permanent.\footnote{1} Although some evidence of mean reversion in real exchange rates has been found for long samples that include periods of floating and fixed exchange rates, there is very little evidence of such mean reversion solely during floating rate periods.

This difficulty has led to stage three tests of PPP, which relax the proportionality and symmetry restrictions implied in stage two tests. \footnote{2} It is important to emphasize, however, that only small deviations from proportionality and symmetry are supported by PPP theory (see Froot and Rogoff [1995]). The results of stage three tests have been mixed. Although they have uncovered evidence of mean reversion between nominal exchange rates and relative prices, the estimated deviations from proportionality and symmetry are too large to be consistent with PPP as a long-run relationship. Thus, the evidence from stage three tests suggests that in a strict sense PPP fails as an explanation of the long-run movements in nominal exchange rates and relative prices.

The conclusion to be drawn from the PPP literature is that the long-run real exchange rate appears to be non-constant so that some deviations from PPP are permanent. Since temporary demand-side shocks such as monetary policy actions are invariably modeled as having no long-run implications, the empirical literature on PPP suggests that long-run real factors such as rates of

\footnote{1} I discuss more fully below the various stages the literature has developed for testing PPP.

\footnote{2} Some also use panel data sets to increase the power of the tests (e.g. Frankel and Rose [1996]).
thrift and productivity are part of the story behind exchange rate movements. But this leaves an open question. Do temporary demand side shocks such as monetary shocks and overshooting behavior play any role for nominal exchange rates and relative prices and if they do, what is their importance relative to long-run real factors. The empirical setup developed in chapter 4 of this thesis allows us to address this question.

Interestingly, the long-run real exchange rate literature provides rather compelling evidence that long-run real exchange rates are indeed not constant and functions of long-run real factors. The literature models the long-run real exchange rate using real models of resource allocation such as the models of Balassa [1964] and Stein et. al. [1995]. Stein et. al. find strong evidence that real exchange rates (for both developed and developing countries) are cointegrated along with long-run real factors such as rates of thrift and productivity. Thus the findings of the long-run real exchange rate literature support the findings in the PPP literature that long-run real exchange rates are not constant, i.e., PPP does not hold as a long-run relationship.

One of the main objectives of this thesis is to explore the idea that both the disequilibrium view of Dombusch [1976] and others and the long-run equilibrium view of Balassa and others are both relevant in explaining the movement of nominal exchange rates and relative prices over the long-run. We argue that these two views can be seen as comprising two components of one model.
In order to see this note that the assumption of a constant long-run real exchange is not crucial for the Dornbusch [1976] model, but rather a convenient simplifying assumption that implied a constant long-run anchor towards which exchange rates and relatives prices would be reverting. If, however, this assumption is relaxed, say along the lines of Balassa or Stein et. al., then the extended Dornbusch model still implies overshooting behavior and mean reversion of nominal exchange rates and relative prices. The difference, however, is that the long-run levels toward which exchange rates and relative prices revert will involve a moving long-run real exchange rate anchor. In such a world we would expect the nominal exchange rate and relative prices to be cointegrated along with long-run real factors. The following equation captures this idea:

\[
\log s_t = \beta_0 + \beta_1 p_t - \beta_2 p_t^* + \beta_3 y + \beta_4 y^* + \beta_5 \left( \frac{(C+G)}{Y} \right) + \beta_6 \pi^{*,-1} \tag{1}
\]

where \(s\) is the log of nominal exchange rate, \(p\) and \(p^*\) are the log of domestic and foreign prices, \(y\) and \(y^*\) are the domestic and foreign real GDP, \(\frac{(C+G)}{Y}\) is the ratio to GDP of consumption plus government spending, \(\pi^*\) is the real
interest rate differential, (\(^n\)) indicates rate of growth, and (\(\cdot\)) indicates long-run equilibrium levels.\(^3\)

Interestingly, the above empirical framework provides a way to address the question concerning the relative importance of temporary demand-side factors (and thus the disequilibrium view) and long-run real factors (and thus the long-run equilibrium view) for the nominal exchange rate and relative prices. This is because in the Dornbusch model (i.e., with sticky prices), temporary demand-side shocks influence the nominal exchange rate solely through their effect on relative prices, whereas movements in long-run real factors will only affect the nominal exchange rate and not relative prices.\(^4\) This implies that the cointegrating vector contained in equation (1) should be consistent with homogeneity and proportionality, i.e., \(\beta_1 = -\beta_2 = 1\). This also implies that measuring the contribution of goods prices relative to the contribution of long-run real factors provides a way to quantify the contributions of the disequilibrium and long-run equilibrium views on exchange rates and relative prices.

It is also possible that the overshooting view of Dornbusch, which is based on the assumption of sticky prices, is inconsistent with the data. If prices are fully flexible, then according to the long-run equilibrium view, the movement in real factors should show up in both the nominal exchange rate and relative prices. Thus, if the cointegrating vector contained in equation (1) is not

\(^3\) Another possibility for modeling long-run nominal exchange rates as a function of relative prices and real factors would be to use the cumulative trade balance as one of the real factors in the same fashion of the extension to the Dornbusch [1976] overshooting model developed by Hooper and Merton [1982].
consistent with homogeneity and proportionality and thus $\beta_1 = -\beta_2 \neq 1$, then this can be taken as a rejection of the disequilibrium view.

The foregoing discussion makes clear that the findings of the long-run real exchange rate literature imply the specifications used in the PPP literature for testing the extent of mean reversion of nominal exchange rates and relative prices (which omit long-run real factors) are incorrect. This raises three very important questions. First, is the difficulty of finding evidence of cointegration and mean reversion during floating rate periods due to the omission of long-run real factors from the regression? Second, is the problem of finding slow mean reversion, when mean reversion is found (this is often referred to as the PPP puzzle), also connected to the omission of long-run real factors? Finally, if long-run real factors are included in the cointegrating regression, then will the estimated coefficients for goods prices become more consistent with the predictions of symmetry and proportionality, i.e. will they be more consistent with the disequilibrium view? The findings of the long-run real exchange rate literature suggest that the answers to all three questions may in fact be yes.

The remainder of chapter 1 is structured as follows. Section 1.1 focuses on the PPP view and the three stages of its theoretical and empirical development. This section also examines the empirical results for developed and developing countries. Section 1.2 deals with the long-run real exchange rate literature and the most important empirical findings for developed and

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$^4$ See appendix to chapter 4.
developing countries. It also includes a presentation of the Balassa [1964] and the Natural Real Exchange Rate (NATREX) models and their contribution to the real exchange rate literature. We use these models to model in chapter 4 the long-run real exchange anchor. Section 1.3 is dedicated to some concluding thoughts.

1.1 – The Purchasing Power Parity (PPP) View

The PPP notion of equilibrium for real exchange rates has dominated most models developed during the past decades. No one argues that PPP holds as a short-run phenomenon. The question rather, is whether PPP provides a useful description of the long-run movements in exchange rates and relative prices. There have been many studies employing recent advances in time-series econometrics that have tested PPP as a long-run relationship, and for the floating rate period the evidence appears mixed.

One can say that by the mid 80s the empirical literature on PPP has experienced the development of some giant steps when the field of open macroeconomics started to incorporate the cointegration techniques and the nonstationarity tests.\(^5\) It is necessary to mention that the past fifteen years have seen an enormous number of studies on PPP and regardless of the new

\(^5\) See chapter 2 for a detailed discussion on stationarity and cointegration. See also Campbell and Perron [1991], Engle and Granger [1987], and Johansen [1988] among many other papers regarding stationarity and cointegration tests and their relevance for time-series analysis in Economics.
techniques used, achieving a consensus is far from reality. Examining recent tests on PPP has revealed that in many cases it is not possible to reject the null of no long-run PPP relationship (unit root), i.e. no mean reversion, using the post-73 data for most industrial countries. This failure to detect PPP is frequently attributed to the fact that these unit root tests have low power when dealing with small spans of data. 6 Therefore, in recent years, the literature on PPP has evolved in order to develop new and more powerful tests that are able to handle this problem.

The PPP theory in its absolute version states that in equilibrium, the exchange rate between two currencies, is determined by the relative price levels from each country:

\[ s_t = p_t - p_t^* + q_t \]  

where \( s \) is the nominal exchange rate, \( q \) is the long-run real exchange rate, \( p \) is the domestic price level and \( p^* \) is the foreign price level, both expressed in national currency units (all variables are in log).

The absolute version of PPP assumes not only that the long-run real exchange rate is constant, but also that it is equal to zero.

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6 See Froot and Rogoff [1995], which shows that for a real exchange rate with a half-life of three years will require 72 years to be able to reject the null at a 5% ADF critical value. In our case we will be working in chapters two and three with a sample of data for five and eleven countries respectively, each one using approximately forty years of monthly data.
Our research work will not perform tests for absolute PPP since the data we have for domestic and international prices are indexes, which can only be used to test for relative PPP.\(^7\)

The relative version of PPP states that over a given period of time the percentage change (not the level as in the absolute version) in the exchange rate should be equal to the inflation rate differential between any two countries. It is usually tested through the following regression, assuming that the long-run real exchange rate is constant:

\[ \Delta s_t = \Delta p - \Delta p^* \quad (3) \]

It is important to emphasize however that although relative PPP is expressed in first difference, it still implies a relationship in levels.

Next, we will describe the three stages of testing for PPP so that we can have a better knowledge about the development in the literature of testing for PPP.\(^8\)

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\(^7\) Usually testing for absolute PPP has been done by using database such as the one developed by Summers and Heston (1991), known as The Penn World Table.

\(^8\) Breuer (1994) and Froot and Rogoff (1995) were responsible for the demarcation of the various stages of testing for PPP.
1.1.1 – Testing for PPP: the Three Stages and Empirics

This section of chapter one will address the historical developments in testing for PPP, known as the three stages.9

This section of our review of the literature elaborates an overview of the most important empirical results for developed and developing countries when testing for PPP. The review of the empirical results will follow the criteria to classify them as part of one of the three stages of testing for PPP. We start by describing the empirical results obtained since mid 1980s up to the end of the 90s, both in terms of rejecting or supporting PPP.10 The literature on PPP is so extensive that in chapter one we do not have the intention of reviewing most studies, but only to highlight some of them and some of the results obtained from these studies.11

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9 See Froot and Rogoff (1995) and Breuer (1994).

10 There are some good surveys on the literature about exchange rates, among those we can mention Froot and Rogoff [1995], and more recently, Edwards and Savastano [2000]. The former elaborates a theoretical and empirical review of the developments in the literature until mid 90s mostly for industrial countries, where the latter concentrates in the empirical findings for developing countries, mostly in Latin America. Other references for empirical findings for developed countries are: Frenkel and Rose [1996], Rogoff [1996], while for developing countries we can mention Liu [1992], McNown and Wallace [1989], among others.

11 The research work reviewed here concentrates on those elaborated during the 80s up to mid 90s, even though the literature on PPP goes way back on time.
Stage 1 – Simple Tests of PPP as the Null Hypothesis

The first stage is essentially testing PPP as the null hypothesis (Ho) and it is based on the following procedure by running a regression for the nominal exchange rate as described below.

\[ s_t = \alpha + \beta (p_t - p_t^*) + \varepsilon_t \]  \hspace{1cm} (4)

The test hypothesis is:

Ho: \( \beta = 1 \rightarrow \) PPP holds

Ha: \( \beta \neq 1 \rightarrow \) PPP does not hold \(^{12}\)

If we run the regression, and based on the estimated value of the parameter (µ) and its t-statistics we are not able to reject Ho, this means that relative PPP holds as a long run equilibrium relationship.

Stage one tests for PPP were widely used since late 70s up to mid-80s but they were criticized on the grounds that they do not deal with the issue of the possibility that the series (nominal exchange rates and relative prices) might be non-stationary. The stage one tests are not able to deal with a unit root in the error term (\( \varepsilon_t \)), which precludes meaningful inference from single-equation OLS.

\(^{12}\) Froot and Rogoff (1995) discuss the possibility that \( \beta \) is different from one and we can still find evidence of PPP in the long-run due to a possible Balassa-Samuelson effect or measurement error.
The empirical tests for PPP using the stage one setup were implemented during late 70s and early 80s. Among them, we can include Frenkel [1978] as one of the pioneer studies, which finds some support for long-run PPP using data for hyperinflation countries. The empirical results are somewhat expected given the predominance of monetary shocks in this kind of environment.

Frenkel [1981] and Krugman [1978] are early studies that rejected PPP without using longer time series or cointegration techniques, since these techniques were developed later by Engle and Granger [1987] and Johansen [1988].

Stage one empirical findings indicates some support for PPP within countries with high inflation but a strong rejection of PPP once we consider industrialized countries with more stable inflationary environment. We can say that stage one tests indicates that PPP does not hold most of the time, but it does not provide a useful yardstick to address the question of whether or not PPP holds in the long-run.

Stage 2 – Univariate Tests of Time Series Property of Real Exchange Rate

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13 Another example of a stage one test is Officer [1976].
The second type of test of PPP is called stage two and it is formulated in the following way:\textsuperscript{14}

\[ q_t = s_t - p_t + p_t^* \]  

(5)

where \( q \) is the real exchange rate (in natural log).

The hypothesis testing is:

\textbf{Ho:} the real exchange rate \( q \) follows a Random Walk (Unit Root)

\textbf{Ha:} \( q_t \) is mean reverting (I(0) implying that relative PPP holds in the long run

The idea of the stage two test is to impose that \( \beta=1 \) (different from stage one) and test if \( q \) is stationary or not. One of the problems with this kind of stage two test is that it is considered to have a low power in the sense that one can have problems to distinguish a random walk in the real exchange rate from a slow mean reversion when the root is close to one.

One of the early studies finding support for PPP using a longer time series and testing for stationarity of the real exchange rate is Edison [1987], with data for the dollar / pound from 1890 to 1978 and developing an error-correction model (ECM). Edison found a half-life of 7.3 years.\textsuperscript{15} Johnson [1990]

\textsuperscript{14} Examples of Stage Two tests of PPP are Darby [1983], Adler and Lehman [1983], Hakkio [1984], Meese and Rogoff [1988] and Frankel [1986] which uses longer time series for the dollar / pound real exchange rate.

\textsuperscript{15} This half-life of more than seven years has not been the rule for most studies testing for mean reversion in developed countries. In general, the half-life is around four years.
did a very similar study and the results also indicated a rejection of the random walk, with the difference that he found a much faster half-life of 3.1 years using more than one hundred years of data for the Canadian dollar / US dollar exchange rate.

Hakkio [1984] has tested for PPP for UK, France, Canada and Japan using a time series-cross sectional estimation procedure and it was unable to reject the hypothesis that PPP holds $\beta = 1$, but at the same time it was unable to reject the hypothesis that holds $\beta = 0$.

The work done by Lothian and Taylor [1994] using almost 200 years of data for U.S, UK and France, rejected the random walk hypothesis for the entire sample for both cases (US$ / Pound and Franc / Pound). The same results were not found when using only post-Breton Woods data for the same series. Using the entire sample, they found a half-life of 4.7 years for the dollar / pound and 2.7 years for the franc / pound.

Abuaf and Jorion [1990] use time series data from 1901 to 1972 for eight industrialized countries and they were able to reject a random walk, finding a half-life of 3.3 years. Glen [1992] has found similar results for nine bilateral rates from 1900 to 1987. Another empirical study that reject the random walk hypothesis is Diebold, Husted and Rush [1991] using data for the gold standard period applied for six countries and finding a half-life of 2.8 years.

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Froot and Rogoff [1995] developed a cointegration test for PPP for Argentina using Cavallo’s [1986] database, extending it from 1913 to 1988. The idea was to compare the behavior of the domestic real exchange rate for the Peso vis-à-vis the US dollar and the British pound. The result was that it could not reject the null hypothesis of unit roots for the real exchange rate (random walk).16

Engel [1996] has tested for long-run PPP and the main empirical result is that there can be large size biases in tests for long-run PPP. This means that many previous tests may have a problem in terms that a significant unit root component is not detected by these tests. At the end, Engel [1996] argues that the long-run PPP tests can tell us the existence of some mean reversion for the real exchange rate but this does not allow one to say if there is convergence to PPP in the long-run.

Another kind of empirical study that finds support for long-run PPP are the ones testing for convergence to PPP based on cross-country data sets (panel data).17 The idea is not only to use longer series but also to expand the range of countries tested in order to increase the power of unit root tests.18 Frankel and Rose [1996] is a clear example of this where they have a data set for 150 countries using annual data from 1948-92 using panel data and they

16 See Froot and Rogoff (1995) for additional comments on Cavallo’s (1986) work.

17 The argument in defense of using panel data relies on the idea that volatile large panel allows one to estimate mean reversion with greater precision than short time series regression because a data set with insufficient total variation may fail to reject the null hypothesis due to inadequate power.

were able to reject the random walk model for the full period and when they restrict the tests to the floating period. The half-life they estimate for the real exchange rate is around four years, given the point estimate for the speed of convergence of the real exchange rate around fifteen percent annually.

Wei and Parsley [1995] have tested for PPP during the floating period using a panel of 12 tradable sectors in 91 OECD country pairs, where the empirical findings suggesting that the deviations from PPP are positively related to exchange rate volatility and to transportation costs. They also find evidence of mean reversion where the half-lives of the deviations from PPP are around 4.5 years for both EMS and non-EMS countries.

O'Connell [1998] has used a panel data for 64 real exchange rates in order to test for long-run PPP controlling for cross-sectional dependence and the empirical evidence supports the random-walk hypothesis.

Phylaktis and Kassimatis [1994] has done an empirical work testing for PPP applied to the Pacific Basin countries using data from 1974 to 1987 and they find evidence that PPP holds as a long run equilibrium condition. 19 They use an ECM model and apply the Johansen's multivariate test for unit roots. The outcome is that there is mean reversion of the real exchange rate regardless of using CPI or WPI indexes. The surprising result is the half-life around one year, which is much faster than the results obtained for developed countries.

19 The countries used in the database were Korea, Japan, Taiwan, Malaysia, Phillipines, Singapore, Thailand and Indonesia.
The review of empirical results from stage two show us that testing for stationarity of real exchange rates have some problems in finding support for PPP for post-Bretton Woods data and the trend has been to use longer and broader data sets which has some clear limitation in terms of the countries included in these tests. We can see that the use of panel data has also provided better empirical support for PPP in terms of finding mean reversion for the real exchange rate. In the case of developing countries, we can say that the hypothesis of stationary real exchange rates does not have much support from most of the studies pursued during the past fifteen years, but at the same time the hypothesis that the real exchange rate follows a random walk did not have a lot of support either.20

Regarding the empirical results from stage two and what we are doing in our dissertation we can say that stationarity is one of our key concerns but instead of checking for stationarity of the real exchange rate we want to test for mean reversion between the nominal exchange rate and relative prices since we are not imposing the vector \([1 \ -1 \ 1]\), as stage two test does.

Stage 3 – Cointegrating Tests of PPP

Stage three tests of PPP are the ones developed since mid-80s and one of its main features is the idea that testing for long-run PPP requires not only

the incorporation of new cointegration techniques but also the use of longer time series.\textsuperscript{21} We know that cointegration only requires stationarity in any linear combination between the nominal exchange rate and relative prices (domestic and foreign) which is easier to be verified when compared to finding a unique vector $[1 \ -1 \ 1]$ as suggested by PPP in its strict version. The setup used by stage three results in an increase in the power of the tests, which is crucial to capture if in the long run there is a tendency for the exchange rate to move towards the long-run equilibrium level (PPP).

Whereas stage two tests ask whether $q_t = S_t - P_t + P_t^*$ is stationary, stage three asks whether $S_t - \beta_1 P_t + \beta_2 P_t^*$ is stationary for any constant $\beta$ and $\beta^*$. The equation to be estimated is:

$$s_t = \alpha + \beta_1 p_t - \beta_2 p_t^* + \varepsilon_t \quad (6)$$

One way to estimate equation (6) is to use the Engle and Granger (E-G) two step procedure which involves the following:

i) Test $s_t$, $p_t$ and $p_t^*$ in order to see if there is a Unit Root component using the ADF and the P-P tests. It is a test to see if each variable is $I(0)$ or $I(1)$ in levels.

\textsuperscript{21} Examples of Stage Three tests of PPP are Edison and Klovland [1987], Corbae and Ouliaris [1988], Kim [1990], Mark [1990], Fisher and Park [1991], Cheung and Lai [1993], among many others. Surveys on long-run real exchange rate and empirics can be found in Giovannetti [1992], Breuer [1994] and Froot and Rogoff [1995].
ii) If we cannot reject Ho (Random Walk, i.e., there is a Unit Root) for all of the three variables then we can estimate the above equation by OLS and derive the OLS residuals.

iii) Use residuals from the OLS estimation above to run the ADF regression and test if $\gamma = 1$:

The ADF will then be applied to the following regression:

\[
\Delta \hat{e}_t = \alpha + \beta t + \gamma \hat{e}_{t-1} + \phi(L) \Delta \hat{e}_{t-1} + \mu_t
\]  

(7)

where ($^\wedge$) indicates estimated errors from previous regression.

The hypothesis test is:

Ho: prices ($P_t$ and $P_t^*$) and exchange rate are not cointegrated

Ha: $\gamma < 1$ (prices and exchange rate are cointegrated)

The development of stage three was an important step in the defense of the PPP theory since in general it allows for better results in terms of rejecting the random walk hypothesis and so in favor of PPP. The controversy in the literature still exist after stage three tests since for the floating period the empirical evidence is mixed and many studies fail to reject the unit root hypothesis.\(^2\)

Froot and Rogoff [1995] when discussing the stage three tests (cointegration) for PPP, shows that these cointegration tests can be used to test

\(^2\) Further details on cointegration tests and the relevance of nonstationarity tests are provided in chapters two and three of the dissertation where we applied those tests to selected OECD countries (chapter two) and to Latin America (chapter three).
weaker versions of PPP since they require only that some linear combination of exchange rate and relative prices be stationary. The additional power from stage three tests when compared to stage two tests is due to relaxing symmetry and proportionality restrictions. If one finds that $\beta_1 \neq -\beta_2 \neq 1$, this can be explained by measurement errors which can happen due to problems in how price data is collected, affecting the way price indexes (and inflation) are measured. This kind of problem may result in a situation where one finds that changes in the nominal exchange rates are not offsetting the inflation rate differential and reach the conclusion that relative PPP does not hold, which might not be the case due to measurement error problems if the $\beta$ coefficients do not deviate too far from what is predicted by PPP (1, -1). If the deviations are sufficient large, then it is a clear indication that PPP does not hold.

One of the early three stage empirical study using cointegration techniques that found no evidence for PPP is Corbae and Ouliaris [1988]. They used monthly exchange rate data for Canada, France, UK, Japan, Italy and Germany vis-à-vis the U.S dollar from July of 1973 to September of 1986. The outcome was that they were not able to reject the null that the real exchange rate has a unit root in all cases.

Another study that rejects PPP as a long-run equilibrium relationship is Taylor [1988]. It uses a set of five countries (UK, Germany, France, Canada and Japan) with data for nominal exchange rates against the US dollar from June of
1973 to December of 1985. The results are considered extremely unfavorable to the PPP hypothesis since the exchange rate and relative prices are not cointegrated for all five countries.\textsuperscript{23} It is important to mention that the empirical results from Taylor [1988] were obtained even allowing for measurement errors and transportation costs, which somehow breaks down part of the argument suggested by Froot and Rogoff [1995] regarding the reasons why testing for PPP might fail ($\beta_1 \neq -\beta_2 \neq 1$) at a first glance.\textsuperscript{24}

One of the PPP studies using cointegration techniques and applied to the US real exchange rate compared to Canada, France, UK, Japan and Italy using a dataset that goes beyond the post-Breton Woods period (1900-1987), is Kim [1990] who finds evidence in favor of rejecting the random walk hypothesis, which is an indication of support to PPP. The empirical findings regarding the cointegration tests has shown that Kim [1990] was able to reject no cointegration, except for the case of Canada.

Mark [1990] has tested real and nominal exchange rates in the long-run for eight industrialized countries during the floating period and he finds unfavorable evidence to the PPP hypothesis in the long-run.

Fisher and Park [1991] has tested for long-run PPP using the null of co-integration testing for a wide cross-section data for major industrial countries

\textsuperscript{23} Among the studies testing for PPP that did not find support for cointegration between exchange rate and relative prices (PPP) we can also mention Mark [1990], Fisher and Park [1991]. Enders [1988] found mixed support for PPP.
over the floating period. The empirical results suggests a weak form of PPP for all countries except for US and Canada and that there is little evidence of stationarity for the real exchange rate. The adjustment to the disequilibrium situation occurs in the foreign exchange market and not in the goods market.

Cheung and Lai [1993] while testing for long-run PPP and allowing for measurement errors during the floating period have found favorable evidence that PPP holds as a long-run relationship with measurement errors in prices. The paper also finds that proportionality and symmetry are not consistent with the data, which is a clear empirical result supporting stage three recommendation.

Mark and Choi [1997] applied to study monthly real exchange rates between the US, Germany, Canada, United Kingdom and Japan from 1961 to 1993 using panel data has found evidence that short-run changes in the real exchange rates are very noise but since it is governed by economic fundamentals, one can find evidence of mean reversion for the long-run real exchange rate. The main conclusion of the paper is that while it was easy to reject the random walk hypothesis, it is necessary to go beyond PPP to understand long-run movements in the long-run exchange rate.  

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24 The results from Taylor [1988] are also interesting in terms of demystifying the argument that taking into account barriers to trade can solve the PPP puzzle. Regarding the PPP puzzle, see Rogoff [1996] and Obstfeld and Rogoff [2000].

25 The monetary model and how does it help to understand long-run movements in the real-exchange rate is one of the contributions of Mark and Choi [1997]. This is also related to the sticky-price models like Dornbusch [1976] which argues that monetary variables have a significant impact in the real exchange rate.
A recent empirical study by O'Connell [1997] accounts for the problem of market frictions. O'Connell finds evidence to reject PPP when applied to OECD countries from 1973 to 1995. The idea is that market frictions play a role in terms of being an obstacle to trade and thus an obstacle to PPP. The results show that large deviations from PPP are as persistent as small deviations and thus large PPP deviations do not show tendency for a stronger mean reversion when compared to small deviations. The paper emphasizes the relevance of looking not only at the duration of the deviations but also in their size.

Among the few samples of three stages tests for PPP in developing countries we can mention Liu [1992], which has tested PPP in Latin America using cointegration analysis using a database for 9 countries that have experienced high inflation in the post-WWII period.26 The paper uses bilateral nominal exchange rates for all countries vis-à-vis the U.S dollar. The results show more support to PPP when using the WPI instead of the CPI. Although Liu [1992] found mixed result from the cointegration tests in terms of supporting PPP, if one focuses on the existence of a long run relationship then PPP is accepted.

McNown and Wallace [1989] has tested long-run PPP for Argentina, Brazil, Chile and Israel using time-series analysis with monthly data during the

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26 Argentina, Brazil, Bolivia, Chile, Colombia, Peru, Mexico, Uruguay and Venezuela. The time series period varies from 1948, 1949, 1956 and 1957 as starting date depending on availability for each country, until the end of 1989 for all countries.
1970s and 1980s (12 years) and the main empirical finding is that evidence in favor of PPP can only be found when using the WPI index.  

Another empirical work on PPP for Latin America countries is of Liu and Burkett [1995], which has the main purpose of testing instability in short run adjustments to PPP. They found that short run adjustments to PPP were characterized by instability. The time-series used includes quarterly data for the post-WWII period of exchange rate vis-à-vis the US dollar for Argentina, Chile, Mexico and Colombia. Another empirical result from Liu and Burkett [1995] is that current account deficits and changes in international capital flows can result in short-run relative price changes.

The paper by Mahdavi and Zhou [1994] applied to thirteen high inflation countries using data from the post-73 (floating) period has revealed support for PPP in the cases of Argentina, Brazil, Mexico, Israel, Peru, South Africa, Uruguay and Yugoslavia. The results are indicative that PPP will hold more consistently as a long run equilibrium relationship whenever the inflationary process is very strong. Another important empirical finding from Mahdavi and Zhou [1994] is that the adjustment towards correcting short-run deviations from PPP is done by relative prices and not by the exchange rate, which is an indication that the exchange rate is weakly exogenous.

After all the empirical tests for long-run PPP examined before, we can derive some general conclusions. The major conclusion from reviewing the

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27 See also McNown and Wallace [1994] for co-integration tests for Israel, Argentina and Chile where the empirical evidence indicates the existence of at least one cointegrating vector for Chile and
empirical findings from stage three tests for PPP is that there is evidence of supporting cointegration between nominal exchange rates and relative prices, but $\beta_1 = -\beta_2 \neq 1$. This result suggests that we have a non-constant long-run real exchange rate and so PPP does not hold as a long-run anchor. This conclusion is already part of the literature on long-run real exchange rate (Balassa-Samuelson and Natrex) suggesting that in order to understand long-run exchange rate behavior it is necessary to incorporate real factors, either coming from the supply side of the economy (Balassa-Samuelson), or from both the supply and the demand sides (Natrex).

The theory suggests that we should find evidence of faster mean reversion of the exchange rate towards its equilibrium level, but in reality (post-73 data) most studies either do not find reversion at all for most developed countries or when they find, it is too slow. This is often referred to as the PPP puzzle.28

The empirical and theoretical propositions derived from stage three tests are much closer related to our empirical and theoretical framework since we are not imposing the symmetry and the proportionality restrictions, and we are working with a model specification where we want to test for mean reversion between nominal exchange rate, domestic and foreign price which moves away

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28 See Rogoff [1996] and Froot and Rogoff [1995] for a discussion about the PPP puzzle. The field of Open Macroeconomics has some puzzles that are still to be solved. A description of six of these puzzles can be found in Obstfeld and Rogoff [2000] and in Engel [2000]. Our research work will provide some empirical results that will shed some light to the debate regarding the fifth puzzle, i.e., the PPP puzzle.
from stage one (unique coefficient for relative prices) and stage two (unique vector of coefficients, i.e. \([1 -1 1 ]\)).

1.1.2 – Empirical Tests of PPP in Developing Countries: Limitations and Recent Trends

It is fair to say that empirical studies testing for PPP in developing countries are much fewer in number than those applied to developed countries. One reason is probably related to the fact that most developing countries have shown some reluctance in adopting floating exchange rates since the breakdown of the Breton Woods system. Most developing countries held on for a while to fixed exchange rate regimes characterized by different forms of current and capital account restrictions, where these aspects made it less meaningful to test for PPP using developing country data.29

Since the end of 1980s the situation has changed in the sense that new studies testing for different versions of PPP in developing countries have been developed. Edwards and Savastano [2000] has an interesting comparison of thirteen of these studies, with information regarding the countries and the time period covered by each study, as well as information on the type of exchange

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29 See Edwards and Savastano [2000] p.28 for a table comparing the empirical studies on PPP for developing countries.
rates and relative prices used, the PPP hypothesis tested, and the results obtained.

The overall interpretation of empirical studies testing for PPP in developing countries includes the existence of more evidence for Latin America when compared to developing countries around the world. The periods covered by most studies for emerging economies are short when compared to those from industrial countries.30

Edwards and Savastano [2000] emphasizes that only three empirical studies, among the thirteen analyzed, use data series for more than thirty-five years, where most of the studies work with quarterly or monthly data in order to minimize the small sample problem. It is also true that most studies rely on consumer price indexes instead of wholesale price ones. 31

Another difference that can be highlighted from the table I. presented by Edwards and Savastano [2000] regarding studies of PPP for developing countries is the fact that almost half of them do not use bilateral exchange rates vis-à-vis the US dollar, as it is usually the case for most industrial countries empirical studies. It is quite common to see the use of nominal effective exchange rate among the studies of PPP for developing countries.

30 Most of the studies covered a period between fifteen and twenty five years whereas our empirical study pursued on chapter three will cover forty years for eleven Latin American economies. That is one of our main contributions to better understand the behavior of exchange rates and prices in Latin America since we are using a much longer and broader data sample.
31 Chapter three of the present dissertation uses the CPI index as a proxy for price given the limited availability of WPI data for all eleven countries for the period of 1957 to 1997.
Most of the studies testing for PPP in developing countries use the stage two specifications, where only four out of thirteen studies use the stage three bivariate cointegration techniques for testing for PPP. Another problem with the PPP empirical studies for developing countries is that most of them do not specify what kind of PPP version they are testing, the absolute or the relative version. We can now select some studies of PPP applied to developing countries to be analyzed and to present their main results.

Another conclusion that we can draw from comparing various studies on PPP for developing countries is that whenever they use cointegration techniques, the evidence seems to support better the PPP hypothesis when compared to the empirical tests for industrialized countries. In general, the conclusion from the empirical studies testing for PPP and mean reversion in developing countries is that the real exchange rate mean reverts faster when compared to developed countries. The struggle for testing PPP for developing countries is still related to the span of data available, which is shorter than those for developed countries, and sometimes they are not available at all.

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32 Among those studies testing for PPP in developing countries using cointegration techniques, see Liu [1992] and Seabra [1995].

33 The half-life for developing countries is around two and three years, while for developed countries the literature suggests a half-life somewhat between four and five years. The empirical findings obtained from chapters two and three suggests a half-life for developed countries around four and a half years, and around three and a half for Latin America.

34 See Edwards and Savastano [2000] for additional consideration on the lack of empirical studies on exchange rates for developing countries as well as in terms of data problem to pursue this kind of research.
Finally, we can say that our empirical study will certainly help having a better understanding of one of the main gaps in the literature of testing for PPP in developing countries, which according to Edwards and Savastano [2000] is due to a lack of studies testing for mean reversion in developing countries.$^{35}$

Looking at empirical studies testing for PPP in developing countries we can say that we still have only a limited knowledge of the time-series properties of real exchange rates with a long way to go. The two most important shortcomings are related to the limitations imposed by stage two tests, the data problems encountered by most studies, and the concentration on Latin American countries instead of having a more widespread sample of developing countries from different parts of the world.

1.2 - The Real Equilibrium Model of Resource Allocation and Empirics

First of all, we should mention that what we are calling here, as the real equilibrium model of resource allocation is also known as structural models of permanent deviations from PPP. Up to this point we have seen that the PPP model focuses on nominal exchange rate and relative prices, but now we will

$^{35}$ Chapter three of our dissertation will tackle the issue of checking for mean reversion of the real exchange rate for eleven Latin American economies, using two error-correction model specifications in order to calculate the half-life, and we also used cointegration techniques to search for the existence of cointegration vectors.
examine a branch of the literature that attempts to explain empirically permanent deviations from PPP based on some fundamental factors such as, productivity growth, thrift ratio, price of tradables and non-tradables, among others. The premise of this literature is that PPP does not hold even as a long-run relationship. We will specify the Balassa-Samuelson model and the NATREX model, emphasizing their main theoretical contributions and empirical findings to the long-run real exchange rate literature.\footnote{See Froot and Rogoff [1995] section 3 for a review of structural models of deviations from PPP, as well as Edwards and Savastano [2000]. A pioneer work was Balassa [1964] and Samuelson [1964].}

The empirical studies using real models of resource allocation aim to explain the existence of structural (permanent) deviations from absolute PPP across countries. The database used by most of these studies is from the United Nations International Comparison Program (ICP) and more recently from the Penn World Table.\footnote{See Kravis et al., [1975] [1982] for early data, and Summers and Heston [1988] [1991] for the methodology and data coverage of the ICP.}

The most important model of long-run real exchange rate deviations from PPP is based on Balassa [1964] and Samuelson [1964], which basically argues that empirically, when all country's price levels are translated to dollars at prevailing nominal exchange rates, there is a tendency for an increase in price levels when compared to poor countries. The reason for this is not simply because rich countries have higher absolute productivity levels when compared to poor countries, but because relative productivity in traded goods sector
relative to non-traded goods sector is higher in rich countries when compared to low-income countries.\(^{38}\)

It is also important to mention that the Balassa-Samuelson model explains real exchange rate movements in terms of sectoral productivities based on two theoretical notions:

i) The model implies that the relative price of non-traded goods in each country should reflect the productivity of labor in the traded and nontraded goods sectors.

ii) The model assumes that PPP holds for traded goods in the long run.

The idea behind the original work done by Balassa [1964] and Samuelson [1964] is that technological progress is faster in the traded goods sector when compared to non-traded goods sector in developed over developing countries, resulting in a traded-goods productivity bias for high-income countries and in higher CPI levels with implications in terms of real exchange rate appreciation.\(^{39}\) A number of studies have examined empirically what factors may account for the differences between a country’s exchange rate and its purchasing power parity.\(^{40}\)

\(^{38}\) \( (A_T / A_{NT})^H > (A_T / A_{NT})^L \), where \( A \) is the productivity parameter, \( T \) (\( NT \)) indicates tradable (non-tradable) goods sector, and \( H (L) \) is for high (low) income countries.

\(^{39}\) The Baumol-Bowen effect states that within a country there is a tendency for the prices of service intensive goods to rise over time, where productivity in the service sector historically has a lower growth rate when compared to manufacturing (capital intensive) sector. The link between the Baumol-Bowen effect and the Balassa-Samuelson is given by the fact that the service sector is composed by a lot of non-traded goods, but the presence of the first effect is not sufficient to imply the second effect.

\(^{40}\) See Edwards and Savastano [2000] table 4 for a comparison of the results from fifteen studies based on the model of structural deviations from PPP. The most important empirical results will be stated in
The idea derived from the Balassa-Samuelson work is that balanced growth across the traded and non-traded sectors can lead to a rise in the relative price of non-tradables, if non-traded goods are relatively labor intensive.

In order to represent the Balassa-Samuelson hypothesis, consider an economy that produces tradable (T) and non-tradable (N) goods and the production function with constant-returns of capital (K) and labor (L) are the following:

\[ Y_T = A_T F(K_T, L_T) \]  
\[ Y_N = A_N G(K_N, L_N) \]

where T denotes the traded sector and N the non-traded sector, and A is the productivity parameter.

The growth in productivity in both sectors is represented by the following equations:

\[ \hat{A}_T = \theta_{LT} \omega \]
\[ \hat{A}_N + \hat{p} = \theta_{LN} \hat{\omega} \]  

(11)

where \( \theta_{LT} = \omega_{LT}/Y_T \) and \( \theta_{LN} = \omega_{LN}/p_Y \) are the labor's share of the income generated in the traded and non-traded goods sectors, respectively, \( p \) is both the absolute and relative price of non-tradables since the price of tradables in both countries is set equal to one, \( \omega \) is wage, and \(^{(\hat{\cdot})}\) denotes a small percentage change or logarithmic derivative.

Using equation (10) in (11) we can derive the following expression for changes in the relative price of non-tradables:

\[ \hat{p} = [(\hat{\theta}_{LN}/\hat{\theta}_{LT})\hat{A}_T] - \hat{A}_N \]  

(12)

The main lesson from equation 12 is that if the condition that \( \hat{\theta}_{LN} / \hat{\theta}_{LT} \geq 1 \) holds, faster productivity growth in the tradables sector than in the non-tradables sector will result in an increase in the price of non-tradables \( (p) \).

The Balassa-Samuelson effect argues that there is a tendency for countries with higher productivity in tradables to have higher price levels. In order to show this, first assume that the price level is a geometric average with

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41 The following representation of the Balassa-Samuelson hypothesis is based on Obstfeld and Rogoff [1996], chapter 4.
weights \( \lambda \) and \((1 - \lambda)\) of the prices of tradables and non-tradables. The home
and foreign price indexes taking the tradable sector as the numeraire, are:

\[
P = (1)^{\lambda}p^{1-\lambda} = p^{1-\lambda} \tag{13}
\]

\[
P^* = (1)^{\lambda}(p^*)^{1-\lambda} = (p^*)^{1-\lambda} \tag{14}
\]

Therefore, the ratio between home and foreign price is:

\[
(P / P^*) = (p / p^*)^{1-\lambda} \tag{15}
\]

Once we log-differentiate equation 15 and use equation 12 it is possible
to see how changes in relative productivity affects the real exchange rate,
expressed by movements in relative price levels:

\[
P - P^* = (1 - \lambda) (p - p^*) =
\]

\[
= (1 - \lambda) \{[\theta_{LN} / \theta_{LT} (A_T - A_T^*)] - (A_N - A_N^*)\} \tag{16}
\]

If productivity growth advantage of the home country is bigger in tradable
goods when compared to non-tradable goods and assuming that \( \theta_{LN} / \theta_{LT} \geq 1 \),
home country will face a real appreciation of the exchange rate, which is shown in equation 16 through a rise in home relative price level.

One important key feature of this result from the Balassa-Samuelson model is that it holds regardless of any demand-side factor in the model.

The supply factors (productivity) are keys to the dynamics of the Balassa-Samuelson model and to understand real exchange rate appreciation for high-income countries. But demand factors such as government spending can play an important role in relative price behavior in a small-country case if capital cannot be transferred instantaneously across sectors. In a situation like this, there is a tendency for government spending to increase the relative price of non-tradables.\(^{42}\)

The way Balassa [1964] tested the proposition that high-income countries have higher real exchange rates was implemented through the following regression using a database for twelve industrial countries:\(^{43}\)

\[
\frac{P}{SP^*} = \alpha + \beta \frac{GNP}{POP} \tag{17}
\]

where \(P\) is the domestic price index

\(P^*\) is the foreign price index

\(S\) is the nominal exchange rate

\(^{42}\) See Froot and Rogoff [1991] [1995].

\(^{43}\) This equation is a test for absolute PPP.
GNP is the gross national product
POP is the population

Findings of a positive and significant ($\beta$) would be an indication that higher income countries have a higher exchange-rate adjusted price levels, resulting in real exchange rate appreciation over time.

Most of empirical studies using the structural deviations from PPP model were done until early 90s by estimating cross-sectional regressions of real price levels (PPP index divided by the nominal exchange rate) or some other subset of commodity groups real prices on a small number of explanatory variables. Usually, the explanatory variables include a measure of per-capita income, the openness ratio, the share of primary sector output in total GDP, among others.

The theoretical debate behind these studies was to address the relevance of different factors in explaining sustained deviations from absolute PPP that might be due to productivity differentials between tradable and nontradable sectors (Balassa [1964] and Samuelson [1964]); differences in the degree of factor mobility (Clague [1985]); differences in consumer preferences (Bergstrand [1991]); and differences in relative factor endowments (Bagwati [1984] and Kravis and Lipsey [1983]).

Rogoff [1996] has developed a good review of what he called the three modifications (deviations) to long-run PPP. The first one is the Balassa-Samuelson hypothesis discussed above, where the second one is the studies
trying to show that cumulated current account deficits result in long-run real exchange rate depreciation, while the third one emphasizes the role of government spending to explain deviations from PPP in the long-run.  

We can now highlight the most significant empirical results from the models of structural deviations from PPP.

1.2.1 - Empirical Findings

Balassa [1964] was the first cross-section study for twelve industrial countries for 1960 where the dependent variable was the inverse of the real exchange rate \((P/SP^*)\) and the per capita income coefficient estimated had the expected positive sign. After the seminal work of Balassa, we have the development of new studies using the ICP database and similar regressions, including Iserman [1980], and Salazar and Carrillo [1982], finding significant and positive coefficient for per capita income.

One of the only studies that did not make use of the ICP database was Clague and Tanzi [1972], using ECLA data for almost twenty Latin American countries and it founds that per capita income has the expected sign and was significant in a regression with the inverse of the real exchange rate as the dependent variable.

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44 Hooper and Morton (1982) and Krugman (1990) are examples of the second modifications to PPP while Froot and Rogoff (1991) and De Gregorio, Giovannini and Wolf (1994) are part of the third modification to PPP.
Since early 80s we have seen some empirical studies using a different specification for the dependent variable, where now they will use not only the ratio of purchasing power parity to the exchange rate \( (P / P^*S) \) as before, but also the US dollar price of tradable \( (Pt / S) \) and nontradable \( (Pn / S) \). The results obtained were pretty much the same as the ones obtained before but in Kravis and Lipsey [1988] the per capita income had the expected sign only for OECD countries but not for less developed countries.

The empirical studies developed by Officer [1989] and Bergstrand [1991] have used the relative price of non-tradables to tradables \( (Pn / Pt) \) as another specification for the dependent variable in the model, and both still got the expected sign and significance for the per capita income variable. Heston, Nixxon and Summers [1994] was the first empirical study to use the ratio of price of tradables and price of non-tradables relative to the purchasing power parity level \( (P_t / PPP = P_t P^* / P \) or \( P_n / PPP = P_n P^* / P) \) and for most cases the per capita income have the expected sign and significance when testing for real exchange rate deviations from PPP.

Among the studies suggesting evidence of a Balassa-Samuelson effect we can mention Marston [1987] and Edison and Klovland [1987]. The former looks at the yen / dollar real exchange rate over the period of 1973-83 using OECD disaggregated date for ten sub sectors (two traded sectors and six nontraded sectors), and calculates traded-nontraded goods productivity.

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45 See Kravis and Lipsey [1988].
differentials. It also calculates the labor productivity differentials between traded and nontraded goods using sectoral employment data. The idea is that these variables provide an explanation for the long-run real appreciation of the Japanese currency against the dollar.

Since early 90s the empirical studies on deviations from PPP has seen an application of panel data using the Penn World Table I. data, especially for the case of developing countries as we can see by Dollar [1992] and Connolly and Deveneaux [1995].46 Both studies made use of the Summers and Heston database, using the inverse of the real exchange rate (P / SP*) as the dependent variable, where the first study uses a hundred and seventeen countries, where ninety five were developing countries for the period of 1976-85, and the second uses data for seventeen developing countries from 1960 to 1985, and they both found the expected sign for the per-capita income variable.

The empirical evidence from the work done by Froot and Rogoff [1991] [1992] to a set of twenty-two OECD countries from 1950 to 1989 suggests a weak correlation between the real exchange rate and productivity differentials. Asea and Mendoza [1994] developed a dynamic two-country general equilibrium model for fourteen OECD countries over the period of 1975-85 and they conclude that although productivity differentials between traded and nontraded goods are important in explaining changes in the relative price of

46 Connolly and Devereaux [1995] is part of the NATREX model and will be explored in details in the next section of this chapter.
nontraded goods for each country, changes in non-traded goods prices cannot explain changes in real exchange rate across countries. 47

Another set of studies trying to understand deviations from PPP is Wood [1991], which uses World Bank data and includes some structural determinants in the same way as those tested before by the Balassa-Samuelson tradition, but now variables were expressed in terms of the ratio of their average value of one period relative to the average in another period of time. Empirical findings suggest that the real exchange rate in developing countries had depreciated relative to those of industrial countries, where the magnitude depends on the level of income of developing countries. The explanation for this kind of behavior by the real exchange rate was suggested to be due to the large increase in the price of non-traded to traded goods within industrialized countries, which is a clear sign of a strong Balassa-Samuelson effect. 48

More recently we can mention the study of Canzoneri, Cumby and Diba [1996] tested relative labor productivity and real exchange rate in the long-run for a panel of OECD countries and the results suggests that in the logn-run

47 De Gregorio, Giovannini and Wolf [1994] find similar results to Asea and Mendoza [1994] but with more positive results in terms of the ability of productivity differentials in explaining changes in the real exchange rate. They also calculate total factor productivity using the Solow residual and they consider demand factors such as government spending and income, where over the long-run productivity differentials are relevant to explain movements in the relative price of tradables and non-tradables whereas demand factors are less important.

48 Another recent study examining long-run movements in the real exchange rates for the APEC countries is Isard and Symansky [1996] suggesting that most of the fast growing APEC countries have experienced a depreciation of the real exchange rate, except for Japan, Korea and Taiwan (real appreciation). The study also suggests that the relative price of tradables can explain the variation in the real exchange rate for the majority of APEC countries.
relative prices generally reflect relative labor productivity but the evidence that PPP holds in the long-run for traded goods is less favorable. 49

It is fair to say that the empirical studies on deviations from PPP testing the Balassa-Samuelson hypothesis have shown empirical support especially in comparisons between poor and rich countries, and in time-series data the case of Japan seems to be the most striking case.

Edwards and Savastano [2000] suggests that even though studies like Wood [1991] and Isard and Symansky [1996] have made significant progress towards understanding deviations from PPP in the long-run, the results questioned the presence of a Balassa-Samuelson effect for developing countries during the past decades.

One of the main criticisms to the empirical results from studies testing the structural deviations from PPP is that they do not have a dynamic analysis. In other words, they do not explain the origin or the duration of the deviations from PPP, and so one can say that they have only a limited value as a benchmark to explain long-run real exchange rate behavior. 50

The main conclusion from the empirical findings from the real equilibrium model is that the long-run real exchange rate is not constant and it depends on supply-side real factors like productivity growth.

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49 The results supporting PPP in traded goods are more favorable when they use the DM instead the US$ as the numeraire currency.

50 See Edwards and Savastano [2000] table 4, pp.37 where only five out of sixteen studies have some kind of dynamic analysis.
1.2.2 – Real Exchange Rates and the NATREX Model: Theory and Empirical Findings

Another approach to modeling the long-run real exchange rate, which differs from the Balassa-Samuelson model in that it takes into account demand-side factors, is the NATREX model of Stein et al. [1995]. This section describes the main features of the NATREX model and its empirics. It is also important to mention that the NATREX literature has close links to the work developed by authors like Sebastin Edwards [1988] and applied to developing countries, especially Latin America.

1.2.2.1 – The NATREX Model

The NATREX (NATural Real Exchange) refers to a medium-run moving equilibrium real exchange rate, which is determined by real fundamentals (factors). One of the key components of the NATREX model is the balance between desired saving and investments since this will have implications in terms of determining the medium-run real exchange rates, the current account balance, and the real interest rate (large country case).  

51 The NATREX approach assumes that savings and investment decisions are independent of one another, differently from intertemporal optimization models.
assumes that all speculative and cyclical factors already played themselves out, which ultimately results in a setup similar to the equilibrium models. The primary goal of the NATREX model is an empirical one, and it tries to explain medium to long-run movements in real exchange rate.

The main criticism the NATREX approach formulates towards the PPP theory is that the PPP hypothesis fails to take into account the evolution of the fundamentals, which have not been stationary during the floating period, and that is the reason why many PPP tests have failed as a benchmark for long-run real exchange rates.

The NATREX model includes the rate of time preference of thrift and the productivity of capital as the two main exogenous fundamentals to explain medium to long-run movements in real exchange rates. The empirical results suggest that a decrease in thrift lead to long-run depreciation, while an increase in productivity has mixed effects on the long-run NATREX.

The NATREX approach also relies on the existence of empirical evidence that real exchange rates are non-stationary, and so they do not move towards a given mean or trend since the exogenous fundamentals are non-stationary. Another feature of the NATREX model is that the NATREX rate is constantly changing and it is unpredictable because fundamental disturbances

52 Thrift is defined in most NATREX empirical studies as the ratio of savings to GNP (S / GNP) where savings is GNP less private consumption and governments spending (S = GNP − C − G) and GNP (GDP) growth is the most common proxy for productivity growth. We can also use the average product of labor or the capital-employment ratio as proxies for productivity.

are non-stationary and unpredictable. In this kind of framework, there is no role for long-run expectations in the NATREX model.  

The two main features distinguishing the NATREX approach and the Balassa-Samuelson view is that the former allows for terms of trade effect while the later assumes constant terms of trade, and the real exchange rate in the NATREX model depends on both demand (thrift) and supply (productivity) factors while in the Balassa-Samuelson models the real exchange rate is solely a function of supply factors.

Empirical tests of the NATREX model use exogenous changes in thrift and productivity as proxy for the fundamentals, and the terms of trade and the world real interest rate for small country cases. Previous studies using the NATREX model have found that real exchange rate (q), growth in productivity (PROD) and the thrift ratio (TR) are all series integrated or order one, I(1), and so they are cointegrated. The explanation given to explain the failure in finding cointegration for the pos-73 period when using only the nominal exchange rate (S) and domestic and foreign prices (P and P*) is due to the presence of omitted real variables. Therefore it does not make sense to run S on P and P* in the way the PPP literature does.

The intuition behind the NATREX model and based on the empirical findings from Stein [1995], which have tested the NATREX model to the US

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54 This is another difference between the NATREX model and the PPP theory.
economy during the floating period. It can be expressed through the following equation:

\[ q_t = \beta_0 + \beta_1 q_{t-1} + \beta_2 DRG + \beta_3 FRG + \beta_4 CG + \beta_5 r^{*}_{t-1} + \mu_t \]  (18)

where \( s \) is the log of the nominal exchange rate, \( p \) and \( p^* \) are the logs of domestic and foreign price indexes, \( q \) is the log of the real exchange rate, DRG and FRG are the domestic and foreign real growth in GDP, CG is the index of social time preference \(((C+G)/GNP))\), \( r^* \) is the real interest rate differential.\(^{55}\)

In chapter four of our dissertation we will test for stationarity of the series \((s, p, p^*, DRG, FRG, CGGDP, \text{ and } r^*)\) using the ADF test, and test for cointegration using the Johansen test of cointegration for a system including all seven variables to see if we can find evidence of mean reversion during the floating period for selected OECD countries.

We can now move to briefly present the most relevant empirical results from the NATREX model.

\(^{55}\) Stein [1995] does not provide an explanation of why to include a lagged real exchange rate in the regression. Regarding the variables \( y \) and \( y^* \), Stein [1995] advocates using a moving average series in order to abstract from the cyclical elements.
I.2.2.2 – Empirical Results from the NATREX Model

Stein [1995] finds that for US the real exchange rate and the current account ratio to GNP respond to thrift and productivity in the same way predicted by the NATREX model, increase in productivity leads to long-run real appreciation and a decline in thrift results in an increase in the current account relative to GNP.

Table I. 2 in the appendix summarizes the empirical work of Stein [1995] for the US and it shows that the time preference has a negative (depreciation) impact on both the real exchange rate and it deteriorates the current account. Domestic growth appreciates the real exchange rate but we have problem of significance, and it alto deteriorates the current account relative to GNP. Finally, foreign growth depreciates the real exchange rate and improves the current account relative to the GNP.

The NATREX model applied to a small open economy (Australia) was developed by Lim and Stein [1995] and used to explain the evolution of the relative price of non-tradables and the real exchange rate with fundamentals (thrift, productivity, the world real rate of interest, and the terms of trade) determining the relative price of non-tradables. The study also used the Engle-Granger and the Johansen techniques to estimate long-run relationships and to determine the number of cointegrating vectors.
Empirical findings suggest that fundamentals (terms of trade, savings ratio, productivity growth of capital in tradable and non-tradable sectors, and world real interest rates) can explain relative price of non-tradables, but fundamentals cannot explain much of the exchange rate variation in the short-run. The paper argues that there is a faster convergence of the real exchange rate to the NATREX in the free-exchange period when compared to the stabilized period, given that nominal exchange adjusts quickly to movements in the real exchange rate but we still have price stickiness.

The empirical work developed by Connolly and Devereux [1995] is an application of the NATREX model to Latin America with some minor changes, for the period of 1960 to 1985. Some of the empirical findings are: technological progress and increase in the capital stock generate real appreciation; trade liberalization (increase in the degree of openness) tend to appreciate the real exchange rate; deterioration in the external terms of trade results in real depreciation of the exchange rate; real exchange rate is positively related to economic size; and government spending has ambiguous effect but it is more likely to appreciate the real exchange rate.

1.3 – Concluding Remarks

The review of the literature has shown that there are two separate literatures on long-run exchange rates, the PPP and the model of real resource
allocation, which have, for the most part, been developed separately. The idea was to show that there are lessons contained in the latter that can be used for modeling long-run nominal exchange rates and relative prices.

Although some evidence of mean reversion in real exchange rates has been found for long samples that include periods of floating and fixed exchange rates, there is very little evidence of such mean reversion solely during floating rate periods. This difficulty has led to stage three tests of PPP, which relax the proportionality and symmetry restrictions implied in stage two tests. The results of stage three tests have been mixed. Although they have uncovered evidence of mean reversion between nominal exchange rates and relative prices, the estimated deviations from proportionality and symmetry are too large to be consistent with PPP as a long-run relationship. Thus, the evidence from stage three tests suggests that in a strict sense PPP fails as an explanation of the long-run movements in nominal exchange rates and relative prices.

One of the main conclusions we can draw from the PPP literature is that the long-run real exchange rate appears to be non-constant so that some deviations from PPP are permanent. Since temporary demand-side shocks such as monetary policy actions are invariably modeled as having no long-run implications, the empirical literature on PPP suggests that long-run real factors such as rates of thrift and productivity are part of the story behind exchange rate movements. But this leaves an open question as to whether monetary shocks and overshooting behavior also play some role for nominal exchange rates and
relative prices and if they do, what is their importance relative to long-run real factors. The empirical setup of chapter four will allow us to address this question.

On the other hand, the long-run real exchange rate literature, provides rather compelling evidence that long-run real exchange rates are indeed not constant and functions of long-run real factors.

Furthermore, chapter one has also provided us with the necessary theoretical discussion on long-run exchange rates in order to explain how the thesis will try to bring together both the disequilibrium view of Dornbusch [1976] and others and the long-run equilibrium view of Balassa [1964] and others in explaining the movement of nominal exchange rates and relative prices over the long-run. We argue that these two views can be seen as comprising two components of one model.

Reviewing some of the most striking empirical studies has shown us that evidence of mean reversion between nominal exchange rates and relative prices was not easy to be found, specially during the floating period. The half-life of the exchange rate is around four and a half years for high-income countries and two and a half years for less developed countries. The next two chapters of this dissertation will address this calculation for selected OECD countries and for eleven Latin American economies during the period of January of 1957 to March of 1997 using two different error correction model specifications.
What we will do in the remaining chapters is to run non-stationarity (unit-root) and cointegration tests for selected OECD and Latin American countries using monthly data from January of 1957 to March of 1997 (depending on data availability) to touch bases with testing for mean reversion and calculate the half-lives for developed and developing countries over a long-time period. Once we do that, we can work on chapter four and try to incorporate some real factors into our analysis and test for mean reversion of long-run nominal exchange rates and relative prices during the floating period.
Chapter Two

Mean Reversion and Cointegration Between Nominal Exchange Rate and Relative Prices:
Testing PPP for Selected OECD Countries (1957-97)

II.1 – Introduction

The main task of chapter 2 is to examine if there is evidence of cointegration between nominal exchange rates and relative price levels for five OECD countries during the period of 1957 to 1997 and for the floating period. Based on some techniques of modern day time-series, we want to know whether the nominal exchange rate and relative prices mean reverts back to some constant level in the long-run or whether it contains a unit root. Therefore, we are testing for PPP.

One of the main underlying objectives of chapter 2 is to use some of the empirical lessons proposed by stages two and three tests of PPP in order to empirically test for mean reversion between nominal exchange rates and relative prices for developed countries in such a way that this chapter can be a benchmark for the remaining empirical chapters. Among these lessons from
stages two and three, chapter 2 will incorporate the use of longer span of data (40 years of monthly data), which mix fixed and flexible regimes and compared the results with the floating period, and calculate the speed of mean reversion of the nominal exchange rate for both periods. Other than this, we will use some of the techniques for cointegration, including the EG and the Johansen tests, where the former is less powerful to detect cointegration and less used in recent empirical studies testing for long-run PPP, while the latter is less restrictive and more powerful and therefore widely used by most empirical studies using cointegration techniques.

Another crucial goal of chapter 2 is to calculate the half-lives for 5 OECD countries so that we can compare them to the half-lives of 11 Latin American economies (chapter 3) within the same time period (1957-97) and see if we find evidence that in countries with a history of high inflation rate we should find faster mean reversion.

One of the key empirical results from stage three tests is that the assumption of a constant long-run real exchange rate (PPP) is not correct for modeling long-run exchange rates, especially for the floating period. The Johansen empirical results allow us to test whether or not the \( \beta \) coefficients are statistically different from \([1 \ -1 \ 1]\), i.e., if we can reject PPP as a long-run relationship for both periods, 1957-97 and the floating period.

The structure of the paper will be the following. Section II will introduce the main issues regarding the relevance of testing for stationarity of time-series
and the theoretical notion of cointegration. Section III will describe the tests to be performed and the reasons for implementing such tests. Section IV deals with the empirical findings for all five OECD countries for the 1957-97 and the post-73 periods. Section V has some concluding thoughts emphasizing the main empirical findings from chapter two.

II.2 - Relevance of Testing for Stationarity in Time-Series

Analysis

The literature on unit-roots and its relevance to macroeconomic time series goes back to the early 1980s with empirical works developed among others by Nelson and Plosser [1982]. Almost at the same time, the literature on stationarity of time-series and more specifically the field of macroeconomics, has seen the development of some tests for unit-roots like the one proposed by Dickey and Fuller [1979] [1981]. Since that the empirical tests of macroeconomics time-series have faced a revolution brought by the development of cointegration analysis, where one of the earlier cointegration test procedure was developed by Engle and Granger [1987].

In order to understand the issue of stationarity in time-series analysis we first need to introduce the concept of a stochastic process. A stochastic process \{X_t\} is a family of real valued random variables and it is said to be covariance stationary if the first two moments of the joint and conditional probability
distributions of the process does not change over time. Formally, it has to show the following properties: 

\[ E(X_t) = \text{constant} = \mu \]
\[ \text{Var}(X_t) = \text{constant} = \sigma^2 \]
\[ \text{Cov}(X_t, X_{t+j}) = \sigma_j \]

where \( \mu \) is the mean of the stochastic process, \( \sigma^2 \) is the variance of a stochastic process, and \( \sigma_j \) is the covariance between two of the variables \((X_t \text{ and } X_{t+j})\). \( t \) indicates time period, and \( j \) is the gap between different time periods.

The idea here is that the mean and the variance of the stochastic process are constant over time and the covariance between two periods depends only on the gap between the periods \( (j) \).

Non-stationarity of time series has always been regarded as a problem in econometric analysis since the statistical properties of regression analysis using non-stationarity time-series are dubious as it has been emphasized by Granger and Newbold [1974] regarding the problem of spurious regression.

Testing for the order of integration is important since before any sensible regression analysis can be performed it is crucial to identify the order of integration of each variable (time-series).

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1 Charemza and Deadman [1997] chapter 5, and Campbell and Perron [1991] provide a detailed discussion on the issue of stationarity of time series. The latter has interesting considerations regarding the relevance of correctly specifying deterministic components of time-series.
If one intends to test the hypothesis that a variable \( y_t \) is integrated of order one (I(1)) assuming that \( y_t \) is generated by a process like:

\[
y_t = y_{t-1} + \varepsilon_t
\]  

(1)

where \( \varepsilon_t \) is identically distributed stationary with zero mean.

In general one can test for \( k = 1 \) in the following autoregressive equation:

\[
y_t = \lambda y_{t-1} + \varepsilon_t
\]  

(2)

If in equation (2) \( \lambda = 1 \), then \( y_t \) is a random walk and this will generate a non-stationary \( y_t \). On the other hand, if \( |\lambda| < 1 \), we have a stationary process generating \( y_t \).

If one estimates equation (2) by OLS and use the conventional Student-t test to test the hypothesis that \( \lambda = 1 \), it is not the right test since the null hypothesis is that equation (2) is non-stationary. The outcome of such procedure of running an OLS estimation of a non-stationary series can result in problem of a spurious regression.

Dickey and Fuller [1979] has developed a simple way of testing for non-stationarity incorporating the arguments stated above, and this is the well known DF test. The null hypothesis of the DF test is that \( \lambda - 1 = 0 \) in equation
(2), i.e., the unit-root hypothesis. The DF test is based on the estimation of the following equation:

$$\Delta y_t = \delta y_{t-1} + \varepsilon_t$$  \hspace{1cm} (3)

Equation (3) can be rewritten as:

$$y_t = (1 + \delta) y_{t-1} + \varepsilon_t$$  \hspace{1cm} (3')

Equation (3') and (2) are the same once we consider $\lambda = (1 + \delta)$. If $\delta < 0$ in (3'), then $\lambda < 1$ in equation (2). The DF test is a test to see whether or not $\delta$ is negative in equation (3). The null hypothesis is that $\delta = 0$ (unit-root) and the alternative is that $\delta < 0$, which implies that $\lambda < 1$ and so $y_t$ is stationary (I(0)).

After the DF test, the literature on testing for stationarity of time-series has seen the predominance of tests like the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests.\(^2\)

The ADF test derives from the DF test by adding lagged first differences to take into account possible problems with serial correlation. The null

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\(^2\) For a good distinction between the ADF and the P-P tests see Corbae and Ouliaris (1988), pp.509.
hypothesis of the ADF test is that the series possesses a unit root, meaning that if one can reject the null it is an indication that the series are stationary.³

The ADF(s) with a constant and a time-trend can be written as:

\[
\Delta Y_t = \mu + \gamma t + \delta Y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \varepsilon_t
\]  

(4)

where \( p \) indicates the number of lags.

The ADF (0) corresponds to the DF test. The DF test has a substantial weakness because it does not take into account possible autocorrelation in the error process (\( \varepsilon_t \)). The ADF use lagged left hand-side variables as additional explanatory variables to approximate the autocorrelation. The idea is to increase the lags up to \( t + 1 \) (\( t = \) frequency of the data) to see if autocorrelation disappears.

The primary goal of including augmentation terms is to secure a white noise property of \( \varepsilon_t \). If we have too few augmentations, this affects the size of the test (the null can be rejected too often) but too many augmentations will result in diminishing power of the test (not rejecting the null often enough).

³ The empirical non-stationarity tests for the time-series used in all three empirical chapters of the dissertation rely on reporting the ADF test since it is the most used one in the literature in testing for long-run exchange rates, even though new tests have been lately developed using the null hypothesis of stationarity instead of a unit-root. See Choi [2000] for panel unit root tests under the null of stationarity (G-test).
In order to test the null hypothesis, it is necessary to know the distribution of the statistic used for the test and the associated critical region for evaluation. If the variable \( Y \) is \( I(1) \), the t-ratio does not have a limiting normal distribution.\(^4\)

Once we have described the ADF test, we can briefly introduce one other test, the Phillips-Perron (PP) non-stationarity test, which is a test of the hypothesis \( p = 1 \) in the following equation:

\[
\Delta S_t = \mu + \beta t + \rho S_{t-1} + \varepsilon_t
\]  

(5)

The difference here is that the P-P test does not include any lagged difference term as in the case of the ADF test. Instead, the equation is estimated by OLS (with or without constant and time trend) and then the t-statistics of the \( \rho \) coefficient is corrected for serial correlation. The null is the same as in the ADF test, i.e., a unit root.

The idea proposed by Phillips [1987] and Phillips and Perron [1988] is to add to the original unit root test statistic a correction factor that eliminates the dependency of the asymptotic distribution on the serial correlation of \( Z_t \) (noise function or stochastic component).\(^5\)

In terms of the power of non-stationarity tests we can say that for unit-root hypothesis tests versus the alternative of stationarity the power of the test

\(^4\) Tables with critical values can be found in MacKinnon [1991], Charemza and Deadman [1997] appendix, among others.
depends more on the span of data rather than on the number of observations, where for a given span of data, additional observations using data with a higher frequency (monthly data has higher frequency than quarterly or annually data) will only provide a marginal increase of power.

Once we have presented the two most important non-stationarity tests we can now briefly introduce the idea of cointegration since this is a key issue for our dissertation in terms of trying to find mean reversion between the nominal exchange rate and relative prices. The idea is that although deviations from PPP can occur in the short-run, if PPP holds in the long-run we should find that such deviations are not permanent and that nominal exchange rate and relative prices mean revert to some long-run equilibrium level.

A nonstationary time series \( (X_t) \) is said to be integrated of order \( d \) if it becomes stationary after having been differentiated \( d \) times and it is usually denoted by \( I(d) \). If we have two series, \( X_t \) and \( Y_t \), they will be cointegrated of order \( (d,b) \) and represented by \( X_t, Y_t \sim CI(d,b) \) if: both series are integrated of order \( d \) there exists a linear combination like \( \alpha_1 X_t + \alpha_2 Y_t \) which is integrated of order \( d - b \). The cointegrated vector in this case will be \( [\alpha_1, \alpha_2] \). The most interesting case for us will be when the transformed series using the cointegrated vector becomes stationary \( (d = b) \).

---

11.3 - Tests to be Performed

The empirical tests implemented in chapter two have the main objective to provide empirical results so that we can address the issue of whether or not nominal exchange rates and relative prices mean revert back to a long-run anchor. Other than this, the empirical tests allow us to measure the speed of mean reversion (half-lives) and to test whether or not PPP (constant long-run real exchange rate) is the right framework for modeling long-run exchange rates in two different time periods (1957-97 and post-73) for five OECD countries.

The main purpose of this section is to describe each one of the tests that will be performed for all five OECD countries (Germany, United Kingdom, France, Canada and Japan) while section IV will address and compare the empirical results for the whole period (1957-97) and for the floating period.

11.3.1- Testing for Unit Roots: The ADF Test

This section will describe the ADF test for unit roots, which tests for the null of a unit-root against the alternative that the series are stationary.

Initially, we run the ADF on the real exchange rate, which is defined as the nominal exchange rate deflated by the ratio of domestic to foreign price levels:
\[ q = s + p^* - p \] (6)

where \( q \) is the natural log of the real exchange rate, \( s \) is the natural log of the nominal exchange rate (national currency units / US$), \( p \) is the natural log of domestic price level, and \( p^* \) is the natural log of US price index (CPI).  

The ADF test will be of the following form:

\[ \Delta q_t = \mu + \gamma t + \delta q_{t-1} + \sum_{i=1}^{p} \beta_i \Delta q_{t-i} + \varepsilon_t \] (7)

The normal procedure used by many empirical studies is to test for the first difference of a variable and if one can reject the null of unit roots, it is an indication that the series in first difference is \( I(0) \) and so the original series is \( I(1) \). This is important since it is first necessary to verify if we have nonstationarity and then if the series is \( I(1) \) or \( I(2) \). We run the ADF test for the first difference of the nominal exchange rate and relative prices to check for stationarity.

The ADF is the most used test for nonstationarity along the literature on long-run PPP, which was a key aspect in terms of reporting the ADF tests.

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6 For all five OECD countries we use the CPI index as proxy for domestic and foreign price (US CPI index)
11.3.2 - Cointegration Tests

The idea of cointegration among variables has become popular in macroeconomic analysis because it arises naturally from multivariate macroeconomic models with unit root driving processes. This section describes the Engel and Granger two-step procedure (residual based cointegration procedure) and the Johansen cointegration test for a system of equations.

11.3.2.1- Engel and Granger Two Step Procedure (EG)

A key concept in the analysis of a set of non-stationary variables is that of cointegration, where even though each series may have a unit root, there may exist various linear combinations of the variables, which are stationary. This concept does not require that each of the individual series to be integrated of order one.

The Engel and Granger two-step procedure is part of what was described in the review of the literature in chapter 1 as one of the tests used by stage three tests for PPP. The EG 2-step test for cointegration is among those that do not try to estimate the number of cointegrating vectors, but rather it is designed to distinguish a system without cointegration from a system with at least one cointegrating relationship. The EG test is called a residual-based test for cointegration.
The idea of the EG-2step procedure is to first run a regression in the following way when testing for PPP:

\[ s = \alpha + \beta_1 p + \beta_2 p^* + \varepsilon_t \]  \hspace{1cm} (8)

where \( s \) is the nominal exchange rate, \( p \) and \( p^* \) are domestic and foreign prices (all variables are in log).

The next step is to save the residuals of the regression (\( \varepsilon \)) and run the ADF test for the residuals without the time trend (with or without the intercept) and see if they are stationary or not. If one finds evidence that the residuals are stationary by rejecting the null, it is an indication of cointegration.

\[ \hat{\Delta \varepsilon}_t = \alpha + \gamma \varepsilon_{t-1} + \phi(L) \hat{\Delta \varepsilon}_{t-1} + \mu_t \]  \hspace{1cm} (9)

where (\(^\wedge\)) indicates estimated residuals from equation (5).

The idea of the E-G procedure is that even though each series may have a unit root, there may exist various linear combinations of the variables which are stationary, and in this case we need to test for that since finding stationarity will be an indication that the variables are cointegrated. Testing for
stationarity of the estimated residuals is the way to capture possible cointegration among variables.

The next step is to describe the Johansen test for cointegration, which is the most used cointegration test in the PPP literature.

### 11.3.2.2 - The Johansen Cointegration Test

The Johansen cointegration test is considered less restrictive and so more powerful than the EG 2-step procedure and it is the most used cointegration test among empirical studies using stage three tests for PPP. Other than this, the Johansen cointegration test is less restrictive and more powerful than the EG residual cointegration test, so we can rely more on the former than on the later to address the issue of cointegration between the nominal exchange rate and relative prices. The Johansen also allow us to test the restriction on the \( \beta \) vectors and check whether or not the estimated vectors are significantly different from \([1 -1 1]\), i.e., to test if the long-run real exchange rate is constant or not.

The Johansen cointegration test is called a test for cointegrating rank since it allows for estimation of the number of cointegrating vectors in a system of equations. The procedure allows one to specify as the null hypothesis an arbitrary number of cointegrating vectors given that this number is less than the
number of cointegrating vector allowed under the alternative hypothesis.\textsuperscript{7} The Johansen procedure does not impose any prior assumption that some or all the variables are I(1).

The intuition of the Johansen procedure is to apply maximum likelihood estimation to an autoregressive model assuming that the errors are Gaussian. The estimated model is given by:

\[ \Delta y_t = \mu + \Pi Y_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta y_{t-i} + \varepsilon_t \]  

(10)

where \( \varepsilon_t \) is normally distributed with zero mean and constant variance, i.e., \( N(0, \Sigma) \).

The Johansen procedure estimates the rank of the matrix \( \Pi \). The rank of \( \Pi \) is equal to \( r \), which indicates the number of cointegrating relationships among any system of equations.

The Johansen procedure provides the likelihood ratio test based on the following hypothesis testing:

- \( H_0: r \) cointegrating vectors
- \( H_a: n \) cointegrating vectors

It also provides what is called the maximum eigenvalue statistics, which tests the following hypothesis:

\textsuperscript{7} We have three series (s, p and p*), so we can test the null of one cointegrating vector against the alternative of two vectors, or we can test the null of two against three vectors. Since PPP assumes only one (1) cointegrated vector, the first case is the more interesting in our case.
Ho: $r$ cointegrating vectors

Ha: $r + 1$ cointegrating vectors

The Johansen procedure has to be implemented with some caution regarding how to handle deterministic trends because the critical values of the test will be affected by the trend characteristics of the data. The Johansen cointegration test allows testing for the following cases in terms of the choice of intercepts and / or deterministic trends:

I) No intercept or trend

II) Restricted intercept and no trend

III) Unrestricted intercept and no trend

IV) Unrestricted intercept and restricted trend

V) Unrestricted intercept and unrestricted trend

The next step, which is also related to the issue of cointegration, is to describe the two error-correction models (ECM) used in this paper in order to provide an estimation of coefficients to be used in the calculation of the half-lives of the exchange rate for all five OECD countries.

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For a description of the four cases and the implication of each one, see Pesaran and Smith [1999]. Pesaran and Smith [1999] argues that cases II and IV are likely to be particularly relevant in practice when compared to cases III and IV.
11.3.3 - Error Correction Models

The error correction model and its parameters will give us an idea of how the nominal exchange rate and relative prices adjust over time in order to reestablish the equilibrium PPP level of the exchange rate, if that is the case. If the parameters are significant it is an indirect test of cointegration among the variables.

This step is important in order to understand how the nominal exchange rate \( s_t \) and domestic price \( p_t \) can deviate from the real exchange rate \( q_t \). The first ECM model is given by the following equations:

\[
\Delta s_t = \beta_0 + \beta_1(L)\Delta s_{t-1} + \beta_2(L)\Delta p_{t-1} + \beta_3(L)\Delta p^*_{t-1} + \beta_4 q_{t-1} \tag{11}
\]

where \( \beta_i(L) \) and \( \varphi_i(L) \) are lag polynomials. We will be use a lag of one (1) for each of our estimated coefficients but the ECM model can be specified to include lags up to \( t+1 \) (\( t = \) frequency of the data). We have used one and two lags originally but since the coefficients estimated did not show significant change, we have decided to report only the results from the one lag specification.

The coefficient \( \beta_4 \) is the one for the error correction terms and once we estimate it we can check if it is statistically significant or not (by looking at the \( t-\)
values). If $\beta_4$ is positive (negative) meaning that if the real exchange rate $(q_t)$ is above its equilibrium level the exchange rate (equation 8) will increase (decrease).

We have also tested another ECM model based only on the equation for the nominal exchange rate $(s)$ using one of the EC models specified in the review of long-run PPP according to Froot and Rogoff (1995), which is the following:

$$\Delta s_t = \alpha + \beta \left[ \Delta(p - p^*)_t \right] + \delta (s - p + p^*)_{t-1} \quad (12)$$

The idea here is to use the estimated coefficient on the real exchange rate ($\delta$) in order to estimate the half-lives of the nominal exchange rate for all five OECD countries.

### 11.3.4 - Granger Causality Test

The idea behind the Granger causality test (GC) is to examine the question of whether $X$ causes $Y$ in terms of analyzing how much of the current $Y$ can be explained by the past values of $Y$ and then to see whether adding lagged values of $X$ can improve the explanation. If the coefficients on the lagged $X$'s are statistically significant, then we can say that $Y$ is Granger-caused by $X$.

---

9 The first ECM specification was based on Phylaktis and Kassimatis [1994].
It is important to mention that in many time series we can find evidence of two-way causation, where Y Granger causes X and X Granger causes Y.

The tests are whether the coefficients of the lagged X’s are all zero. Therefore the null hypothesis is the X does not Granger-cause Y. Rejecting the null is evidence that X has an important role in explaining the behavior of Y, and vice versa if we are testing Y does not Granger cause X. The test will provide us with an F-statistic and the correspondent probability so we can make inference about whether X does not Granger cause Y and if Y does not Granger cause X.10

The standard GC test examines the null hypothesis that $X_t$ does not Granger cause $Y_t$, which is rejected if the coefficients ($\beta$) are jointly significant in the following equation:

$$
(1 - L)y_t = \alpha_0 + \sum_{i=1}^{M} \alpha_i (1 - L)y_{t-m} + \sum_{j=1}^{N} \beta_j (1 - L)x_{t-n}
$$

We can now move to the next section, which will focuses in the interpretation of the empirical results of the non-stationarity and cointegration tests for all five OECD countries.

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10 In chapter 2 we have performed the Granger causality test using the first difference for the nominal exchange rate ($\Delta S$) and the first difference for domestic minus foreign price ($\Delta P - P^*$) as our X and Y in the above equation, and vice-versa. See table II. 9 for the results.
II.4 - Interpreting the Results

This section will summarize the main results from the tests performed for all five OECD countries, including the unit root tests, the cointegration tests (EG and Johansen) and the GC test. Section IV is divided in two sub-sections, where the first one has the results for the entire period (1957-97) of our sample, while the second one reports the empirical findings from the floating period. Before we move to the empirical results, let's briefly comment on some issues behind movements in the nominal and real exchange rates for OECD countries over the period of 1957 to 1997.1

Figures 1 and 2 can describe what happens to the nominal and real exchange rates (in log) in Canada during the period of 1957 to 1997, where the 1970s has seen most of the time an increase in the nominal exchange rate while the opposite happens to the real exchange rate. Since mid 80s the trend has been the same (downward) for both nominal and real exchange rates. Figures 3 and 4 have shown that for Canada the real and the nominal exchange rates have follow almost the same path during the past 4 decades, where since late 70s the trend has been characterized by an increase in both, with the exception of the second half of the 80s. Figures 5 and 6 for the nominal and real exchange rates for France have similar paths throughout the last 4 decades

1 The Appendix to chapter 2 contains not only the tables with the empirical results but also the figures for the natural log of the nominal and real exchange rates for each of the five OECD countries. The idea was to illustrate movements in real and nominal exchange rates over the period of 1957-97 so that the reader can have a better idea of how these two variables behave over time.
with a period of increase in nominal and real exchange rates in the first half of the 80s, followed by a trend of declining nominal and real exchange rates. Figures 7 and 8 have shown a declining trend in both the nominal and real exchange rates for Germany since early 70s, with the exception of the first years of the 80s. Finally, figures 9 and 10 show that the real exchange rate does not move as much as the nominal exchange rate and the trend during the past three decades has been of a decline in both the nominal and the real exchange rates.

At the end, we can say that the real exchange rates for all five countries have experienced a higher variability during the floating period when compared to the fixed period.


This section will present the empirical findings for the period of 1957 to 1997 for the selected OECD countries.

II.4.1.1- Stationarity Test: the Augmented Dickey-Fuller (ADF)

Table II. 1 results concerns the ADF test on the real exchange rate (in log terms) for all five OECD countries.\(^{12}\) The main interpretation is that only for

\(^{12}\) All the tests were run using monthly data from the IFS database for nominal exchange rate (end of the period), domestic price index (CPI) and foreign price index (the US CPI index).
France at the 10% significance level (without time trend) and United Kingdom and Japan at the 5% significance level (with time trend) we have found a t-ADF where we can reject the unit root hypothesis. Somehow this was expected given the low power problem of the unit root tests like the ADF, given the fact that we are working with 40 years (not too long). 13

Tables 2 and 3 are especially important in terms of checking if the the first difference of the nominal exchange rate and the prices (both in natural log) are I(0), i.e., stationary. In the case of the nominal exchange rate (table II. 2) we were able to reject the null hypothesis (nonstationarity) for all countries using first differences and applying the ADF test, this indicates that the original series are I(1). Table II. 3 indicates that we can reject the null when testing for stationarity on the first difference of prices for France, UK, Germany and Japan (without the time trend), where for Germany and Japan we could also reject the null with the time trend. We were not able to reject the null of unit roots for Canada and US including or not the time trend, which is an indication that for both countries, prices are of a higher order of integration (I(2)).

We did not report the ADF test for the original series (in levels of nominal exchange rate and relative prices) since for all countries we fail to reject the null of unit roots and the next step was to certify that the series were I(1), which we did by checking that the series in first difference are stationary I(0).

13 See Froot and Rogoff [1995] for further details on the low power of the unit-root tests.
11.4.1.2 - Results from the E-G Two-Step Procedure

Results from table II. 4 shows the OLS estimation of the nominal exchange rate regressed against the domestic and the foreign price levels. The first step was to run the OLS in order to get the estimated residuals and then run the ADF (without the time trend but with and without the intercept) on the estimated residuals (table II. 5). We still have to make some considerations about the OLS regression. In all cases we got very high R-squared (around 0.95) but at the same time the Durbin-Watson (DW) was very low for all countries, which is an indication of a spurious regression according to Granger and Newbold [1974].

The rule of thumb suggested by Granger and Newbold [1974] to detect spurious regression is that if the R-squared is higher than the DW statistic, it is an indication of existence of a spurious regression. This was the case when we run the OLS regression for all five countries in our sample.

The results from table II. 5 refers to the Engle-Granger second step procedure (residual test of cointegration) and it suggest that only for the case of Japan (without the intercept) at the 10% level of significance we were able to reject the null using the ADF test. This result is a primary indication that we cannot find evidence of cointegration between nominal exchange rates and relative prices for the OECD countries during the period of 1957 to 1997.
The Engle and Granger has not been frequently used in recent empirical tests for cointegration but we report its empirical findings since it is one of the tests suggested by stage-three tests and we want to compare our results with the ones from the literature. We have very poor results in terms of finding cointegration through testing the stationarity of the residuals for the period of 1957 to 1997. This can be due to the fact that we were mixing flexible and fixed exchange rate regimes and due to the low power of the EG cointegration test.

II.4.1.3 - The Half-Life and the Granger Causality Test

This section will discuss the results from the two error correction models to calculate the half-lives for all five OECD countries and it will interpret the Granger causality test in order to understand the causation between changes in the exchange rate and the changes in relative price difference (P-P*).

II.4.1.3.1- ECM Models (1st and 2nd)

The estimated coefficients reported in table II. 6 show us that the β4 coefficients are significant for France at 10% and United Kingdom at 5%, while for the remaining countries (Canada, Japan and Germany) they are not. This suggests an important role of the real exchange rate in the previous period in terms of affecting the way that nominal exchange rate will adjust in the actual
period for France and UK. In terms of the signs of the coefficients, they all have the expected signs (negative) according to the theory, except for the case of Japan. The theory suggests that if the real exchange rate in the previous period is above (below) its equilibrium level, then in order to move back to the equilibrium level, the nominal exchange rate will have to adjust in the actual period in such a way that it will decrease (increase).

The results from the estimation of the second error correction model (ECM) are reported in Table II. 7. The estimated coefficients for $\delta$ are statistically significant only for France and UK at 10%, and the sign is negative for all countries except Japan. The interpretation here is that the real exchange rate in the previous period will play an important role in terms of how the nominal exchange rate ($\mathbf{s}$) will adjust in the actual period from its previous period. The estimation of the above ECM model allows for the to calculate the half-lives for each one of the five OECD countries.

The estimation of the half lives reported in table II. 8 using the estimated coefficients of $\beta_4$ (table II. 6) and $\delta$ (table II. 7) show similar results to the ones calculated from the ECM models in the literature for the cases where the estimated coefficient is significant, i.e. France (3.275 and 3.516 years) and UK (2.760 and 3.620 years). We cannot say the same for the cases of Japan (around 119 years in both cases), Canada (10.103 and 9.832 years) and Germany (6.131 and 9.628 years), but all of them have problems in terms of insignificant coefficients estimated in both ECM models (tables II.6 and II.7).
After all, table II. 8 shows some interesting results in terms of supporting the findings of longer half-lives of the exchange rate for developed countries. The half-lives using the first ECM model is around 5.5 years excluding Japan and 3 years when considering only countries with significant coefficients. The average of the above two results is around 4.5 years which would be consistent with the findings from the empirical literature.

The half-lives using the second ECM model is around 6 years excluding Japan and around 3.5 years when using only countries with significant coefficients, while the average of both calculation is around 5 years.\(^{14}\)

These results are not too far away from what the empirical literature on PPP has suggested. The half-lives for OECD countries are longer when compared to the half-life calculated for developing countries in chapter three of the dissertation (around 2.5 years).\(^{15}\) This result supports the argument that we should expect faster mean reversion in countries with a history of high inflation such as in Latin America given the predominance of monetary shocks in this kind of environment.

### II.4.1.3.2 - Granger Causality Results

Table II. 9 contains the results of the Granger causality test for both variables in first difference, the exchange rate (S) and the difference in domestic

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\(^{14}\) Japan was an outlier among all the other countries used in our research for chapter 2.
and foreign price levels \((P-P^*)\), all in natural log. The idea here is to test for each of the five countries if nominal exchange rate movements Granger cause movements in the inflation differential or the other way round, or both.\(^{16}\)

The results suggest that we do not have a two-way causation except for the case of France where movements the exchange rate \((\Delta S)\) Granger causes movements in relative price difference \((\Delta(P-P^*))\). In other words, we can only reject the null of no Granger causality for the case of France and only for the case where movements in the nominal exchange rate affects movements in relative price difference but not the other way round.

In general, we can say that the empirical findings points out that movements in the nominal exchange rate will not play a role in terms of affecting the behavior of relative price differential, and vice-versa which is significantly different from the results obtained in chapter three for developing countries.

The relevance of running the Granger causality test for the first differences in exchange rate and price differential can be justified based on the fact that in many countries policy markers and monetary authorities can manage exchange rates according to their economic goals, including here inflation targets. This seems to be more likely to happen in developing countries with a history of high inflation and more intervention of monetary authorities in

\(^{15}\) See the calculation of the half-lives for Latin American economies in chapter 3.

\(^{16}\) Remember that the null is that \(\Delta S\) does not Granger cause \(\Delta(P-P^*)\) and that \(\Delta(P-P^*)\) does not Granger cause \(\Delta S\).
managing the exchange rate since most of them have fixed exchange rates during the period of 1957 to 1997, which was not the case for OECD countries since 1973.

II.4.1.4 - The Johansen Cointegration Test: Empirical Findings

Before we run the Johansen test for cointegration it is necessary to choose the order of the system (number of lags) and to include or not an intercept and / or a time trend. The right choice for the number of lags and the nature of the deterministic variables will help in terms of avoiding loss of power and size distortions. These steps are also important considering the fact that the number of cointegrating vectors is sensitive to the choice of number of lags and deterministic components.17

Doornik, Hendry and Nielsen [1998] emphasizes that it is better to include a constant and a trend in the analysis because omitting such deterministic variables generates mi-specification bias, but including them will help in terms of increasing the power and the size of the tests. The authors also show that allowing for an unrestricted trend is correct although it can result in substantial size distortion when the data generating process suggests the existence of a restricted trend, while Pesaran and Smith [1998] find that the

17 See Doornik, Hendry and Nielsen [1998] and Pesaran and Smith [1998] for the discussion regarding the properties of the statistical model, Gaussian errors, the choice of order and deterministic components. See also Goldberg [2000] pp.15-17.
model with a restricted trend is preferable when one or more variables of the model are trended, which was not the case in our model with nominal exchange rate and relative prices. Therefore, we have run the Johansen test for two cases: unrestricted intercept and unrestricted trend; and unrestricted intercept and no trend.

First, we have run the Johansen test for cointegration for all five countries using lags from one to thirteen, including a constant but with the option of including or not the trend. We use the log-likelihood function reported by the Johansen test from each lag and for each country, and then calculate the Schwarz Bayesian Criterion (SBC). Whichever lag (order) maximizes the SBC for each country, that was considered the order of our VAR. \(^{18}\)

Table II. 10 below shows that the order of the VAR is five for Canada (including a trend) where for all the remaining cases the order is thirteen, with no trend. It seems that for all countries except Canada, the more lags we included the higher will be the likelihood function and so we will get a higher SBC, meaning that each additional lag is significant. \(^{19}\)

Table II. 11 contains the diagnostic test for all five OECD countries considering the selected order from table II. 10, for all variables of our model (nominal exchange rate, domestic and foreign prices). The diagnostic test

\(^{18}\) SBC = MLL - (0.5 ln T)K , where MLL is the maximized log-likelihood function , T is the sample size and K is the number of parameters estimated. It should me mentioned that K varies for different rank and including or not the time trend.

\(^{19}\) We have tested up to thirteen lags, which is n + 1, where n is the frequency of the data (12 months).
includes testing for serial correlation (a), normality (b), ARCH test (c) and heteroscedasticity (d). The properties of a well-behaved statistical model should be congruent with Gaussian errors, meaning that the test for each variable would not be able to reject the null for each of the four diagnostic tests.\(^{20}\)

The results from table II. 11 show that for the full-sample statistical model did not deliver a congruent model. Normality is rejected for all OECD countries and for each individual variable. The LM test for autocorrelated residuals (Ho = no autocorrelation) indicates that residual autocorrelation is not a problem for Japan and UK, where for France and Germany we have serial correlation only for foreign price, and for Canada serial correlation appears in both domestic and foreign prices. The LM test for autocorrelated square residuals (ARCH test) reveals that we can reject the null for all countries and variables except for nominal exchange rate (Canada and France) and domestic price (Germany and UK). The results from the heteroscedasticity test have shown that we can reject the null (homoscedasticity) for the case of the exchange rate (Germany and Japan), domestic price (France and Japan) and foreign price (Germany).

After all, we can say that the results from the diagnostic test reported on table II. 11 does not support a well-behaved statistical model congruent with Gaussian errors, which imposes some limitations to the interpretation of the results on testing for cointegrating relationships (Johansen test) reported in tables II.12 and II.13.

\(^{20}\) All the diagnostic tests as well as the Johansen cointegration test were implemented using PC Give 9.0.
A possible explanation for not having a congruent model seems to be related to the presence of structural changes over the period of 1957 to 1997, which is a quite reasonable assumption given the long-run time period and distinct changes in the economy that took place during this time period. ²¹

The Johansen trace and max eigenvalue test statistics for the rank of the \( \Pi \) matrix are reported in tables II.12 and II.13, where the former reports the unadjusted Johansen test statistics while the later reports on these statistics after being adjusted for degrees of freedom by multiplying the test statistics by \( (T - nm)/T \), where \( T \) is the sample size, \( n \) is the number of endogenous variables and \( m \) is the order of the system. ²²

Table II. 12 with the Johansen cointegration test without adjusting for the degrees of freedom, shows that based on the max eigenvalue test there is no cointegrating vector for Canada, France and Germany, and there is one cointegrating vector for Japan and UK at the 10\% level of significance. Using the trace test we find that there is no cointegrating relationship for Canada and Germany, and there is one cointegrating vector for France (at 10\%) and UK (at 5\%), while for Japan we find three cointegrating vectors. ²³

Table II. 13 has shown similar results, where both the max and the trace eigenvalue tests reveal that there is no cointegrating vectors for Canada,

²¹ Testing for structural breaks is part of our future research project.

²² We have decided to report both results but due to our relatively large sample size, we do not have significant bias due to small sample.
France and Germany, while Japan has one (two) cointegrating vectors based on the max (trace) tests, and UK has one cointegrating vector regardless of using the max eigenvalue or the trace test.

Summarizing the results from the Johansen cointegration test adjusted for the degrees of freedom for five OECD for the period of 1957 to 1997 using monthly data for nominal exchange rate and relative prices, we can say that we were not able to find cointegration for Canada, France and Germany, while we find at least one cointegrating vector for Japan and UK.

In table II. 14 we have imposed a rank equals to one for all five countries and test the restriction that the β coefficients are equal to $[1\ -1\ 1]$ for $s$, $p$ and $p^*$ respectively. The results from the Johansen test (table II. 13) have indicated that Canada, France and Germany have no cointegrating vector, while Japan has one (two) according to the max (trace) test statistic, while UK has one cointegrating vector. Since the Johansen might not be able to capture the underlying cointegrating vectors due to lack of power, we have decided to test the restriction for all five countries regardless of whether we have found cointegrating vectors.

The test of the restriction has the null hypothesis that the cointegrating vector is not statistically significant different from what is predicted by PPP ($[1\ -1\ 1]$ for $s$, $p$ and $p^*$) and the results from table II. 14 indicate that we cannot reject the null for all countries where for France and Canada we were able to reject

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23 Pesaran and Smith [1998] argues that max eigenvalue test tend to identify fewer cointegrating vectors when compared to the trace test. See also Goldberg [2000], pp. 18.
only at the 5% level and Germany, Japan and UK at the 1% level. These results are an indication that the coefficients are not close to one and so that there is no evidence of a long-run constant real exchange rate for the five OECD countries using monthly data for nominal exchange rate and relative prices from 1957 to 1997.

II.4.2 – Empirical Findings: The Floating Period (Post-73)

This section of chapter 2 will report the empirical findings for the floating period concentrating in the results that are key for us to compared with the entire period (1957-97) and to the results suggested by the literature. Based on this and the empirical suggestions from stage three, we have decided to check for stationarity of the residuals (EG) and the Johansen cointegration test, to calculate the half-lives using two EC model specification, and to test the restriction that the \( \beta \) coefficients are not statistically different from \([1 -1 1]\), for all five OECD countries.

The EG 2-step results reported in table II. 15 indicate that we cannot find stationarity for the residuals for all five countries during the floating period using a model with nominal exchange rate and relative prices while for the entire period we were able to find only for Japan.

Table II. 16 has the results for the first EC model for the floating period and the coefficient is significant for the cases of France, UK and Germany, but
not significant for Japan and Canada. Table II. 17 provides the results for the second EC model for the floating period where the coefficient is not significant for all five OECD countries.

The calculation of the half-lives using the two EC models for the floating period is reported in table II. 18 where for the first EC model the average half-life is around 3.5 years (all countries) and 2.5 years (countries with significant coefficients), while the average between the two previous results is around 3 years. The average half-life using the estimated coefficients from the second EC model suggests a half-life around 4.5 years even though none of the coefficients used for the calculation of the half-lives were significant.

In general, we can say that the half-lives for the entire period were around 4.5 ad 5.5 years and for the floating period they are somewhat around 3 and 4.5 years. Therefore it seems that when we are restricted to the floating period the half-lives of the nominal exchange rates for OECD countries are lower (faster mean reversion).

The diagnostic test for the three variables of our system (nominal exchange rates, domestic and foreign prices) are reported in table II. 19 for the floating period and the message is that the model is not congruent especially when we tested for normality where we were not able to find normality for all countries and all three variables. But the rejection of normality was also found when testing for the entire period (table II. 11). Another empirical finding is that particular to the floating period is that we have problems with heteroskedasticity.
for all countries when testing the foreign price variable (US price), which was not an issue for the entire period of 1957 to 1997.

Tables II. 20 and II. 21 have the results for the Johansen cointegration test for the unadjusted and adjusted trace and max eigenvalue statistics cases respectively, for the floating period. The results from the case adjusted to the degrees of freedom (table II. 21) suggests that we could not find evidence of cointegration between nominal exchange rates and relative prices for Canada, we found evidence of one cointegrating vector for France and Germany, while Japan and UK seems to have three cointegrating vectors, which does not make sense in a three variable system. Comparing these findings with the entire period where Canada, France and Germany have no cointegrating vector, Japan has two and UK has one, the results seems to be more supportive of cointegration at least for France and Germany when we are in the floating period, but the findings for Japan and UK seems to make more sense for the entire period studied.

Finally, table II. 22 provides the results for testing the restriction that the $\beta$ coefficients are not statistically different from $[1 -1 1]$ for the floating period where we have allowed for a rank equals to one for Canada, France and Germany based on the findings from table II. 21, and rank equals to two for UK and Japan since it did not make sense to allow for a rank of three. The results for all five countries and all ranks are that we can reject the null indicating that the coefficients are statistically different from the restriction, ie., $[1 -1 1]$ for the
floating period. Comparing these results with those derived from table II. 14 they are not different in terms of rejecting the null for both periods.

II.5 - Concluding Thoughts

Section five of chapter 2 has the objective of summarizing the main empirical findings from chapter 2 for the 1957-97 and the floating period regarding the issue of mean reversion between nominal exchange rates and relative prices, and relate them to the key empirical results from the literature on testing for PPP discussed in chapter one.

The empirical results from the residual based cointegration test (EG 2-step) indicate that we cannot find stationarity for the residuals for all five countries during the floating period using a model with nominal exchange rate and relative prices while for the entire period (1957-97) we were able to find stationarity on the residuals only for Japan.

Regarding the speed of mean reversion, we can say that the half-lives for the entire period (1957-97) are around 4.5 ad 5.5 years and for the floating period they are around 3 and 4.5 years. Therefore, it seems that when we are restricted to the floating period the half-lives of the nominal exchange rates for OECD countries are lower (faster mean reversion).

The results from the Johansen cointegration test for the floating period and adjusted to the degrees of freedom suggests that we could not find
evidence of cointegration between nominal exchange rates and relative prices for Canada, we found evidence of one cointegrating vector for France and Germany, while Japan and UK seems to have three cointegrating vectors, which does not make sense in a three variable system. Comparing these findings with the entire period where Canada, France and Germany have no cointegrating vector, Japan has two and UK has one, the results seems to be more supportive of cointegration at least for France and Germany when we are in the floating period, but the findings for Japan and UK seems to make more sense for the entire period studied. After all, the floating period seems to provide more evidence of cointegration between nominal exchange rate and relative prices which does not match the empirical findings from stages 2 and 3 where the evidence towards mean reversion seems to be more supportive for longer time-series and when there is some fixed period included in the database.

Finally, the results for testing the restriction that the β coefficients are not statistically different from [1 -1 1] for the floating period where we have allowed for a rank equals to one for Canada, France and Germany and equals to two for UK are that for all five countries and all ranks we can reject the null for the floating period. This is an indication that the coefficients are statistically different from the restriction, ie., [1 -1 1]. Comparing these results with those derived for the whole period (1957-97) they are not different in terms of rejecting the null since that was true for both periods, but the difference seems to be that the
coefficients are less far away from the imposed restriction for the entire period (1957-97), especially for France and Canada.

The main conclusion from all the empirical findings provided in chapter 2 is that there is some evidence supporting mean reversion between nominal exchange rates and relative prices, regardless of the time period considered (floating or 1957-97). One of the reasons for that might be because of structural breaks that were not taken into account in chapter two, especially for the longer period (1957-97) when it is clear that all the countries have experienced structural changes. The empirical findings from chapter two does not provide support for the assumption of a constant long-run real exchange rate and so we have poor results supporting PPP for OECD countries during the 1957-97 and the floating periods. It is still necessary to relax the constant long-run real exchange rate assumption and include some real factors (either from the demand or from the supply side) into our model in order to see if we can find evidence of mean reversion between nominal exchange rates and relative prices for the floating period, which is a task to be fulfilled in chapter four.
Chapter Three

Mean Reversion and Cointegration Between Nominal Exchange Rate and Relative Prices: Testing PPP for Latin American Countries (1957-97)

III.1 - Introduction

The main goal of this chapter is to examine the question of whether or not we can find evidence of mean reversion between nominal exchange rates and relative prices for Latin American countries using monthly data from January of 1957 to March of 1997.

One of the crucial contributions of chapter 3 is to calculate the half-lives for a broader number of countries in Latin America using a longer span of data (1957-97), since previous studies for developing countries have usually been restricted to annual data starting in the early 1970s up to the end of the 1980s. Other than this, a key motivation for calculating the half-lives in chapter three is to compare them to the half-lives calculated in chapter 2 (OECD countries). The theory suggests that we should find faster mean
reversion (short half-lives) for countries with a history of high inflation as in Latin America during the most part of the last four decades.

Another crucial theoretical question that is empirically tested in chapter three is whether or not there is less price stickiness in countries with a history of high inflation when compared to developed countries with a different inflationary historical path. The Johansen cointegration test is used to answer this question.

After all, chapter three is a benchmark for testing PPP in developing countries and it allows for checking to what extent the empirical findings from stages two and three can be validated or not using a sample of eleven Latin American countries for almost 40 years of data on nominal exchange rates and relative prices.

The remainder of chapter 3 is structured as follows. Section II discusses some issues regarding mean reversion and price stickiness in Latin America. Section III briefly describes the stationarity and cointegration tests to be performed for all eleven Latin American countries. Section IV deals with the empirical findings for Latin America. Section V contains some concluding remarks.
III.2 – Mean Reversion and Price Stickiness in Latin America

The first argument we want to examine in this section of chapter 3 is why we should expect faster mean reversion of nominal exchange rates and relative prices in Latin America when compared to major developed countries? In order to understand this we have to keep in mind that historically, most Latin American countries have experienced high inflation rates and in such environments monetary shocks play a crucial role when compared to real shocks. This suggests that with monetary shocks, prices and nominal exchange rate will adjust quicker to correct misalignments in the nominal (or real) exchange rate relative to its long-run equilibrium level. In a situation like this we should expect a faster mean reversion for Latin America.

The idea here is that monetary shocks tend to be larger in Latin America when compared to OECD countries (chapter 2), and the opposite happens with real shocks. Monetary shocks are transitory and tend to die out faster then real shocks, which is an argument used to explain why one should expect faster mean reversion in Latin America. Real shocks seem to have some permanent component in affecting the dynamics of the economy and its main variables (including nominal exchange rates and relative prices), and they are less important in Latin America when compared to OECD countries.
The literature on testing for PPP has some interesting insights regarding the empirical findings for developing countries with high inflation history. Frenkel [1978] finds some support for PPP for hyperinflation data, which was not surprising given the predominance of monetary shocks in such circumstances. On the other hand, Frenkel [1981] and Krugman [1978] have rejected PPP for more stable monetary environments.

We want to empirically examine the question of whether or not we have less price stickiness in Latin America and provide some contribution to the literature since this is not an issue widely explored for developing countries.

One way to address this question is to run the Johansen test for Latin American and OECD countries and look at the $\alpha$ coefficients to see if they are greater for Latin America when compared to OECD countries. A simple representation of how to get the $\alpha$ coefficients for a one cointegrating vector in a system including nominal exchange rate and relative prices, would be:\(^1\)

\[
\Delta s = \alpha_{11} (\beta_{11}s + \beta_{21} p + \beta_{31} p^*) \\
\Delta p = \alpha_{21} (\beta_{12}s + \beta_{22} p + \beta_{32} p^*) \\
\Delta p^* = \alpha_{31} (\beta_{13}s + \beta_{23} p + \beta_{33} p^*)
\]

---

\(^1\) See Table III. 14 for the empirical results.
where $s$ is the nominal exchange rate, $p$ is the domestic price, $p^*$ is the foreign price, all variables in log.

The results from the Johansen test for the number of cointegrating vectors allow us to look at the $\alpha_{21}$ coefficient for Latin America and compare them to the same coefficients for the OECD countries obtained in chapter 2.

A second way to address the question regarding the existence of less price stickiness in Latin America will be to calculate and compare the half-lives for Latin America and for the selected OECD countries (chapters 2 and 3). A faster mean reversion for the nominal exchange rate in Latin American countries would be an indication that relative prices are less sticky since we know that movements in the exchange rate for these countries were historically restricted by the adoption of fixed regimes throughout the last decades.

### III.3 – Mean Reversion and Cointegration: Empirical Tests

Chapter 2 has already described in details the relevance of non-stationarity tests and cointegration. In this section of chapter three, will only mention which are the tests used in chapter 3, so that the reader can keep
track of the empirical tests that will be performed in the remaining sections of the chapter.

The non-stationarity test used is the Augmented Dickey-Fuller (ADF) test with the null hypothesis of a unit-root. The equation for the ADF test applied to the nominal exchange rate using a constant and a time trend is the following:

\[ \Delta s_t = \mu + \gamma t + \delta s_{t-1} + \sum_{i=1}^{n} \beta_i \Delta s_{t-i} + \varepsilon_t \]  \hspace{1cm} (4)

where \( s \) is the log of the nominal exchange rate, \( t \) is the time trend and \( n \) indicates the number of lags.

The cointegration tests include the Engle and Granger 2-step procedure (residual based test) and the Johansen test for the number of cointegrating vectors. The idea of the EG 2-step procedure is to run the following regressions in order to test for the stationarity of the estimated residuals:

\[ s = \alpha + \beta_1 p + \beta_2 p^* + \varepsilon_t \]  \hspace{1cm} (5)

\[ \Delta \varepsilon_t = \alpha + \gamma \varepsilon_{t-1} + \phi(L) \Delta \varepsilon_{t-1} + \mu_t \]  \hspace{1cm} (6)
The Johansen test for cointegration is based on the following system of equation:

$$\Delta y_t = \mu + \Pi Y_{t-1} + \sum_{j=1}^{k} \Gamma_j \Delta y_{t-j} + \varepsilon_t \quad (7)$$

where $\varepsilon_t$ is normally distributed with zero mean and constant variance, i.e., $N(0, \Sigma)$.

The Johansen procedure provides the likelihood ratio test based on the following hypothesis testing:

$H_0$: $r$ cointegrating vectors

$H_a$: $n$ cointegrating vectors

It also provides what is called the maximum eigenvalue statistics, which tests the following hypothesis:

$H_0$: $r$ cointegrating vectors

$H_a$: $r + 1$ cointegrating vectors

The error-correction models used to estimate the coefficients that are used to calculate the half-lives of the nominal exchange rate are the following:

$$\Delta s_t = \beta_0 + \beta_1(L)\Delta s_{t-1} + \beta_2(L)\Delta p_{t-1} + \beta_3(L)\Delta p^*_{t-1} + \beta_4 q_{t-1} \quad (8)$$

$$\Delta s_t = \alpha + \beta (\Delta(p - p^*)_t) + \delta (s - p + p^*)_t \quad (9)$$
where $q$ is the log of the real exchange rate.

Finally, the Granger causality test is implemented to address the issue of whether movements in the nominal exchange rates Granger causes movements in relative prices, or vice-versa. The standard GC test examines the null hypothesis that $X_t$ does not Granger cause $Y_t$, which is rejected if the coefficients ($\beta$) are jointly significant in the following equation:

$$M \quad N$$

$$(1 - L)y_t = \alpha_0 + \sum_{m=1}^{M} \alpha_i (1 - L) y_{t-m} + \sum_{n=1}^{N} \beta_j (1 - L) x_{t-n} \quad (10)$$

Once we have briefly presented the empirical tests used in chapter 3, we can move to the analyses of the empirical findings.

III.4 - Empirical Findings for Latin America (1957-97)

Section four summarizes the main results from the tests performed for all eleven countries, including the unit root tests, the cointegration tests and the GC test.\footnote{The appendix to chapter 3 contains not only the tables with the empirical results but also the charts for the natural log of the nominal and real exchange rates for each of the eleven Latin American countries. The idea was to illustrate movements in real and nominal exchange rates over the period of 1957-97 so that the reader can have a better idea of how these two variables behave over time.} The idea is to empirically check how different the results are for Latin American when compared to OECD countries for the period of 1957 to
1997 regarding cointegration and the speed of convergence between nominal exchange rates and relative prices.

Charts 1 to 22 describe movements in the nominal and real exchange rates (in natural log) for all eleven Latin American economies during the period of 1957 to 1997. The overall trend for the nominal exchange rate for all countries has been characterized by an increase in the nominal exchange rate, especially since early 80s. In the case of the real exchange rate there is no unique trend since over time the real exchange rate follows different paths of appreciation and depreciation. It seems that for countries within Latin America with a history of very high inflationary process (Brazil, Argentina, Bolivia and Mexico) the magnitude of such movements in the real exchange rates are even bigger than for the other countries. Last but not least, since mid 1960s we can say that Uruguay has shown a surprising stability in the real exchange rate, which is clearly an exception comparing to all other countries.

III.4.1- The ADF Empirical Results

Table III. 1 refers to the ADF test on the log of the real exchange rate for all eleven countries. The main interpretation is that only Mexico (at 1% for both cases with and without time trend) and Bolivia (only at 10% and for
the case without time trend) we have found a t-ADF where we can reject the unit root hypothesis.

Tables III. 2 and III.3 are specially important in terms of showing that the series of the first difference of the nominal exchange rate and the price levels (both in natural log) are $I(0)$, i.e., stationary. Since we were able to reject the null hypothesis (nonstationarity) for all countries using first differences for the nominal exchange rate, we can say that the original series for the nominal exchange rate in levels are non-stationary ($I(1)$).

The exceptions in terms of not finding stationarity in the first difference of the price variable using the ADF test were Brazil, Chile, Venezuela, Ecuador and the US, where for the first three countries the t-ADF were very close to be within the rejection range at 10% without the time trend. We were not able to reject the null using the ADF with time trend for the first difference in prices for the cases of Brazil, Chile, Mexico and US, where for Mexico the t-ADF was close to fall within the rejection range at the 10% level.

We did not report the ADF test for the original series (not in first difference) of nominal exchange rate and relative prices in levels since for all countries we fail to reject the null of unit roots and the next step was to check if the series were $I(1)$.

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3 All the test were run using monthly data from the IFS database for nominal exchange rate (end of the period) expressed as a ratio of units of domestic currency over the US dollar, domestic price index (CPI) and foreign price index (the US CPI index).
III.4.2- Results from the E-G Two-Step Procedure

Table III. 4 shows the OLS estimation of the nominal exchange rate regressed against the domestic and the foreign price levels. The first step was to run the OLS in order to get the estimated residuals and then run the ADF on the estimated residuals (Table III. 5). We still have to make some considerations about the OLS regression. In all cases we got very high R-squared (around 0.95) but at the same time the Durbin-Watson (DW) was very low for all countries, which is an indication of a spurious regression according to Granger and Newbold (1974).

The rule of thumb suggested by Granger and Newbold for detecting spurious regression is that if the R-squared is higher than the DW statistic, it is an indication of existence of a spurious regression. This was the case when we run the OLS regression for all eleven countries in our sample.

The results from Table III. 5 reports the Engle-Granger cointegration test based on the estimated residuals from Table III. 4 and we were able to reject the null for five out of eleven cases for the ADF test without the constant (Bolivia at 5%, Mexico, Paraguay, Peru and Venezuela at 10%) and just Bolivia at the 5% level when including the constant. These results provide some empirical support for cointegration between nominal exchange rates and relative prices through the evidence of stationarity in the residuals for Latin America when compared to the findings for OECD countries, both
for the period of 1957 to 1997 using monthly data. For OECD countries we could only find evidence of cointegration using the EG procedure for one (Japan) out of five countries.

The result from the EG 2-step procedure is only a preliminary one in terms of finding support for cointegration between nominal exchange rate and relative prices for Latin America since we still need to check the empirical results from the Johansen cointegration test, which is less restrictive and more powerful than the EG test.

III.4.3- Results from the ECM and Granger Causality

This section presents the results from the two error-correction models used to derive the coefficients used to calculate the half-lives for all eleven countries. It will also interpret the Granger causality test in order to understand the causation between changes in the nominal exchange rate and changes in relative price differential for each country vis-à-vis the US.

III.4.3.1- Speed of Mean Reversion: Calculating the Half-Lives for Latin America

The estimated coefficients reported in Table III. 6 show that for the case of $\beta_4$ they are all significant at both 5 and 10% level (for Brazil only at
10%) except for the cases of Argentina, Venezuela and Ecuador when the coefficients are not significant. This suggests an important role of the real exchange rate in the previous period in terms of affecting the way that nominal exchange rate will adjust in the actual period. In terms of the signs of the coefficients, they all have the expected signs (negative) according to the theory. The theory suggests that if the real exchange rate in the previous period is above (below) its equilibrium level, then in order to move towards equilibrium the nominal exchange rate will have to adjust in the actual period in such a way that it will decrease (increase).

The results from the estimation of the second error-correction model are reported in Table III. 7. The estimated coefficients for $\delta$ are statistically significant for all countries both at 5% except the ones for Paraguay, Chile and Colombia, which are only significant at 10%. In the case of Peru and Ecuador the coefficients are not significant. The interpretation here is that the real exchange rate in the previous period will play an important role in terms of how the nominal exchange rate (s) will adjust in the actual period from its previous period. The estimation of the above ECM model is crucial in order to calculate the half-lives for each one of the eleven countries.

The estimation of the half-lives reported in Table III. 8 using the estimated coefficients of $\beta_4$ (Table III. 6) and $\delta$ (Table III. 7) show similar results to the ones calculated from the ECM models in the literature, except for the cases of Argentina (3.02 vs 0.64 years), Venezuela (31.6 vs 1.27
years), Peru (1.68 vs 4.88 years) and Ecuador (8.25 vs 28.54 years). All of these four countries have problems in terms of insignificant coefficients estimated either in Table III. 6 or Table III. 7, where Ecuador has in both.

The range of the half-lives using the estimated coefficients from the first error-correction model varies, among the remaining 7 countries, roughly from 2.5 to 4 years for all countries except for Mexico (almost 1 year) and Bolivia (almost 3 months). The results from Table III. 8 using the first error-correction model and only countries with significant coefficients support a faster half-lives (2.5 years) for developing countries with high inflation when compared to the ones calculated in chapter 2 for developed countries (around 4.5 years). When we included all countries with and without significant coefficients and excluded Venezuela (outlier) the average half-life is around 3 years, which is faster than the half-life for developed countries.

The results of the half-lives for each of the eleven countries using the second error-correction model are reported on Table III. 8 where the estimation uses a specification reported by Froot/ Rogoff [1995]. The half-lives for all countries except for Bolivia (0.24 years), Argentina (0.64 years) and Mexico (0.7 years) are roughly between 2 years and 4.5 years. Again the average for the countries with significant coefficients is 2.48 years while the average including all countries except Ecuador (outlier) is 2.72 years. These results are consistent with the literature for developing countries.

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4 The results for Peru and Ecuador obtained in Table III. 8 (second part) have questionable meaning since the coefficients used are not significant as indicated by Table III. 7.
suggesting that we should find faster mean reversion when compared to developed countries.

The two error-correction models used for the nominal exchange rate seems to fit much better for Latin America when compared to OECD countries since the number of significant coefficients in both models are much higher in relative terms (8 and 9 out of 11 countries for the first and second EC models for Latin American and 2 out of 5 for both EC models for OECD countries) for Latin America than for the OECD countries used in chapter two.

We can say that both error-correction models and the estimation of the half-lives for Latin American countries support the argument that mean reversion is faster in developing countries with a history of high inflation. The half-life of the exchange rate for Latin American economies is around 2.5 years, while for OECD countries (chapter 2) is around 4.5 years.

III.4.3.2- Granger Causality Results

Table III. 9 contains the results of the Granger causality test using two variables, the first difference of the nominal exchange rate ($\Delta s$) and the first difference in relative price differential ($\Delta(p - p^\ast)$), all variables in log. The idea here is to test for each of the eleven countries if the behavior of the exchange
rate will Granger cause movements in the inflation differential or the other way round, or both.\(^5\)

The results suggest that we have a two way causation except for the cases of Paraguay and Uruguay where movements in the nominal exchange rate \((\Delta s)\) does not Granger causes movements in relative prices \((\Delta(p-p^*))\), neither movements in relative prices \((\Delta(p-p^*))\) Granger causes movements in the nominal exchange rate \((\Delta s)\). Therefore, we can say that in both cases we were not able to reject the null hypothesis. In the case of Chile, it is true that changes in the nominal exchange rates \((\Delta s)\) does not Granger cause changes in relative prices \((\Delta(p-p^*))\), but changes in relative prices \((\Delta(p-p^*))\) Granger causes changes in the nominal exchange rate \((\Delta s)\).

In general, the message here is that movements in the nominal exchange rate plays a role in terms of affecting the behavior of relative price levels differential, and vice-versa since for many countries with high inflation rate the difference in terms of domestic and foreign price (US price) is very important in affecting how monetary authorities will formulate the exchange rate policy.

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\(^5\) The Granger causality tests were performed using the first difference of each variable. The null is that \(\Delta S\) does not Granger cause \(\Delta(P-P^*)\) and that \(\Delta(P-P^*)\) does not Granger cause \(\Delta S\).
III.4.4- Results from the Johansen Test for Cointegration

Before we run the Johansen test for cointegration it is necessary to choose the order of the system (number of lags) and to include or not an intercept and / or a time trend. The right choice for the number of lags and the nature of the deterministic variables will help in terms of avoiding loss of power and size distortions. These steps are also important considering the fact that the number of cointegrating vectors is sensitive to the choice of number of lags and deterministic components. 6

Doornik, Hendry and Nielsen [1998] emphasizes that it is better to include a constant and a trend in the analysis because omitting such deterministic variables generates mi-specification bias, but including them will help in terms of increasing the power and the size of the tests. The authors also show that allowing for an unrestricted trend is correct although it can result in substantial size distortion when the data generating process suggests the existence of a restricted trend, while Pesaran and Smith [1998] find that the model with a restricted trend is preferable when one or more variables of the model are trended, which was not the case in our model with nominal exchange rate and relative prices. Therefore, we have run the

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6 See Doornik, Hendry and Nielsen [1998] and Pesaran and Smith [1998] for the discussion regarding the properties of the statistical model, Gaussian errors, the choice of order and deterministic components. See also Goldberg [2000] pp. 15-17.
Johansen test for two cases: unrestricted intercept and unrestricted trend; and unrestricted intercept and no trend.

First, we ran the Johansen test for cointegration for all eleven countries using lags from one to thirteen, including a constant but with the option of including or not the trend. We use the log-likelihood function reported by the Johansen test from each lag and for each country, and then calculate the Schwarz Bayesian Criterion (SBC). Whichever lag (order) maximizes the SBC for each country, that was considered the order of our VAR. 7

Table III. 10 shows that the order of the VAR is six for Argentina (including a trend) where for all the remaining cases the order is thirteen, with no trend for most of them except for Brazil, Peru and Uruguay (with trend). It seems that for all countries except Argentina, the more lags we included the higher will be the likelihood function and so we will get a higher SBC, meaning that each additional lag is significant. 8

Table III. 11 contains the diagnostic test for all eleven Latin American countries considering the selected order from Table III. 10, for all variables of our model (nominal exchange rate, domestic and foreign prices). The diagnostic test includes testing for serial correlation (a), normality (b), ARCH test (c) and heteroscedasticity (d). The properties of a well-behaved statistical

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7 $SBC = MLL - (0.5 \ln T)K$, where $MLL$ is the maximized log-likelihood function, $T$ is the sample size and $K$ is the number of parameters estimated. It should be mentioned that $K$ varies for different rank and including or not the time trend.

8 We have tested up to thirteen lags, which is $n + 1$, where $n$ is the frequency of the data (12 months).
model should be congruent with Gaussian errors, meaning that the test for each variable would not be able to reject the null for each of the four diagnostic tests.

The results from Table III. 11 show that for the full-sample statistical model did not deliver a congruent model. Normality is rejected for all Latin American countries and for each individual variable. The LM test for autocorrelated residuals (Ho = no autocorrelation) does not seem to be a problem for Brazil, Ecuador, Mexico and Uruguay. Argentina has residual autocorrelation in domestic price and foreign price, Bolivia and Colombia have in all three variables, Chile has in domestic price, Paraguay in nominal exchange rate, Peru in foreign price, and Venezuela in domestic price. The LM test for autocorrelated square residuals (ARCH test) reveals that we can reject the null for all three variables for Argentina, Bolivia and Brazil. For Chile, we cannot reject the null for all three variables. Rejection of the null is also true for Colombia, Mexico and Paraguay for relative prices, Ecuador Peru and Venezuela for foreign price. The heteroscedasticity test has shown that we cannot reject the null (homoscedasticity) only for the case of Ecuador, and we can reject the null for Bolivia in all three variables. For Argentina, Colombia e Mexico we can only reject the null for domestic price, while for Brazil, Paraguay, Peru, Uruguay and Venezuela we reject for both nominal exchange rate and domestic price. Chile is the only case where we can reject the null for both prices.
After all, we can say that the results from the diagnostic test reported on Table III.11 does not support a well-behaved statistical model congruent with Gaussian errors, which imposes some limitations to the interpretation of the results on testing for cointegrating relationships (Johansen test) reported in Tables III. 12 and III.13.

A possible explanation for not having a congruent model seems to be related to the presence of structural changes over the period of 1957 to 1997, which is a quite reasonable assumption given the long-run time period and distinct changes in the economy that took place during this time period.

The Johansen trace and max eigenvalue test statistics for the rank of the $\Pi$ matrix are reported in Table III.s 12 and 13, where the former reports the unadjusted Johansen test statistics while the later reports on these statistics after being adjusted for degrees of freedom by multiplying the test statistics by $(T - nm)/T$, where $T$ is the sample size, $n$ is the number of endogenous variables and $m$ is the order of the system.9

Table III. 12 shows that based on the max eigenvalue test there is no cointegrating vector for Brazil, Chile, Colombia and Uruguay, there is one cointegrating vector for Argentina, Ecuador, Paraguay, Peru and Venezuela, and two cointegrating vectors for Bolivia and Mexico. On the other hand, using the trace test we reject no cointegration for all of the eleven countries except Colombia, and there is one cointegrating vector for Argentina,

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9 We have decided to report both results but due to our relatively large sample size, we do not have significant bias due to small sample.
Ecuador, Paraguay, Uruguay and Venezuela, where Bolivia, Chile and Mexico have two cointegrating vectors. Both Brazil and Peru (at the 10% level) have three cointegrating vectors, which does not make sense since we have only three variables.\footnote{10 Pesaran and Smith [1998] argues that max eigenvalue test tend to identify fewer cointegrating vectors when compared to the trace test. See also Goldberg [2000], pp. 18.}

Table III.13 reports the Johansen cointegration test with max eigenvalues and trace statistics adjusted for the degrees of freedom and it shows similar results from Table III. 12, where using the max eigenvalue test statistics the only difference is Peru which now has one cointegrating vector and it had three before. No cointegrating vector is still true for Brazil, Colombia and Uruguay as before. Argentina, Chile, Ecuador, Paraguay and Venezuela have one cointegrating vector, while Bolivia and Mexico have two. The trace test reveals that we reject no cointegration for all of the eleven countries except for Brazil and Colombia. All the remaining countries have one cointegrating vector, except for Bolivia and Mexico who have two based on the trace test.

Summarizing the results from the Johansen test for eleven Latin American countries for the period of 1957 to 1997 using monthly data for nominal exchange rate and relative prices, we can say that we were able to find one cointegration vector for six out of the eleven countries when using the adjusted max eigenvalue statistics, and nine out of eleven when using the adjusted trace statistics.
These results are consistent with Pesaran and Smith (1998). Most of the Latin American countries seems to have one cointegrating vector especially if we consider the trace test regardless of making or not the correction for the degrees of freedom, and if we use the max test statistics the results are mixed for Latin American countries where half of them have no cointegrating vector and half has one cointegrating vector.

The striking difference comparing the results for Latin American (chapter 3) and selected OECD countries (chapter 2) is that it was much easier to reject no cointegration for developing countries than for the case of developed countries, especially when using the trace test statistics. After all, the Johansen test for cointegrating vectors has provided us with empirical evidence supporting the theoretical argument that it is easy to find cointegration between nominal exchange rate and relative prices in developing countries with a history of high inflation rates.

Table III. 14 reports the results of the comparison between the $\alpha$ coefficients for domestic price from the Johansen cointegration test for the nominal exchange rate and the relative prices for OECD and Latin American countries. The average coefficient for the five OECD countries is 0.00166 while for the eleven Latin American countries is 0.021424. We can see that the coefficient for Latin American countries is much bigger than the one for the OECD countries, which a clear indication that domestic prices in Latin America adjust much quicker than in OECD countries. This result supports
the theoretical argument that monetary shocks play a crucial role in high inflation countries and we should expect less price stickiness under these circumstances. This result is also in fine-tuning with the calculation of half-lives from chapters 2 and 3, which have shown faster mean reversion for Latin America when compared to OECD countries.

Table III. 15 reports the results from testing the $\beta$ coefficients from the Johansen cointegration test to see whether or not the coefficients are statistically different from the vector assumed by PPP, i.e., $[1\ -1\ 1]$ for the nominal exchange rate, domestic and foreign prices respectively. We have decided to impose rank one for all countries that the empirical results from Table III. 13 have indicated no cointegrating vector (Brazil and Colombia) and one cointegrating vector (Argentina, Chile, Ecuador, Paraguay, Peru, Uruguay and Venezuela), where only two countries (Bolivia and Mexico) we have tested the restrictions for rank one and two. The empirical results indicate that we can reject the null ($\beta$ coefficients are not statistically different from the restriction, $[1\ -1\ 1]$) for all cases, except for Mexico when testing the restriction for rank equals one.

The empirical results from testing the $\beta$ coefficients together with the Johansen test (adjusted for the degrees of freedom) suggest that we can find evidence of cointegration between nominal exchange rates and relative prices for 9 out of 11 Latin American countries for the period of 1957 to 1997.
but this does not imply that PPP holds as a long-run relationship since the β coefficients are not consistent with the PPP theory.

The empirical findings from Tables III.13 and III.15 support the argument that the right model for long-run exchange rates should not be based on the assumption of a constant long-run real exchange rate as it is usually assumed by the PPP theory.

### III.5 - Concluding Remarks

Section five of chapter three intends to highlight the most important empirical results in such a way to compare them with the ones from chapter two, keeping in mind how they fit within the dissertation objectives expressed in the introduction of chapter one.

The results regarding the speed of mean reversion from the calculation of the half-lives for all eleven countries show that for high inflation countries like the ones used in our sample, the half-lives are faster (around 2.5 years) when compared to those obtained in previous studies for developed countries (around 4.5 years).

The Granger causality test shows that nominal exchange rate and the difference in relative price (domestic and foreign) have a two-way causation for most of the countries in Latin America. This result suggests that policymakers in general will have to consider both (exchange rate and the
difference in relative price) when dealing with exchange rate policy and its impact in terms of stabilization and balance of payments adjustment.

The Johansen cointegration test allowed us to obtain the estimation of the $\alpha$ coefficients, where for the domestic price variable we could compare the estimated coefficients for OECD and Latin America to address the question of whether or not we have less price stickiness in the latter. The empirical results have shown us that the answer to this question is a yes.

The empirical evidence of testing for mean reversion between the nominal exchange rate and relative prices for Latin America is more favorable when compared to the OECD case (chapter 2) using the Johansen cointegration test. The evidence is that we can find cointegration between nominal exchange rates and relative prices (adjusted for the degrees of freedom) for 9 out of 11 Latin American countries for the period of 1957 to 1997. At the same time, we know that the empirical findings supporting cointegration does not necessarily imply that PPP holds as a long-run relationship since the $\beta$ coefficients might not be consistent with what is predicted by PPP.

The empirical findings obtained after imposing the restriction $[1 \ -1 \ 1]$ for $s$, $p$ and $p^*$ indicate that the right model for long-run exchange rates should not be based on the assumption of a constant long-run real exchange rate as it is usually assumed by the PPP theory. Mexico is the only exception where we found evidence that the estimated $\beta$ coefficients are not statistically
different from what is suggested by PPP. These results support our conclusion derived after reviewing stage three empirical findings in chapter one, which basically argues that a constant long-run real exchange rate is not a reasonable assumption for modeling long-run exchange rates. This seems to be a valid statement regardless if we are working with OECD (chapter 2) or Latin American (chapter 3) countries, for the period of 1957-97 in both set of countries and even for the floating period for the OECD countries.
Chapter Four

Mean Reversion and Cointegration Between Nominal Exchange Rates, Relative Prices and Real Factors: Evidence from the Floating Period for Selected OECD Countries

IV.1 – Introduction

The main objective of chapter 4 is to explore the idea that both the disequilibrium view of Dornbusch [1976] and others and the long-run equilibrium view of Balassa [1964] and others are both relevant in explaining the movement of nominal exchange rates and relative prices over the long-run. The proposed argument in chapter 4 is that these two views can be seen as comprising two components of one model for testing long-run behavior of exchange rates.

The main purpose of the empirical tests in chapter 4 is to shed light on the following question: to what extent, if at all, do nominal exchange rates and
relative prices mean revert to some long-run equilibrium levels once we include real factors in the model?

We already know from chapter 1 that the empirical findings from stage three tests of PPP and from the long-run real exchange rate literature imply that the specifications used in testing for mean reversion in the PPP literature are incorrect. This argument has also been tested in chapters 2 and 3 for both OECD and Latin American countries and the empirical findings pointed out in the same direction.

Chapter 4 also explores the open question of whether or not temporary demand side shocks such as monetary shocks and overshooting behavior play any role for nominal exchange rates and relative prices and if they do, what is their importance relative to long-run real factors.

After all, the empirical results from chapter 4 will shed light in answering three crucial questions. First, is the difficulty of finding evidence of cointegration and mean reversion during floating rate periods due to the omission of long-run real factors from the regression? Second, is the problem of finding slow mean reversion, when mean reversion is found (this is often referred to as the PPP puzzle), also connected to the omission of long-run real factors? Finally, if long-run real factors are included in the cointegrating regression, then will the estimated coefficients for goods prices become more consistent with the predictions of symmetry and proportionality, i.e. will they be more consistent with the disequilibrium view?
The remainder of chapter 4 is structured as follows. Section II focuses on the role of real factors in testing for mean reversion and cointegration between nominal exchange rates and relative prices in the long-run, both in theoretical and empirical grounds. Section III deals with the empirical results for testing mean reversion and cointegration between nominal exchange rates and relative prices when real factors are included in the model. Section IV is dedicated to summarize the most important empirical findings from chapter 4 and explicitly show how they can help us answering the open questions regarding mean reversion and cointegration between nominal exchange rates and relative prices during the floating period for OECD countries.

**IV.2 - The Role of Real Factors for Mean Reversion and Cointegration Between Exchange Rates and Prices**

Section II provides a theoretical discussion regarding the issue of omitted real variables when testing for mean reversion and cointegration between nominal exchange rates and relative prices for OECD countries during the floating period.
IV.2.1 - Long-Run Exchange Rates and the Role of Real Factors

Up to this point and based on the review of the literature detailed in chapter one, we have seen that the PPP literature is based on the assumption that the long-run real exchange rate is constant and the determinants of long-run nominal exchange rates are relative prices. The most used model in explaining short-run deviations is the disequilibrium, overshoooting model of Donbusch [1976]. The Dombusch model is designed to explain the implications of temporary demand-side shocks (such as monetary shocks) for the short-run movement of nominal exchange rates and relative prices, given that goods prices are sticky in the short-run. In the long-run, the model assumes PPP, i.e., a constant long-run real exchange rate.

The empirical results of stage three tests have been mixed. Although they have uncovered evidence of mean reversion between nominal exchange rates and relative prices, the estimated deviations from proportionality and symmetry are too large to be consistent with PPP as a long-run relationship. Thus, the evidence from stage three tests suggests that PPP fails as an explanation of the long-run movements in nominal exchange rates and relative prices. The conclusion to be drawn from the PPP literature is that the long-run real
exchange rate appears to be non-constant, implying that some deviations from PPP are permanent.

The empirical results from testing for PPP have also suggested that long-run factors such as rates of thrift and productivity can help us understand exchange rate movements since temporary demand-side shocks such as monetary policy actions are invariably modeled as having no long-run implications.

On the other hand, the empirical results of the long-run real exchange rate literature support the empirical findings of stage three tests in the PPP literature that long-run real exchange rates are not constant, i.e., PPP does not hold as a long-run relationship.

In order to address the questions regarding the inadequacy or not of the disequilibrium model in testing for mean reversion and cointegration between nominal exchange rates and relative prices for the floating period, the proposed theoretical and empirical framework in chapter 4 is represented by the following equation:

\[ s_t = \beta_0 + \beta_1 \bar{p}_t - \beta_2 \bar{p}_t^* + \beta_3 y + \beta_4 y^* \]

\[ + \beta_5 ((C+G)/Y) + \beta_6 r_{t-1} \]  

(1)
where $s$ is the log of nominal exchange rate, $p$ and $p^*$ are the log of domestic and foreign prices, $y$ and $y^*$ are a moving average (12 quarters) of the domestic and US real GDP, $\left(\frac{(C+G)}{Y}\right)$ is the discount rate represented by the sum of private consumption ($C$) and government consumption ($G$) over the GDP, $\pi^*$ is the real interest rate differential, (*) indicates rate of growth, and (') indicates long-run equilibrium levels.

Our empirical research has used the above proxies to capture the long-run real factors that might play a role in affecting the long-run behavior of nominal exchange rates based on the work of Stein et. al. [1995], and future research could also incorporate some other proxies such as the domestic and foreign trade balance difference.

The empirical framework proposed in chapter 4 provides a way to address the question concerning the relative importance of temporary demand-side factors (and thus the disequilibrium view) and long-run real factors (and thus the long-run equilibrium view) for the nominal exchange rate and relative prices.\footnote{The theoretical and empirical approach suggested in chapter 4 is different from previous studies including real factors to test for long-run exchange rates since we are not imposing the $\left[ \begin{array}{c} 1 \\ 1 \\ 1 \end{array} \right] \beta$ coefficient by testing the real exchange rate as in the Natrex model, neither we are restricted to test for a Balassa-Samuelson effect including only supply-side real factors.}

In order to understand how this will be done empirically we have to go back to the Dornbusch model. The overshooting model (i.e., with sticky prices) has as one of its key feature the property that temporary demand-side shocks influence the nominal exchange rate solely through their effect on relative

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prices, whereas movements in long-run real factors will only affect the nominal exchange rate and not relative prices. In a situation like this, the cointegrating vector contained in equation (1) should be consistent with symmetry and proportionality, i.e., $\beta_1 = -\beta_2 = 1$. On the other hand, if prices are fully flexible, then according to the long-run equilibrium view, the movement in real factors should show up in both the nominal exchange rate and relative prices. Thus, if the cointegrating vector contained in equation (1) is not consistent with symmetry and proportionality and thus $\beta_1 \neq -\beta_2 \neq 1$, then this can be taken as a rejection of the disequilibrium view.

**IV.2.2 - Empirical Findings from Real Models**

This section will highlight the most important empirical findings from real equilibrium models for long-run exchange rates in develop countries, including the Balassa-Samuelson [1964] and the Natrex model of Stein [1995].

The two main features distinguishing the NATREX approach and the Balassa-Samuelson view is that the former allows for terms of trade effect while the later assumes constant terms of trade, and the real exchange rate in the NATREX model depends on both demand (thrift) and supply (productivity).

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2 See appendix to chapter 4 for the dynamics of the Dornbusch model allowing for a one-time change in the long-run real exchange rate.
factors while in the Balassa-Samuelson model the real exchange rate is solely a function of supply factors.

The empirical studies on deviations from PPP testing the Balassa-Samuelson hypothesis have shown empirical support to the Balassa-Samuelson hypothesis (tendency for countries with higher productivity in tradables to have higher price levels and so to face an exchange rate appreciation over time) during the floating period.3

The main conclusion from the empirical findings from the Balassa-Samuelson model is that the long-run real exchange rate is not constant and it depends on supply-side real factors like productivity growth.

The NATREX model includes the rate of time preference of thrift and the productivity of capital as the two main exogenous fundamentals to explain medium to long-run movements in real exchange rates. The empirical results suggest that a decrease in thrift should lead to long-run depreciation of the real exchange rate, while an increase in productivity has mixed effects.

Stein [1995] applied the Natrex model to the US the real exchange rate, suggesting that an increase in productivity leads to long-run real appreciation. The empirical results show that the time preference has a negative (depreciation) impact on the real exchange rate. Domestic growth appreciates

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3 The reason for this is not simply because rich countries have higher absolute productivity levels when compared to poor countries, but because over time, relative productivity in traded goods sector relative to non-traded goods sector is higher in rich countries when compared to low-income countries.
the real exchange rate but the estimated coefficient is not significant, whereas foreign growth depreciates the real exchange rate.

Finally, the empirical findings from the two real equilibrium models suggest that the long-run real exchange rate is not constant, which is the same conclusion from the empirical studies using stage three tests for PPP during the floating rate period. Both real equilibrium models argue that the poor results from the empirical literature on PPP arises due to omitted real variables, where the difference between the two relies on using only supply-side real factors (Balassa-Samuelson model) and both supply and demand factors (Natrex).

IV.3 - Mean Reversion and Cointegration Nominal Exchange Rates and Relative Prices when Real Factors are included: Empirical Results for the Floating Period

This section will summarize the main results from the tests performed for five OECD countries during the floating period, including the unit root tests and the cointegration tests (EG and Johansen). The main empirical issues to be examined here are linked to answer the question of whether or not we can find evidence of cointegration between nominal exchange rates and relative prices when we include real factors into our model, and to test the restriction on the $\beta$ coefficients in order to address the question regarding the adequacy of the
disequilibrium model in explaining long-run exchange rate behavior, once real factors are included into the analysis.

IV.3.1 - Stationarity Test: the Augmented Dickey-Fuller (ADF)

First of all, it is necessary to mention that tables IV.1 to IV.6 report the ADF tests for all the variables used throughout chapter 4.4.

Table IV.1 includes the results of the ADF test on the real exchange rate (in log) for five OECD countries. The main interpretation is that we could not reject the null (unit-root) at the 1% and 5% levels of significance for all five OECD countries during the floating period, meaning that the real exchange rate is non-stationary. This result was valid for both ADF specifications, with and without the time trend.

Tables IV.2 to IV.6 are especially important in terms of checking if the the first difference of the nominal exchange rate, relative prices and the real variables are I(0), i.e., stationary. In the case of the nominal exchange rate (table IV.2) we were able to reject the null hypothesis (non-stationarity) for all countries using first differences and applying the ADF test, indicating that the original series are I(1). Table IV.3 indicates that we can reject the null when

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* All the tests were run using quarterly data from the IFS database for nominal exchange rate (end of the period), domestic price index (CPI), foreign price index (the US CPI), a moving average of real
testing for stationarity on the first difference of prices for Germany and Japan without the time trend, and for Canada, UK, Germany, Japan and US with the time trend, suggesting that the original price series in levels are of a higher order than one for these cases.

Table IV. 4 describes the ADF test on the first difference of a twelve-quarter moving average of the domestic and foreign (US) real GDP growth and the null hypothesis was rejected for Canada, France, UK, Japan and US with and without the time trend. The only exception was Germany where we could not reject the null in both cases of the ADF test specification.

Table IV. 5 reports the ADF test on the first difference for the discount rate \([C + G / GDP]\) and we were able to reject the null for all countries with and without the time trend, suggesting that the original series in level were I(0).

Finally, table IV. 6 reports the ADF test on the first difference of the real interest rate differential for each country vis-à-vis the US (using the long-run government bond yield for the nominal interest rate and the CPI) and the results imply that we can reject the null of a unit-root for all countries in both ADF specification (with and without the time trend).
IV.3.2 - Results from the E-G Two-Step Procedure

Results from table IV. 7 shows the OLS estimation of the nominal exchange rate regressed against the domestic and the foreign price levels (in log). The first step was to run the OLS in order to get the estimated residuals and then run the ADF (without the time trend but with and without the intercept) on the estimated residuals (table IV. 8). In all cases we got very high R-squared and the Durbin-Watson (DW) was very low for all countries, which is an indication of a spurious regression according to Granger and Newbold [1974].

The empirical results reported in table IV. 8 refers to the Engle-Granger second step procedure (residual test of cointegration) and it suggest that we were not able to reject the null for all countries, indicating that the residuals are not stationary. This result is a primary indication that we cannot find evidence of cointegration between nominal exchange rates and relative prices for the OECD countries during the floating period.

Table IV. 9 has the results of the OLS regression of nominal exchange rates against relative prices, domestic and US real GDP growth, the discount rate and a lagged (one) real interest rate differential. The Durbin-Watson are not as low when compared to the results from table IV. 7, but still we have the problem of spurious regression.
The results reported in table IV. 10 for the second step of the EG procedure when we include the real variables into the model and the results are the same as when we have only nominal exchange rates and relative prices when we could not reject the null of non-stationarity residuals during the floating period.

Therefore, we can say that regardless of including or not real variables into our model, the EG residual cointegration test was not able to find any cointegration for five OECD countries during the floating rate period. We still have to check the results from a more powerful and less restrictive cointegration test, which is the Johansen cointegration test.

**IV.3.3 – Speed of Mean Reversion: The Half-Lives**

The calculation of the half-lives of the nominal exchange rate for five OECD countries during the floating period was carried on using two error-correction model specifications applied to a model with and without real factors.

The estimated coefficients reported in table IV. 11 show us that the $\beta_4$ coefficients are significant for all countries except for Canada, suggesting that the real exchange rate in the previous period has an important role in terms of affecting the way that nominal exchange rate will adjust in the actual period. In terms of the signs of the coefficients, they all have the expected signs
(negative) according to the theory. The theory suggests that if the real exchange rate in the previous period is above (below) its equilibrium level, then in order to move back to the equilibrium level, the nominal exchange rate will have to adjust in the actual period in such a way that it will decrease (increase).

The results from the estimation of the second error correction model (ECM) are reported in Table IV. 12 and the estimated coefficients for $\delta$ are statistically significant only for France, Germany and UK, and the sign is negative for all countries.

The estimation of the above error-correction models is important in terms of providing the required coefficients to be used in the calculation of the half-lives for each one of the five OECD countries.

The estimation of the half-lives of the nominal exchange rate without including real factors are reported in table IV. 13 where for the first EC model the average including only countries with significant coefficients was 2.2 years, 2.7 years when all five countries were included, with an overall average (two previous results) around 2.5 years. The results from the second EC model suggests that the average when including only countries with significant coefficients is the same as before (2.2 years), but when we include all five countries the average is 4.2 years (consistent with the literature) and around three years for an overall average between the two previous results. It should
be emphasized that these results do not match with the ones we have obtained in chapter 2.

After all, table IV.13 shows some interesting results in terms of supporting the findings of longer half-lives of the exchange rate (around 4 years) for developed countries during the floating period when using the second EC model, and a somewhat faster mean reversion according to the first EC model (around 2.5 years).

Once we have estimated the half-lives without the real factors, we need to include these real factors into our model and see how this will affect the speed of mean reversion for the nominal exchange rate.

The first EC model for the nominal exchange rate including relative prices and real factors reveals that the estimated coefficients ($\beta_5$) are not statistically significant for all countries except UK as reported in table IV.14. The second EC model results, including real factors, are reported in table IV.15 and they show that the estimated coefficients ($\beta_5$) are not significant for all countries except for France.

The calculation of the half-lives using two EC models for the nominal exchange rates including real factors is reported in table IV.18. The average half-life for the first EC model is around 3 years, while for the second EC model is around 5 years. The results from the first EC model is very similar to the one from the first EC model without including real factors, while the results from the second EC model with real factors does not match with the same results from
the second EC model without real factors. After all, the empirical evidence when including real factors does not support a faster mean reversion for the nominal exchange rate during the floating period for selected OECD countries.

IV.3.4 - The Johansen Cointegration Test: Empirical Findings for the Floating Period

This section will report and discuss the main empirical results from the Johansen cointegration test for five OECD countries during the floating period, including not only the results regarding the number of cointegrating vector but also the results for testing the restriction that the β coefficients are not statistically different from [1 -1 1]. The Johansen test will be first implemented in a system with three variables (nominal exchange rates and relative prices) and then to a system including real variables (domestic and US real GDP growth, and the discount rate), where the time period for both cases is the floating period.

IV.3.4.1 – Empirical Results for Nominal Exchange Rates and Relative Prices

First, we run the Johansen test for cointegration for all five countries using lags from one to five, including a constant but with the option of including or not
the trend. We use the log-likelihood function reported by the Johansen test from each lag and for each country, and then calculate the Schwarz Bayesian Criterion (SBC). Whichever lag (order) maximizes the SBC for each country, that was considered the order of our VAR.\textsuperscript{5}

The results from table IV. 17 indicate that the order of the VAR is five for all countries, including a trend.\textsuperscript{6} Table IV. 18 contains the diagnostic test for all five OECD countries considering the selected order from the previous table IV., for all variables of our model (nominal exchange rate, domestic and foreign prices). The diagnostic test includes testing for serial correlation (a), normality (b), ARCH test (c) and heteroscedasticity (d). The properties of a well-behaved statistical model should be congruent with Gaussian errors, meaning that the test for each variable would not be able to reject the null for each of the four diagnostic tests.

The results from table IV. 18 show that the statistical model did not deliver a congruent model for Canada, Germany, Uk and Japan, whereas the model is congruent for France. Normality is rejected for Canada, Germany and UK for the domestic price variable, while for the Japan normality is rejected for the foreign price variable. Regarding the LM test for autocorrelated residuals (Ho = no autocorrelation) the indication is that residual autocorrelation is not a problem for Canada, France and Germany, while for UK the null was rejected

\textsuperscript{5} SBC = MLL - (0.5 \ln T)K, where MLL is the maximized log-likelihood function , T is the sample size and K is the number of parameters estimated. It should me mentioned that K varies for different rank and including or not the time trend.

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for the nominal exchange rate and for Japan we could reject the null for domestic price. The LM test for autocorrelated square residuals (ARCH test) reveals that we can reject the null for all countries and variables. The results from the heteroscedasticity test have shown that we can reject the null (homoscedasticity) only for Japan for the domestic price variable.

After all, we can say that the results from the diagnostic test reported on table IV. 18 reveals a much more congruent model when compared to the results from chapters 2 and 3, which can be explained by the fact that for a shorter period (floating) we have less structural breaks when compared to the 1957-97 period used in the previous two chapters.

The Johansen trace and max eigenvalue test statistics for the rank of the $\Pi$ matrix without including the real factors are reported in tables IV.19 and IV.20, where the former reports the unadjusted Johansen test statistics while the later reports on these statistics after being adjusted for degrees of freedom by multiplying the test statistics by $(T - nm)/T$, where $T$ is the sample size, $n$ is the number of endogenous variables and $m$ is the order of the system.

Table IV. 19 reports the Johansen cointegration test without adjusting for the degrees of freedom, indicating that we have no cointegration for Canada and Japan, while for Germany and UK we have two cointegrating vectors and three for the case of France.

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6 We have tested up to thirteen lags, which is $n + 1$, where $n$ is the frequency of the data (4 quarters).
Table IV. 20 has shown similar results, where we could not find cointegration for Canada, Germany and Japan, two (one) cointegrating vectors for France using the max (trace) test statistics, and three (two) for UK using the trace (max) test statistics. Just for two our of five countries we could find cointegration between nominal exchange rates and relative prices during the floating period.

In table IV. 21 we have imposed a rank equals to one for all countries except for UK where we have allowed for a rank of two, and test the restriction that the $\beta$ coefficients are equal to $[1 -1 1]$ for $s$, $p$ and $p^*$ respectively. This procedure was based on the results from table IV. 20 and assuming that the Johansen cointegration test might not be able to capture the underlying cointegrating vectors due to lack of power, we have decided to test the restriction for all five countries regardless with we have found or not evidence of cointegrating vectors.

The test of the restriction has the null hypothesis that the cointegrating vector is not statistically significant different from what is predicted by PPP ($[1 -1 1]$ for $s$, $p$ and $p^*$) and the results from table IV. 21 indicate that we can reject the null for all countries except for Japan.$^7$ These results indicate that the coefficients are not close to $[1 -1 1]$ for Canada, France, Germany and UK, and so that there is no evidence of a long-run constant real exchange rate for four

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$^7$ Canada we can only reject the null at the 5% level of significance but not at the 1% level.
out of five OECD countries using quarterly data for nominal exchange rate and relative prices during the floating period.

Finally, table IV. 22 reports the $\alpha$ coefficients from the Johansen test without including real factors and the results suggest that the exchange rate is responsible for most of the adjustment that has been taking place between nominal exchange rates and relative prices, which is captured by looking at the coefficients for rank one and see how they are far bigger than the coefficients for the other variables (relative prices). This argument is especially true for Canada, France, Germany and Japan, while for UK the coefficients for the nominal exchange rate and the domestic price are very similar for the rank one case. We will later compare these coefficients with the ones obtained when real factors are included.

**IV.3.4.2 – Cointegration and Mean Reversion for Nominal Exchange Rates, Relative Prices and Real Factors: Empirical Findings from the Johansen Cointegration Test**

This section will report the empirical findings from the Johansen cointegration test for five OECD countries during the floating period, including real variables. The empirical results include the diagnostic test of the model, the test for the number of cointegrating vectors (adjusted and unadjusted to the degrees of freedom), the test to see if the $\beta$ coefficients are statistically
different from [1 -1 1], and the α coefficients. We will run the same tests for a
model specification including three real variables (domestic and US real GDP
growth, and the discount rate), and then add another real variable which is the
real interest rate differential.

IV.3.4.2.1 - Empirical Findings from the Johansen
Cointegration Test Including Three Real Factors: Domestic
and US Real GDP Growth and the Discount Rate

The results from table IV. 23 indicate that the order of the VAR is five for
all countries, including a trend. The choice of the order of our system was
based in the maximum Schwartz Bayesian Criteria (SBC).

Table IV. 24 reports the diagnostic test for all five OECD countries
considering the selected order from the previous table IV., for all six variables
of our model (nominal exchange rate, relative prices, domestic and US real
GDP growth, and the discount rate). The diagnostic test includes testing for
serial correlation (a), normality (b), ARCH test (c) and heteroscedasticity (d).
The properties of a well-behaved statistical model should be congruent with
Gaussian errors, meaning that the test for each variable would not be able to
reject the null for each of the four diagnostic tests.

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We have tested up to five lags, which is n + 1, where n is the frequency of the data (4 quarters).
The results from table IV. 24 show that the statistical model did not deliver a congruent model for all countries, but France only had problems for the US price (non-normality) and US real GDP growth (serial correlation), and UK has serial correlation for the nominal exchange rate and US real GDP growth. Canada reveals serial correlation for nominal exchange rate, foreign price, and domestic real GDP growth, whereas non-normality was found for the real GDP growth of US. Germany has problems of non-normality for the nominal exchange rate, domestic and foreign real GDP growth, and for the discount rate. Serial correlation was a problem for domestic price and real US GDP growth. Finally, Japan has problems of serial correlation for all variables except nominal exchange rate and US real GDP growth, whereas non-normality was found for domestic real GDP growth and the discount rate. We have not found any problems regarding ARCH and heteroscedasticity.

After all, we can say that the results from the diagnostic test reported on table IV. 24 reveals a much less congruent model when compared to the results from table IV. 18, indicating that the introduction of real variables will have implications in terms of affecting the assumption of Gaussian errors which is crucial for the Johansen cointegration test.

The Johansen trace and max eigenvalue test statistics for the rank of the \( \Pi \) matrix including the real factors are reported in table IV.s 25 and 26, where the former reports the unadjusted Johansen test statistics while the later reports on these statistics after being adjusted for degrees of freedom by
multiplying the test statistics by \((T - nm)/T\), where \(T\) is the sample size, \(n\) is the number of endogenous variables and \(m\) is the order of the system.

Table IV. 25 reports the Johansen cointegration test without adjusting for the degrees of freedom, indicating that we can reject no cointegration for all five countries. But since we have to correct to the degrees of freedom, we should rely on the results from table IV. 26.

Table IV. 26 has shown similar results, where we could reject no cointegration for all countries except UK. When using the trace statistics, there is one cointegrating vector for France and Germany, two for Japan, and three for Canada. These results are significantly distinct from the results in table IV. 20 (without real factors) since now we have at least one cointegrating vector for four out of five countries where before just two out of five have indicated the presence of cointegration.

In table IV. 27 we have imposed a rank equals to one for all countries except for Japan (rank of two) and Canada (rank of three), and test the restriction that the \(\beta\) coefficients are equal to \([1 \ -1 \ 1]\) for \(s\), \(p\) and \(p^*\) respectively. This procedure was based on the results from table IV. 26 and assuming that the Johansen cointegration test might not be able to capture the underlying cointegrating vectors due to lack of power, we have decided to test the restriction for all five countries, including UK which did not indicate the presence of at least one cointegrating vector.
The test of the restriction has the null hypothesis that the cointegrating vector is not statistically significant different from what is predicted by PPP ([1 -1 1] for s, p and p*). We have found striking differences between the results from tables IV.27 (with the real factors) and IV.21 (without real factors), where the former has shown that we cannot reject the null for Germany, Japan and UK for rank one, while the results from table IV.21 indicate that we can reject the null for all countries except for Japan.9

The results from table IV.27 indicate that the coefficients are statistically close to [1 -1 1] for Germany, Japan and UK, which is an indication that when we include real factors into our model there is evidence supporting the disequilibrium view for three out of five OECD countries using quarterly data for the floating period. This result provides new evidence for the empirical literature on testing for long-run exchange rates, where the empirical findings suggest that once real factors are included in our model not only we can find evidence of cointegration but the coefficients for nominal exchange rates and relative prices are statistically similar to what was assumed by the disequilibrium view. This result supports our original idea when developing chapter 4, which was that the disequilibrium view and the long-run equilibrium view are both relevant in explaining the movement of nominal exchange rates and relative prices over the long-run. The proposed argument is that these two views can be seen as comprising two components of one model for testing long-run behavior of exchange rates.

9 Canada we can only reject the null at the 5% level of significance but not at the 1% level.
Finally, table IV. 28 reports the \( \alpha \) coefficients from the Johansen test including three real factors and the results suggest that the exchange rate is responsible for most of the adjustment for Canada, France and Germany, which is captured by looking at the coefficients for rank one and see how they are far bigger than the coefficients for the other variables (relative prices and real factors). The case of Japan the \( \alpha \) coefficient is bigger for the domestic price variable, while for UK both domestic and relative prices coefficients are responsible for the majority of the adjustment instead of the nominal exchange rate.

Therefore, these results help us answering one of the questions proposed in our introduction to chapter 4, which is whether or not temporary demand side shocks such as monetary shocks and overshooting behavior play any role for nominal exchange rates and relative prices and if they do, what is their importance relative to long-run real factors. Based on the coefficients from table IV. 28, we can say that the relative importance of nominal exchange rates and relative prices are far bigger than the relevance of real factors for all five OECD countries, with few exceptions. One of them is the role played by the discount rate for Canada and Japan when compared to relative prices, and for UK when compared to the nominal exchange rate and relative prices.
IV.3.4.2.2 - Empirical Findings from the Johansen Cointegration Test Including Four Real Factors: Domestic and US Real GDP Growth, the Discount Rate, and the Real Interest Rate Differential

The second part of this sub-section includes the empirical results from the Johansen cointegration test for five OECD countries during the floating period but now including a fourth real variable to the model, i.e., the real interest rate differential.¹⁰

The results are reported in table IV.29 to 32 in the appendix, where in table IV. 29 the inclusion of the real interest rate differential variable has brought problems of serial correlation for France and Japan, and non-normality for UK. Other than this, the diagnostic test does not reveal significant changes from what was reported in table IV. 24 when we have only three real factors instead of four. Both results (table IV.24 and 29) show that the model is not congruent when we included real variables.

Table IV.30 and 31 show the empirical results for the unadjusted and adjusted Johansen test for the number of cointegrating vectors, where in table IV. 31 there is no cointegration vector for Germany and UK, one for France and Japan, and two for Canada. Previously, in table IV. 26 (with three real

¹⁰ This procedure was in part based on the work of Stein [1995] where the real interest rate differential (lagged one) was included as one of the variables in the regression for the determinants of the real...
factors) UK had no cointegrating vector, France and Germany had one, Japan had two, and Canada had three. Therefore, including the real interest rate differential implies in losing one cointegrating vector for Germany, Canada, and Japan, while for France and UK the number of cointegrating vector is the same once we include or not real interest rate differential as one of the real variables.

In table IV. 32 we have imposed a rank equals to one for all countries except Canada (rank of two) and test the restriction that the β coefficients are equal to [1 -1 1] for s, p and p* respectively. This procedure was based on the results from table IV. 31 and assuming that the Johansen cointegration test might not be able to capture the underlying cointegrating vectors due to lack of power, we have decided to test the restriction for all five countries, including Germany and UK which did not indicate the presence of at least one cointegrating vector.

The test of the restriction has the null hypothesis that the cointegrating vector is not statistically significant different from [1 -1 1] for s, p and p* respectively. We were able to reject the null for all countries except Germany, where for the UK the rejection was found only at the 5% level. Comparing the results from tables IV. 27 (three real variables) and IV.32 (four real variables), we can say that Germany was the only case where we could not reject the null in both cases, whereas with three real variables we could not reject the null exchange rate but was not included in the cointegrating vector when using the Johansen cointegration test.
also for Japan and UK, which was not true when including four real variables. At the end, including the four real variable (real interest rate differential) seems to decrease the empirical support to the disequilibrium view when compared to the results with three real variables. With a fourth real variable the empirical results seem to support the disequilibrium view for one (Germany) out of five countries, and three out of five (Germany, Japan and UK).

**IV.4 – Concluding Remarks**

Section five of chapter 4 has the objective of summarizing the main empirical findings from the floating period regarding the issue of mean reversion between nominal exchange rates and relative prices, with and without real factors, and relate them to the key empirical results from the review of the literature on long-run exchange rates presented in chapter one.

The empirical evidence from one of the cointegration tests (EG residual test) has revealed that regardless of including or not real variables into our model, we were not able to find any cointegration for five OECD countries during the floating rate period. Even though this cointegration test is not widely used in recent empirical studies on testing for long-run exchange rates, the results support the empirical findings from stage three tests for the floating period, which suggests no mean reversion between nominal exchange rates and relative prices during the floating period.
The calculation of the half-lives (with and without real factors) has helped us answering the question of why is problematic finding slow mean reversion, when mean reversion is found (this is often referred to as the PPP puzzle) for the floating period, and to what extent this is connected to the omission of long-run real factors. The evidence from our empirical findings indicates that including real factors help us finding evidence of mean reversion (Johansen test) but it does not imply in faster mean reversion during the floating period.

The results from the Johansen cointegration test for the floating period and adjusted to the degrees of freedom without including the real factors suggest that there is no cointegrating vector for three out of five countries (Canada, Germany and Japan), while the empirical results when (three) real factors are included suggest that no cointegration was found only for UK. Including the fourth real variable has resulted in finding no cointegration for two (Germany and UK) out of five countries. Therefore, we have stronger evidence of mean reversion for the nominal exchange rate and relative prices for the floating period once real factors are included, especially for the case where the cointegrating vector does not include the real interest rate differential.

The results from the estimation of the $\alpha$ coefficients from the Johansen cointegration test help us answering one of the questions proposed in our introduction to chapter 4, which is whether or not temporary demand side shocks such as monetary shocks and overshooting behavior play any role for nominal exchange rates and relative prices and if they do, what is their
importance relative to long-run real factors. Based on the $\alpha$ coefficients (table IV. 28) we can say that the relative importance of nominal exchange rates and relative prices are far bigger than the relevance of real factors for all five OECD countries, with few exceptions. One of them is the role played by the discount rate for Canada and Japan when compared to relative prices, and for UK when compared to the nominal exchange rate and relative prices.

The empirical results from testing the restriction on the $\beta$ coefficients indicate the coefficients are statistically indistinct from $[1 -1 1]$ for Germany, Japan and UK with three real variables (domestic and US real GDP growth, and the discount rate), which is an indication that when we include real factors into our model, there is evidence supporting the disequilibrium view for three out of five OECD countries using quarterly data for the floating period. Once we have included a fourth real variable (real interest rate differential) the empirical results seems to support the disequilibrium view only for one (Germany) out of five countries.

It should be emphasized that these results does not imply a rejection of the equilibrium view since they were obtained using a model specification that incorporates real factors such as the ones suggested by the real equilibrium model.

Interestingly, we can say that these empirical findings provide support to our original idea when developing chapter 4, which was that the disequilibrium view and the long-run real models are both relevant in explaining the
movement of nominal exchange rates and relative prices over the long-run. The proposed argument is that these two views can be seen as comprising two components of one model for testing long-run behavior of exchange rates, that is why we called a unified approach to testing for mean reversion of exchange rates and prices in the title of our dissertation.

Finally, we can say that the empirical findings from chapter four help us answer in an affirmative way two of the three open questions listed in the introduction of this chapter. The difficulty in finding evidence of cointegration and mean reversion during floating rate periods can be (at least in part) explained by the omission of long-run (demand and supply-side) real factors, and the estimated coefficients for goods prices have become more consistent with the predictions of symmetry and proportionality and so with the disequilibrium view once we have included the real factors for three out of five OECD countries studied. On the other hand, the empirical findings from chapter 4 have not allowed us to relate the problem of finding slow mean reversion (the PPP puzzle) with the omission of long-run real factors.
Conclusion

The main goal of the present section of the dissertation is to summarize the most important theoretical and empirical findings from the previous four chapters so that the reader can have a clear picture about our research in the field of open macroeconomics using some of the new time-series econometric techniques.

Chapter one reviews the work on long-run exchange rates, by comparing the theory and empirical results from two competing literatures, the purchasing power parity (PPP) literature and the long-run real exchange rate literature. Chapter one has shown us that the findings of the long-run real exchange rate literature imply that the specifications used in testing for mean reversion in the PPP literature are incorrect. Other than this, the review of the literature developed in chapter one was important in the sense that we could raise three crucial questions for our research. First, is the difficulty of finding evidence of cointegration and mean reversion during floating rate periods due to the omission of long-run real factors from the regression? Second, is the problem of finding slow mean reversion, when mean reversion is found, also connected to the omission of long-run real factors? Finally, if long-run real factors are included in the cointegrating regression, then will the estimated coefficients for goods prices become more consistent with the predictions of symmetry and proportionality, i.e. will they be more consistent with the disequilibrium view?
The findings of the long-run real exchange rate literature suggest that the answers to all three questions may in fact be yes.

The main task of chapter 2 was to examine if there is evidence of cointegration between nominal exchange rates and relative price levels for five OECD countries during the period of 1957 to 1997 and for the floating period. It incorporates the use of longer span of data (40 years of monthly data), which mix fixed and flexible regimes and compared the results with the floating period, and calculate the speed of mean reversion of the nominal exchange rate for both periods.

The empirical results regarding the speed of mean reversion indicate that the half-lives for the entire period (1957-97) are around 4.5 and 5.5 years, while for the floating period they are around 3 and 4.5 years. Therefore, it seems that when we are restricted to the floating period the half-lives of the nominal exchange rates for OECD countries are lower (faster mean reversion).

The results from the Johansen cointegration test suggest that the floating period seems to provide more evidence of cointegration between nominal exchange rate and relative prices for the selected OECD countries, which does not match the empirical findings from stages 2 and 3 where the evidence towards mean reversion seems to be more supportive for longer time-series and when there is some fixed period included in the database.

Finally, the results for testing the restriction that the $\beta$ coefficients are not statistically different from $[1 -1 1]$ for the floating period have not been corroborated, which is not a supportive result for the disequilibrium view.
The main goal of chapter 3 is to examine the question of whether or not we can find evidence of mean reversion between nominal exchange rates and relative prices for Latin American countries using monthly data from 1957 to 1997. Another crucial contribution of chapter 3 is to calculate the half-lives for a broader number of countries in Latin America using a longer span of data when compared to previous studies for developing countries, which are usually restricted to annual data starting in the early 1970s up to the end of the 1980s. Other than this, a key motivation for calculating the half-lives is to compare them to the ones from chapter 2. Another important theoretical question that is empirically tested in chapter 3 is whether or not there is less price stickiness in countries with a history of high inflation when compared to developed countries with a different inflationary historical path.

The empirical findings from chapter three has shown us that the half-lives are faster (around 2.5 years) for the eleven Latin American countries when compared to those obtained in previous studies for developed countries (around 4.5 years), where this result matches those suggested by the literature on long-run exchange rates. The Granger causality tests have shown us that nominal exchange rate and relative prices have a two-way causation for most Latin American countries.

The estimation of the \( \alpha \) coefficients from the Johansen cointegration tests has shown that there is less price stickiness in Latin America when compared to the selected OECD countries during the period of 1957 to 1997.
The empirical evidence of testing for mean reversion between the nominal exchange rate and relative prices for Latin America is more favorable when compared to the OECD case (chapter 2) using the Johansen cointegration test. The evidence indicates that we can find cointegration between nominal exchange rates and relative prices for 9 out of 11 Latin American countries for the period of 1957 to 1997.

The empirical findings obtained after imposing the restriction \([1 \ -1 \ 1]\) for \(s, p\) and \(p^*\) indicate that the right model for long-run exchange rates should not be based on the assumption of a constant long-run real exchange rate. Mexico is the only exception where we found evidence that the estimated \(\beta\) coefficients are not statistically different from what is suggested by PPP. These results support our conclusion derived after reviewing stage three empirical findings in chapter one. This seems to be a valid statement regardless if we are working with OECD (chapter 2) or Latin American (chapter 3) countries.

The main objective of chapter 4 is to explore the idea that both the disequilibrium view of Dornbusch [1976] and others and the long-run equilibrium view of Balassa [1964] and others are both relevant in explaining the movement of nominal exchange rates and relative prices over the long-run. The proposed argument in chapter 4 is that these two views can be seen as comprising two components of one model for testing long-run behavior of exchange rates.

The empirical results from chapter 4 will shed light in answering three crucial questions. First, is the difficulty of finding evidence of cointegration and
mean reversion during floating rate periods due to the omission of long-run real factors from the regression? Second, is the problem of finding slow mean reversion, when mean reversion is found (this is often referred to as the PPP puzzle), also connected to the omission of long-run real factors? Finally, if long-run real factors are included in the cointegrating regression, then will the estimated coefficients for goods prices become more consistent with the predictions of symmetry and proportionality, i.e. will they be more consistent with the disequilibrium view?

The suggested evidence from our empirical work indicates that including real factors help us finding evidence of mean reversion (Johansen test) but it does not imply in faster mean reversion during the floating period. The results from the Johansen cointegration test for the floating period and adjusted to the degrees of freedom without including the real factors suggest that there is no cointegrating vector for three out of five countries (Canada, Germany and Japan), while the empirical results when (three) real factors are included suggest that no cointegration was found only for UK. Including the fourth real variable has resulted in finding no cointegration for two (Germany and UK) out of five countries. Therefore, we have stronger evidence of mean reversion for the nominal exchange rate and relative prices for the floating period once real factors are included, especially for the case where the cointegrating vector does not include the real interest rate differential.

The results from the estimation of the $\alpha$ coefficients from the Johansen cointegration test help us answering one of the questions proposed in our
introduction to chapter 4, which is whether or not temporary demand side shocks such as monetary shocks and overshooting behavior play any role for nominal exchange rates and relative prices and if they do, what is their importance relative to long-run real factors. We can say that the relative importance of nominal exchange rates and relative prices are far bigger than the relevance of real factors for all five OECD countries, with few exceptions. One of them is the role played by the discount rate for Canada and Japan when compared to relative prices, and for UK when compared to the nominal exchange rate and relative prices.

The empirical results from testing the restriction on the $\beta$ coefficients has provided the most striking empirical result of the entire dissertation. The coefficients are statistically indistinct from $[1 \ -1 \ 1]$ for Germany, Japan and UK with three real variables (domestic and US real GDP growth, and the discount rate), which is an indication that when we include real factors into our model, there is evidence supporting the disequilibrium view for three out of five OECD countries using quarterly data for the floating period. Once we have included a fourth real variable (real interest rate differential) the empirical results seems to support the disequilibrium view only for one (Germany) out of five countries. It should be emphasized that these results does not imply a rejection of the equilibrium view since they were obtained using a model specification that incorporates real factors such as the ones suggested by the real equilibrium model.
Interestingly, we can say that these empirical findings provide support to our original idea when developing chapter 4, which was that the disequilibrium view and the long-run real models are both relevant in explaining the movement of nominal exchange rates and relative prices over the long-run. The proposed argument is that the two views can be seen as comprising two components of one model for testing long-run behavior of exchange rates.

Finally, we can say that the empirical findings from chapter four help us answer in an affirmative way two of the three open questions listed in the introduction of this chapter. The difficulty in finding evidence of cointegration and mean reversion during floating rate periods can be (at least in part) explained by the omission of long-run (demand and supply-side) real factors, and the estimated coefficients for goods prices have become more consistent with the predictions of symmetry and proportionality and so with the disequilibrium view once we have included the real factors for three out of five OECD countries studied. On the other hand, the empirical findings from chapter 4 have not allowed us to relate the problem of finding slow mean reversion (the PPP puzzle) with the omission of long-run real factors.
BIBLIOGRAPHY


Goldberg, M.D. [2000] "Do Monetary Models of the Exchange Rate with RE Fit the Data?." Mimeo, Whittemore School of Business and Economics, University of New Hampshire.


APPENDIX A

Tables – Chapter One
Table I.1: Classification of Empirical Tests for Long-Run PPP (Three Stages)

<table>
<thead>
<tr>
<th>Stages</th>
<th>Empirical Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Officer [1976]; Frenkel [1978]; Frenkel [1981]; Krugman [1978]</td>
</tr>
</tbody>
</table>

1 The classification of the empirical studies into one of the three stages is somewhat imperfect since there are some studies that used mixed procedures from more than one stage tests. We have tried to classify them according to their major contribution and to the highest possible stage.
Table I.2: Empirical Results from the NATREX Model for the US Economy During the Floating Period

<table>
<thead>
<tr>
<th>Fundamentals</th>
<th>Impact on Real Exchange Rate</th>
<th>CA / GNP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive = appreciation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Negative = depreciation</td>
<td></td>
</tr>
<tr>
<td>(C + G) / GNP</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>US Growth</td>
<td>Positive •</td>
<td>Negative</td>
</tr>
<tr>
<td>Foreign Growth</td>
<td>Negative</td>
<td>Positive</td>
</tr>
</tbody>
</table>

* Time Preference (discount rate)

• Not significant

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APPENDIX B

Tables – Chapter Two
Table II.1: ADF Test on the Real Exchange Rate  
(With and without the time trend)  
\[ \Delta q_t = \alpha + \beta t + \gamma q_{t-1} + \phi(L) \Delta q_{t-1} + \varepsilon_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>12</td>
<td>-1.5417</td>
<td>1</td>
<td>-2.7882</td>
</tr>
<tr>
<td>France</td>
<td>13</td>
<td>-2.6876*</td>
<td>13</td>
<td>-3.0541</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>11</td>
<td>-2.3958</td>
<td>11</td>
<td>-3.2810*</td>
</tr>
<tr>
<td>Germany</td>
<td>13</td>
<td>-2.2577</td>
<td>13</td>
<td>-2.7134</td>
</tr>
<tr>
<td>Japan</td>
<td>12</td>
<td>-1.5971</td>
<td>12</td>
<td>-3.3094*</td>
</tr>
</tbody>
</table>

Level of Significance  
At 10%  
At 5%  
At 1%  

ADF Critical Values  
-2.57  
-2.868  
-3.446  

With Time Trend  
-3.13  
-3.421  
-3.982  

* = Significant at 10%  
** = Significant at 5%  
*** = Significant at 1%  

Real Exchange Rate: \( q = s + p^* - p \) (in natural log)  
Data from the IFS CD-ROM (Jan 1957 to Apr 1997)
Table II.2: ADF Test on the First Difference of the Nominal Exchange Rate ($\Delta S$) 
(With and without the time trend)

\[ \Delta \Delta S_t = \alpha + \beta t + \gamma \Delta S_{t-1} + \phi(L) \Delta \Delta S_{t-1} + \varepsilon_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>12</td>
<td>-4.8846***</td>
<td>12</td>
<td>-4.8895***</td>
</tr>
<tr>
<td>France</td>
<td>12</td>
<td>-4.8470***</td>
<td>12</td>
<td>-4.8129***</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>13</td>
<td>-6.0316***</td>
<td>13</td>
<td>-6.0277***</td>
</tr>
<tr>
<td>Germany</td>
<td>12</td>
<td>-4.8323***</td>
<td>12</td>
<td>-4.8183***</td>
</tr>
<tr>
<td>Japan</td>
<td>12</td>
<td>-5.0711***</td>
<td>12</td>
<td>-5.0621***</td>
</tr>
</tbody>
</table>

**Level of Significance**
- At 10% for Canada: -4.8846***
- At 5% for France: -4.8470***
- At 1% for United Kingdom: -6.0316***
- At 1% for Germany: -4.8323***
- At 1% for Japan: -5.0711***

**Critical Values from MacKinnon [1991]**
- ADF Critical Values with Trend:
  - At 10%: -2.57
  - At 5%: -2.868
  - At 1%: -3.446

- ADF Critical Values:
  - At 10%: -3.13
  - At 5%: -3.421
  - At 1%: -3.982

\* = Significant at 10% \** = significant at 5% \*** = significant at 1%

Data from the IFS CD-ROM (Jan 1957 to Apr 1997)

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Table II.3: ADF Test on the First Difference of the Domestic Price ($\Delta P$) 
(With and without the time trend)

$$\Delta \Delta P_t = \alpha + \beta t + \gamma \Delta P_{t-1} + \phi(L)\Delta \Delta P_{t-1} + \varepsilon_t$$

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>11</td>
<td>-1.6891</td>
<td>11</td>
<td>-1.6156</td>
</tr>
<tr>
<td>France</td>
<td>11</td>
<td>-3.1037**</td>
<td>11</td>
<td>-2.9782</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>13</td>
<td>-3.4461***</td>
<td>13</td>
<td>-2.4180</td>
</tr>
<tr>
<td>Germany</td>
<td>10</td>
<td>-3.7460***</td>
<td>10</td>
<td>-3.7402**</td>
</tr>
<tr>
<td>Japan</td>
<td>13</td>
<td>-2.9056**</td>
<td>13</td>
<td>-3.4686**</td>
</tr>
<tr>
<td>United States</td>
<td>13</td>
<td>-2.3114</td>
<td>13</td>
<td>-2.2959</td>
</tr>
</tbody>
</table>

Level of Significance
- At 10%
- At 5%
- At 1%

ADF Critical Values
-2.57
-2.868
-3.446

ADF Critical Values
-3.13
-3.421
-3.982

* = Significant at 10%  ** = significant at 5%  *** = significant at 1%

Critical Values from MacKinnon [1991]
Data from the IFS CD-ROM (Jan 1957 to Apr 1997)
Table II.4: OLS Regression for Developed Countries

\[ S = \alpha + \beta_1 P + \beta_2 P^* + \varepsilon \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>( \alpha )</th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>Durbin Watson</th>
<th>Wald Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>8.0169 (0.040452)</td>
<td>0.52859 (0.039488)</td>
<td>-1.2005 (0.040748)</td>
<td>0.0367</td>
<td>4468.1 **</td>
</tr>
<tr>
<td>Germany</td>
<td>4.4023 (0.21206)</td>
<td>-0.82544 (0.13474)</td>
<td>-0.0052608 (0.090798)</td>
<td>0.0396</td>
<td>2991.7 **</td>
</tr>
<tr>
<td>UK</td>
<td>-0.96966 (0.21343)</td>
<td>0.49422 (0.13374)</td>
<td>-0.38342 (0.13374)</td>
<td>0.0646</td>
<td>2271.6 **</td>
</tr>
<tr>
<td>France</td>
<td>2.9080 (0.12475)</td>
<td>1.4665 (0.095047)</td>
<td>-1.7144 (0.12133)</td>
<td>0.0484</td>
<td>476.58 **</td>
</tr>
<tr>
<td>Canada</td>
<td>-0.37636 (0.045199)</td>
<td>0.33514 (0.11188)</td>
<td>-0.19950 (0.12041)</td>
<td>0.0311</td>
<td>1264.5 **</td>
</tr>
</tbody>
</table>

All Variables are in natural log terms (S, P and P*)
Std. Errors in parenthesis
** Indicates we can reject the null that the coefficients are jointly insignificant (equal to zero)
Data from the IFS CD-ROM (Jan 1957 to Apr 1997)
### Table II.5: ADF Test on Estimated Residuals from OLS
2nd Step of Engel and Granger Procedure

\[ \Delta \varepsilon_t = \alpha + \gamma \varepsilon_{t-1} + \phi(L) \Delta \varepsilon_{t-1} + \mu_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF without intercept</th>
<th>k-max</th>
<th>t-ADF with intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>11</td>
<td>-2.8445</td>
<td>11</td>
<td>-2.8403</td>
</tr>
<tr>
<td>France</td>
<td>13</td>
<td>-2.9778</td>
<td>13</td>
<td>-2.9732</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>11</td>
<td>-3.4686</td>
<td>11</td>
<td>-3.4644</td>
</tr>
<tr>
<td>Germany</td>
<td>13</td>
<td>-3.2087</td>
<td>13</td>
<td>-3.2064</td>
</tr>
<tr>
<td>Japan</td>
<td>12</td>
<td>-3.6413*</td>
<td>12</td>
<td>-3.6375</td>
</tr>
</tbody>
</table>

**Level of Significance**
- At 10%
- At 5%
- At 1%

**ADF Critical Values**
- Without Intercept: -3.56, -3.86, -4.10
- With Intercept: -3.82, -4.46

* = Significant at 10%  ** = significant at 5%  *** = significant at 1%

Critical Values from Charenza and Deadman [1997]

Data from the IFS CD-ROM (Jan 1957 to Apr 1997)
Table 11.6: 1st Error-Correction Model
\[ \Delta s_t = \beta_0 + \beta_1(L)\Delta s_{t-1} + \beta_2(L)\Delta p_{t-1} + \beta_3(L)\Delta p^*_{t-1} + \beta_4 q_{t-1} \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated ( \beta_4 ) (t-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.0057169 (-0.943)</td>
</tr>
<tr>
<td>France</td>
<td>0.017635 (-1.875)*</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>-0.020924 (-2.399)**</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.0094207 (-1.47)</td>
</tr>
<tr>
<td>Japan</td>
<td>0.00048537 (0.172)</td>
</tr>
</tbody>
</table>

Data from IFS from the IMF CD-ROM from Jan /'57 to Apr /'97

where* indicates significance at the 10% level and ** at the 5% level.
Table II.7: 2nd Error-Correction Model

\[ \Delta s_t = \alpha + \beta (\Delta(p - p^*)_t) + \delta (s - p + p^*)_{t-1} \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated ( \delta ) (t-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.0058748 (-0.975)</td>
</tr>
<tr>
<td>France</td>
<td>-0.016426 (-1.880)*</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>-0.015954 (-1.909)*</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.0059994 (-1.006)</td>
</tr>
<tr>
<td>Japan</td>
<td>0.00048422 (0.174)</td>
</tr>
</tbody>
</table>

Data from IFS CD-ROM from the IMF from Jan / 57 to Apr / 97

where * indicates significance at the 10% level and ** at the 5% level
Table II.8: Half-Lives of the Nominal Exchange Rate for OECD Countries
Results from Two Error Correction Models

<table>
<thead>
<tr>
<th>Countries</th>
<th>First EC Model</th>
<th>Second EC Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated Coefficient on q.t</td>
<td>Half Lives [LN (0.5) / (Coefficient)] / 12</td>
</tr>
<tr>
<td>Canada # ##</td>
<td>-0.005716</td>
<td>10.103</td>
</tr>
<tr>
<td>France</td>
<td>-0.017635</td>
<td>3.275</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>-0.020924</td>
<td>2.760</td>
</tr>
<tr>
<td>Germany # ##</td>
<td>-0.009420</td>
<td>6.131</td>
</tr>
<tr>
<td>Japan # ##</td>
<td>0.0004853</td>
<td>119.006</td>
</tr>
<tr>
<td>Average*</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Average **</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Total Average ***</td>
<td>4.25</td>
<td>5.05</td>
</tr>
</tbody>
</table>

# indicates that the coefficients used for calculation are not significant in the first ECM model
## indicates that the coefficients used for calculation are not significant in the second ECM model
* without including Japan, which is an outlier.
** average using only countries with significant coefficient.
*** Total Average = (Average* + Average**) / 2

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Table II.9: Granger Causality Test

$\Delta s \rightarrow \Delta(p - p^*)$ and $\Delta(p - p^*) \rightarrow \Delta s$

**Null Hypothesis: No Granger Causality**

<table>
<thead>
<tr>
<th>Countries</th>
<th>$\Delta (p - p^*) \rightarrow \Delta s$</th>
<th>Reject Ho</th>
<th>$\Delta s \rightarrow \Delta(p - p^*)$</th>
<th>Reject Ho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>F-stat 0.57436 (0.63211) No</td>
<td></td>
<td>F-stat 0.54041 (0.65482) No</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>F-stat 1.29015 (0.27712) No</td>
<td></td>
<td>F-stat 5.96182 (0.00054) Yes</td>
<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td>F-stat 0.70162 (0.55142) No</td>
<td></td>
<td>F-stat 0.30990 (0.81824) No</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>F-stat 2.03313 (0.10841) No</td>
<td></td>
<td>F-stat 0.35436 (0.78601) No</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>F-stat 0.27558 (0.84302) No</td>
<td></td>
<td>F-stat 0.71655 (0.54246) No</td>
<td></td>
</tr>
</tbody>
</table>

Source: IMF CD-ROM / IFS - Monthly Data from January of 1957 to April of 1997

Probability in Parenthesis

All variables are in natural log.
Table II.10: Number of Lags and the Schwartz Criteria for Selected OECD Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Lags *</th>
<th>Maximum SBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>5 with trend</td>
<td>7811.1798</td>
</tr>
<tr>
<td>France</td>
<td>13 no trend</td>
<td>7367.1398</td>
</tr>
<tr>
<td>Germany</td>
<td>13 no trend</td>
<td>7367.6598</td>
</tr>
<tr>
<td>Japan</td>
<td>13 no trend</td>
<td>6982.1798</td>
</tr>
<tr>
<td>UK</td>
<td>13 no trend</td>
<td>7107.1898</td>
</tr>
</tbody>
</table>

* The choice of lag for each country was based on the maximum value for the SBC using the log likelihood function from the Johansen test for cointegration using lags from one to thirteen for each country.
### Table II.11: Diagnostic Test for Selected OECD Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Order of System</th>
<th>Nominal Exchange Rate (s)</th>
<th>Domestic Price (p)</th>
<th>Foreign Price (p*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>AR (5)</td>
<td>bb,</td>
<td>a,bb</td>
<td>aa,bb,cc</td>
</tr>
<tr>
<td>France</td>
<td>AR (13)</td>
<td>bb,</td>
<td>bb,cc,dd</td>
<td>a,bb,cc</td>
</tr>
<tr>
<td>Germany</td>
<td>AR (13)</td>
<td>bb,cc,d</td>
<td>bb</td>
<td>a,bb,c,d</td>
</tr>
<tr>
<td>Japan</td>
<td>AR (13)</td>
<td>bb,cc,dd</td>
<td>bb,cc,dd</td>
<td>bb,cc</td>
</tr>
<tr>
<td>UK</td>
<td>AR (13)</td>
<td>bb,cc,</td>
<td>bb</td>
<td>bb,c</td>
</tr>
</tbody>
</table>

The Table reports significance levels for four diagnostic tests:

i) An f-statistic on one-to-seven lags for serial correlation

ii) Doornik and Hansen (1994) chi-square test for normality

iii) The f-form of the ARCH test


Significance level are denoted by the letters a, b, c and d for these four tests respectively.

One letter denotes significance at the 10% level, two letters at the 5% level and three letters at the 1% level.
Table II.12: Johansen Test for Cointegration for Selected OECD Countries
Unadjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>r = 0 Max</th>
<th>Trace</th>
<th>r ≤ 1 Max</th>
<th>Trace</th>
<th>r ≤ 2 Max</th>
<th>Trace</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Canada</td>
<td>11.65</td>
<td>19.26</td>
<td>6.65</td>
<td>7.605</td>
<td>0.9549</td>
<td>0.9549</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>17.61</td>
<td>31.34*</td>
<td>9.184</td>
<td>13.73</td>
<td>4.542*</td>
<td>4.542*</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>17.05</td>
<td>29.11</td>
<td>11.33</td>
<td>12.05</td>
<td>0.7227</td>
<td>0.7227</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>23.27*</td>
<td>41.09**</td>
<td>13.94</td>
<td>17.82*</td>
<td>3.887*</td>
<td>3.887*</td>
</tr>
<tr>
<td></td>
<td>UK</td>
<td>24.86*</td>
<td>39.58**</td>
<td>12.43</td>
<td>14.72</td>
<td>2.293</td>
<td>2.293</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have not been adjusted for degrees of freedom.
Significance levels are based on Doornik and Hendry [1997]
where ** denotes significance at the 5% level and * denotes significance at the 10% level.
**Table II.13: Johansen Test for Cointegration for Selected OECD Countries**

**Adjusted Trace and Max Eigenvalue Statistics**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>$r = 0$</th>
<th>$r \leq 1$</th>
<th>$r \leq 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Canada</td>
<td>11.29</td>
<td>18.65</td>
<td>6.442</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>16.15</td>
<td>28.74</td>
<td>8.423</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>15.64</td>
<td>26.7</td>
<td>10.39</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>21.34*</td>
<td>37.68**</td>
<td>12.78</td>
</tr>
<tr>
<td></td>
<td>UK</td>
<td>22.8*</td>
<td>36.3**</td>
<td>11.4</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have been adjusted for degrees of freedom.
Significance levels are based on Doornik and Hendry [1997]
where ** denotes significance at the 5% level and * denotes significance at the 10% level.
Table II.14: Testing the Restriction $[1 -1 1]$ on the $\beta$ Coefficients from the Johansen Cointegration Test
Allowing for At Least One Cointegrating Vector for OECD Countries (1957-97)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Ho: Cointegrating Vector is Not Statistically Different from $[1 -1 1]$ for $s$, $p$ and $p*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>rank=1: Chi^2(2) = 7.6404 [0.0219] *</td>
</tr>
<tr>
<td>France</td>
<td>rank=1: Chi^2(2) = 6.4106 [0.0405] *</td>
</tr>
<tr>
<td>Germany</td>
<td>rank=1: Chi^2(2) = 12.023 [0.0025] **</td>
</tr>
<tr>
<td>Japan</td>
<td>rank=1: Chi^2(2) = 15.793 [0.0004] **</td>
</tr>
<tr>
<td>UK</td>
<td>rank=1: Chi^2(2) = 12.824 [0.0016] **</td>
</tr>
</tbody>
</table>

The tests statistics is a Chi-Square
Data from the IFS CD-Rom (Jan 1957 to Apr 1997)
Table II.15: ADF Test on Estimated Residuals from OLS (Floating Period)
2nd Step of Engel and Granger Procedure

\[ \Delta \varepsilon_t = \alpha + \gamma \varepsilon_{t-1} + \phi(L) \Delta \varepsilon_{t-1} + \mu_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF without intercept</th>
<th>k-max</th>
<th>t-ADF with intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>11</td>
<td>-2.8104</td>
<td>11</td>
<td>-2.8078</td>
</tr>
<tr>
<td>France</td>
<td>13</td>
<td>-2.7301</td>
<td>13</td>
<td>-2.7205</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>11</td>
<td>-2.7185</td>
<td>11</td>
<td>-2.7136</td>
</tr>
<tr>
<td>Germany</td>
<td>7</td>
<td>-1.9793</td>
<td>7</td>
<td>-1.9779</td>
</tr>
<tr>
<td>Japan</td>
<td>12</td>
<td>-2.8697</td>
<td>12</td>
<td>-2.8606</td>
</tr>
</tbody>
</table>

Level of Significance
- At 10%
- At 5%
- At 1%

ADF Critical Values
- With Intercept
- At 10%: -3.57
- At 5%: -3.87
- At 1%: -4.46

* = Significant at 10%  ** = significant at 5%  *** = significant at 1%

Critical Values from Charenza and Deadman [1997]
Data from the IFS CD-ROM (Mar 1973 to Apr 1997)

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Table II.16: 1st Error-Correction Model for the Floating Period
\[ \Delta s_t = \beta_0 + \beta_1(L)\Delta s_{t-1} + \beta_2(L)\Delta p_{t-1} + \beta_3(L)\Delta p^*_{t-1} + \beta_4 q_{t-1} \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated ( \beta_4 ) (t-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.0098295 (-1.093)</td>
</tr>
<tr>
<td>France</td>
<td>-0.024318 (-1.844)*</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>-0.029423 (-2.111)**</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.020770 (-1.693)*</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.011106 (-1.280)</td>
</tr>
</tbody>
</table>

Data from IFS from the IMF CD-ROM from Mar / 73 to Apr / 97
where * indicates significance at the 10% level and ** at the 5% level

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Table II.17: 2nd Error-Correction Model for the Floating Period

$$\Delta s_t = \alpha + \beta \left( \Delta(p - p^*)_t \right) + \delta (s - p + p^*)_{t-1}$$

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated $\delta$ (t-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.0091506 (-1.082)</td>
</tr>
<tr>
<td>France</td>
<td>-0.020786 (-1.173)</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>-0.021547 (-1.558)</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.017696 (-1.475)</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.0071909 (-0.879)</td>
</tr>
</tbody>
</table>

Data from IFS CD-ROM from the IMF from Mar/73 to Apr/97

where * indicates significance at the 10% level and ** at the 5% level.
Table II.18: Half-Lives of the Nominal Exchange Rate for OECD Countries
Results from Two Error Correction Models
(Floating Period)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated Coefficient on q,1</th>
<th>Half Lives [LN (0.5) / (Coefficient)] / 12</th>
<th>Estimated Coefficient on q,1</th>
<th>Half Lives [LN (0.5) / (Coefficient)] / 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada #</td>
<td>-0.0098295</td>
<td>5.876</td>
<td>-0.0091506</td>
<td>6.312</td>
</tr>
<tr>
<td>France</td>
<td>-0.024318</td>
<td>2.375</td>
<td>-0.020786</td>
<td>2.779</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>-0.029423</td>
<td>1.963</td>
<td>-0.021547</td>
<td>2.680</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.020770</td>
<td>2.781</td>
<td>-0.017696</td>
<td>3.264</td>
</tr>
<tr>
<td>Japan #</td>
<td>-0.011106</td>
<td>5.20</td>
<td>-0.0071909</td>
<td>8.032</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>3.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average *</td>
<td></td>
<td>2.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Average **</td>
<td></td>
<td>3.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# indicates that the coefficients used for calculation are not significant in the first ECM model
All the coefficients used from the second ECM are not significant
* average using only countries with significant coefficient for the first EC model
** Total Average = [(Average + Average*) / 2], which is valid only for the first EC model
### Table II.19: Diagnostic Test for Selected OECD Countries (Floating Period)

<table>
<thead>
<tr>
<th>Country</th>
<th>Order of System</th>
<th>Nominal Exchange Rate (s)</th>
<th>Domestic Price (p)</th>
<th>Foreign Price (p*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>AR (5)</td>
<td>bb,</td>
<td>bb,</td>
<td>aa,bb,dd</td>
</tr>
<tr>
<td>France</td>
<td>AR (13)</td>
<td>bb,</td>
<td>bb,</td>
<td>bb,dd</td>
</tr>
<tr>
<td>Germany</td>
<td>AR (13)</td>
<td>a,bb,</td>
<td>bb,</td>
<td>a,bb,dd</td>
</tr>
<tr>
<td>Japan</td>
<td>AR (13)</td>
<td>bb,cc,</td>
<td>bb,cc,dd,</td>
<td>bb,c,dd</td>
</tr>
<tr>
<td>UK</td>
<td>AR (13)</td>
<td>bb,c,</td>
<td>aa,bb,</td>
<td>bb,d</td>
</tr>
</tbody>
</table>

The Table reports significance levels for four diagnostic tests:

- v) An f-statistic on one-to-seven lags for serial correlation
- vi) Doornik and Hansen (1994) chi-square test for normality
- vii) The f-form of the ARCH test

Significance levels are denoted by the letters a, b, c and d for these four tests respectively.

One letter denotes significance at the 10% level, two letters at the 5% level and three letters at the 1% level.
Table II.20: Johansen Test for Cointegration for Selected OECD Countries
(Floating Period)
Unadjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>$r = 0$</th>
<th>$r \leq 1$</th>
<th>$r \leq 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Max</td>
<td>Trace</td>
</tr>
<tr>
<td>1</td>
<td>Canada</td>
<td>19.03</td>
<td>25.76</td>
<td>5.61</td>
</tr>
<tr>
<td>2</td>
<td>France</td>
<td>25.06*</td>
<td>37.76**</td>
<td>10.27</td>
</tr>
<tr>
<td>3</td>
<td>Germany</td>
<td>22.04*</td>
<td>34.89*</td>
<td>9.593</td>
</tr>
<tr>
<td>4</td>
<td>Japan</td>
<td>56.43**</td>
<td>75.63**</td>
<td>13.94</td>
</tr>
<tr>
<td>5</td>
<td>UK</td>
<td>32.71**</td>
<td>59.28**</td>
<td>18.07*</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have not been adjusted for degrees of freedom.
Significance levels are based on Doornik and Hendry [1997],
where ** denotes significance at the 5% level and * denotes significance at the
10% level.
Table II.21: Johansen Test for Cointegration for Selected OECD Countries (Floating Period)
Adjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>r = 0</th>
<th>r ≤ 1</th>
<th>r ≤ 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
</tr>
<tr>
<td>1</td>
<td>Canada</td>
<td>18.03</td>
<td>24.41</td>
<td>5.314</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>21.69*</td>
<td>32.68*</td>
<td>8.892</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>19.08</td>
<td>30.02*</td>
<td>8.303</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>48.81**</td>
<td>65.43**</td>
<td>12.06</td>
</tr>
<tr>
<td></td>
<td>UK</td>
<td>28.31**</td>
<td>51.31**</td>
<td>15.64*</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have been adjusted for degrees of freedom
Significance levels are based on Doornik and Hendry [1997]
where ** denotes significance at the 5% level and * denotes significance at the 10% level.
Table II.22: Testing the Restriction $[1 -1 1]$ on the $\beta$ Coefficients from the Johansen Cointegration Test
Allowing for At Least One Cointegrating Vector for OECD Countries (Floating Period)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Ho: Cointegrating Vector is Not Statistically Different from $[1 -1 1]$ for $s$, $p$ and $p^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>rank=1: $\text{Chi}^2(2) = 16.339 [0.0003]$ **</td>
</tr>
<tr>
<td>France</td>
<td>rank=1: $\text{Chi}^2(2) = 15.779 [0.0004]$ **</td>
</tr>
<tr>
<td>Germany</td>
<td>rank=1: $\text{Chi}^2(2) = 15.544 [0.0004]$ **</td>
</tr>
</tbody>
</table>
| Japan     | rank=1: $\text{Chi}^2(2) = 48.142 [0.0000]$ **
           | rank=2: $\text{Chi}^2(5) = 62.079 [0.0000]$ **                                                             |
| UK        | rank=1: $\text{Chi}^2(2) = 21.408 [0.0000]$ **
           | rank=2: $\text{Chi}^2(5) = 39.476 [0.0000]$ **                                                             |

The test statistics is a Chi-Squared
Data from IFS CD-Rom from Mar 1973 to Apr 1997

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APPENDIX C

Tables – Chapter Three
Table III.1: ADF Test on the Real Exchange Rate (q)  
(With and without time trend)  
\[ \Delta q_t = \alpha + \beta t + \gamma q_{t-1} + \phi(L) \Delta q_{t-1} + \varepsilon_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>8</td>
<td>-2.5755</td>
<td>8</td>
<td>-2.7120</td>
</tr>
<tr>
<td>Bolivia</td>
<td>12</td>
<td>-2.5941 *</td>
<td>12</td>
<td>-2.6731</td>
</tr>
<tr>
<td>Brazil</td>
<td>10</td>
<td>-1.3875</td>
<td>10</td>
<td>-1.4244</td>
</tr>
<tr>
<td>Chile</td>
<td>10</td>
<td>-1.4836</td>
<td>10</td>
<td>-2.7964</td>
</tr>
<tr>
<td>Mexico</td>
<td>12</td>
<td>-3.4860 ***</td>
<td>12</td>
<td>-3.6537 **</td>
</tr>
<tr>
<td>Paraguay</td>
<td>9</td>
<td>-2.2586</td>
<td>9</td>
<td>-2.3841</td>
</tr>
<tr>
<td>Uruguay</td>
<td>13</td>
<td>-2.2682</td>
<td>13</td>
<td>-2.0091</td>
</tr>
<tr>
<td>Colombia</td>
<td>9</td>
<td>-1.2761</td>
<td>9</td>
<td>-1.4366</td>
</tr>
<tr>
<td>Venezuela</td>
<td>3</td>
<td>-1.7751</td>
<td>13</td>
<td>-2.4723</td>
</tr>
<tr>
<td>Peru</td>
<td>9</td>
<td>0.95706</td>
<td>9</td>
<td>-1.5856</td>
</tr>
<tr>
<td>Ecuador</td>
<td>10</td>
<td>-1.2930</td>
<td>10</td>
<td>-1.7586</td>
</tr>
</tbody>
</table>

**Level of Significance**  
At 10%  At 5%  At 1%  

**ADF Critical Values**  
With and without time trend  
-2.57 -2.868 -3.447  
-3.13 -3.422 -3.983

* = significant at 10%  ** = significant at 5%  *** = significant at 1%  
Real Exchange Rate: \( q = s + p^* - p \) (in log terms)  
Data from IFS CD-ROM from Jan / 57 to Mar / 97
Table III.2: ADF Test on the First Difference of the Nominal Exchange Rate 
($\Delta S$) (With and without the time trend)

$$\Delta \Delta S_t = \alpha + \beta t + \gamma S_{t-1} + \Phi(L) \Delta S_{t-1} + \epsilon_t$$

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>7</td>
<td>-4.1301 ***</td>
<td>7</td>
<td>-4.2194 **</td>
</tr>
<tr>
<td>Brazil</td>
<td>10</td>
<td>-2.8431 *</td>
<td>10</td>
<td>-3.4036 *</td>
</tr>
<tr>
<td>Chile</td>
<td>13</td>
<td>-3.5900 ***</td>
<td>13</td>
<td>-3.6813 **</td>
</tr>
<tr>
<td>Mexico</td>
<td>9</td>
<td>-3.5619 **</td>
<td>13</td>
<td>-3.8294 **</td>
</tr>
<tr>
<td>Paraguay</td>
<td>8</td>
<td>-6.7510 ***</td>
<td>8</td>
<td>-7.1143 ***</td>
</tr>
<tr>
<td>Uruguay</td>
<td>13</td>
<td>-5.8263 ***</td>
<td>13</td>
<td>-5.9894 ***</td>
</tr>
<tr>
<td>Colombia</td>
<td>8</td>
<td>-6.4083 ***</td>
<td>8</td>
<td>-6.6837 ***</td>
</tr>
<tr>
<td>Venezuela</td>
<td>3</td>
<td>-10.061 ***</td>
<td>13</td>
<td>-6.7908 ***</td>
</tr>
<tr>
<td>Bolivia</td>
<td>13</td>
<td>-3.2985 **</td>
<td>13</td>
<td>-3.3466 **</td>
</tr>
<tr>
<td>Peru</td>
<td>8</td>
<td>-4.1458 ***</td>
<td>8</td>
<td>-4.4325 **</td>
</tr>
<tr>
<td>Ecuador</td>
<td>9</td>
<td>-4.1777 **</td>
<td>9</td>
<td>-5.1503 ***</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level of Significance</th>
<th>At 10%</th>
<th>At 5%</th>
<th>At 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF Critical Values</td>
<td>-2.57</td>
<td>-2.86</td>
<td>-3.44</td>
</tr>
<tr>
<td>ADF Critical Values</td>
<td>-3.13</td>
<td>-3.42</td>
<td>-3.98</td>
</tr>
</tbody>
</table>

* = significant at 10%  ** = significant at 5%  *** = significant at 1%

Critical values from MacKinnon [1991]

Data from IFS CD-ROM from Jan / 57 to Mar / 97
Table III.3: ADF Test on the First Difference of the Domestic Price (ΔP)
(With and without the time trend)

\[ \Delta \Delta p_t = \alpha + \beta t + \gamma \Delta p_{t-1} + \phi(L) \Delta \Delta p_{t-1} + \varepsilon_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>12</td>
<td>-3.2273 **</td>
<td>6</td>
<td>-3.2944 *</td>
</tr>
<tr>
<td>Brazil</td>
<td>10</td>
<td>-2.4563</td>
<td>10</td>
<td>-2.7317</td>
</tr>
<tr>
<td>Chile</td>
<td>11</td>
<td>-1.7870</td>
<td>11</td>
<td>-1.8819</td>
</tr>
<tr>
<td>Mexico</td>
<td>12</td>
<td>-2.6280 *</td>
<td>12</td>
<td>-3.0071</td>
</tr>
<tr>
<td>Paraguay</td>
<td>11</td>
<td>-3.3221 **</td>
<td>11</td>
<td>-4.0502 ***</td>
</tr>
<tr>
<td>Uruguay</td>
<td>6</td>
<td>-4.4943 ***</td>
<td>6</td>
<td>-4.4964 ***</td>
</tr>
<tr>
<td>Colombia</td>
<td>11</td>
<td>-3.3745 ***</td>
<td>11</td>
<td>-4.2390 ***</td>
</tr>
<tr>
<td>Venezuela</td>
<td>11</td>
<td>-2.5520</td>
<td>9</td>
<td>-5.4103 ***</td>
</tr>
<tr>
<td>Bolivia</td>
<td>10</td>
<td>-3.5466 ***</td>
<td>10</td>
<td>-3.5833 **</td>
</tr>
<tr>
<td>Peru</td>
<td>4</td>
<td>-3.8622 ***</td>
<td>4</td>
<td>-4.1181 ***</td>
</tr>
<tr>
<td>Ecuador</td>
<td>13</td>
<td>-2.4136</td>
<td>13</td>
<td>-4.1389 ***</td>
</tr>
<tr>
<td>United States</td>
<td>13</td>
<td>-2.3114</td>
<td>13</td>
<td>-2.2959</td>
</tr>
</tbody>
</table>

Level of Significance:
- At 10%
- At 5%
- At 1%

ADF Critical Values:
- With and without the time trend

Data from IFS CD-ROM from Jan / 57 to Mar / 97

* = significant at 10%  ** = significant at 5%  *** = significant at 1%

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Table III.4: OLS Regression for Latin America
1st Step of Engel and Granger Procedure
\[ s = \alpha + \beta_1 p + \beta_2 p^* + \epsilon_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>( \alpha )</th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>DW</th>
<th>Wald Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>-0.019127</td>
<td>0.0003</td>
<td>-1.1794</td>
<td>0.105</td>
<td>2.5906e+005 **</td>
</tr>
<tr>
<td></td>
<td>(0.47894)</td>
<td>(0.0061799)</td>
<td>(0.10528)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>-12.589</td>
<td>0.96611</td>
<td>-0.50013</td>
<td>0.047</td>
<td>9.9168e+005 **</td>
</tr>
<tr>
<td></td>
<td>(0.13471)</td>
<td>(0.0019559)</td>
<td>(0.031367)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>4.5456</td>
<td>1.0811</td>
<td>-0.85559</td>
<td>0.0991</td>
<td>1.6685e+005 **</td>
</tr>
<tr>
<td></td>
<td>(0.36903)</td>
<td>(0.010861)</td>
<td>(0.092811)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colombia</td>
<td>6.2391</td>
<td>1.1644</td>
<td>-1.2229</td>
<td>0.0516</td>
<td>40013 **</td>
</tr>
<tr>
<td></td>
<td>(0.27572)</td>
<td>(0.024910)</td>
<td>(0.084435)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>1.3224</td>
<td>1.0384</td>
<td>-1.0933</td>
<td>0.111</td>
<td>1.1676e+005 **</td>
</tr>
<tr>
<td></td>
<td>(0.12207)</td>
<td>(0.0068159)</td>
<td>(0.032044)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolivia</td>
<td>3.1289</td>
<td>1.0566</td>
<td>-1.5021</td>
<td>0.595</td>
<td>2.9871e+005 **</td>
</tr>
<tr>
<td></td>
<td>(0.16451)</td>
<td>(0.0038076)</td>
<td>(0.038403)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Venezuela</td>
<td>1.8191</td>
<td>1.0743</td>
<td>-0.69163</td>
<td>0.122</td>
<td>23732 **</td>
</tr>
<tr>
<td></td>
<td>(0.0847)</td>
<td>(0.01167)</td>
<td>(0.028446)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peru</td>
<td>-3.5006</td>
<td>0.92463</td>
<td>-0.54005</td>
<td>0.201</td>
<td>5.0276e+005 **</td>
</tr>
<tr>
<td></td>
<td>(0.13938)</td>
<td>(0.0024764)</td>
<td>(0.031359)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecuador</td>
<td>6.7953</td>
<td>1.1580</td>
<td>-1.2505</td>
<td>0.0639</td>
<td>55336 **</td>
</tr>
<tr>
<td></td>
<td>(0.10913)</td>
<td>(0.0094007)</td>
<td>(0.032326)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paraguay</td>
<td>8.9236</td>
<td>1.3864</td>
<td>-1.8270</td>
<td>0.109</td>
<td>19259 **</td>
</tr>
<tr>
<td></td>
<td>(0.12032)</td>
<td>(0.017377)</td>
<td>(0.042054)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uruguay</td>
<td>-30.936</td>
<td>-0.23098</td>
<td>6.7888</td>
<td>0.0261</td>
<td>1092.5 **</td>
</tr>
<tr>
<td></td>
<td>(3.6499)</td>
<td>(0.10461)</td>
<td>(0.89780)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All Variables are in natural log
Std. Errors in parenthesis
** Indicates we can reject the null that the coefficients are jointly insignificant (equal to zero)
Data from IFS CD-Rom from Jan / 57 to Mar / 97
Table III.5: ADF Test on Estimated Residuals from OLS

\[ \Delta e_t = \alpha + \gamma e_{t-1} + \phi(L) \Delta e_{t-1} + \mu_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>8</td>
<td>-2.6642</td>
<td>8</td>
<td>-2.6648</td>
</tr>
<tr>
<td>Bolivia</td>
<td>11</td>
<td>-4.4059**</td>
<td>11</td>
<td>-4.4062**</td>
</tr>
<tr>
<td>Brazil</td>
<td>10</td>
<td>-2.3481</td>
<td>10</td>
<td>-2.3346</td>
</tr>
<tr>
<td>Chile</td>
<td>10</td>
<td>-2.9961</td>
<td>10</td>
<td>-2.9917</td>
</tr>
<tr>
<td>Colombia</td>
<td>9</td>
<td>-1.1577</td>
<td>9</td>
<td>-1.0950</td>
</tr>
<tr>
<td>Mexico</td>
<td>12</td>
<td>-3.7365*</td>
<td>12</td>
<td>-3.7347</td>
</tr>
<tr>
<td>Ecuador</td>
<td>10</td>
<td>-1.9372</td>
<td>10</td>
<td>-1.9283</td>
</tr>
<tr>
<td>Paraguay</td>
<td>9</td>
<td>-3.6108*</td>
<td>9</td>
<td>-3.5930</td>
</tr>
<tr>
<td>Peru</td>
<td>9</td>
<td>-3.5779*</td>
<td>9</td>
<td>-3.5855</td>
</tr>
<tr>
<td>Uruguay</td>
<td>0</td>
<td>-1.8518</td>
<td>0</td>
<td>-1.8530</td>
</tr>
<tr>
<td>Venezuela</td>
<td>0</td>
<td>-3.7062*</td>
<td>0</td>
<td>-3.7002</td>
</tr>
</tbody>
</table>

Level of Significance

| ADF Critical Values Without the Constant | 3.56 | 3.86 | 4.46 |
| ADF Critical Values With the Constant  | 3.82 | 4.10 | 4.63 |

* = significant at 10%  ** = significant at 5%  *** = significant at 1%

Data from IFS CD-Rom from Jan / 57 to Mar / 97
Table III.6: 1st Error-Correction Model

\[ \Delta s_t = \beta_0 + \beta_1(L)\Delta s_{t-1} + \beta_2(L)\Delta p_{t-1} + \beta_3(L)\Delta p^*_{t-1} + \beta_4q_{t-1} \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated ( \beta_4 ) (t-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>-0.019100 (-0.0630)</td>
</tr>
<tr>
<td>Brazil</td>
<td>-0.024243 (-1.952) *</td>
</tr>
<tr>
<td>Chile</td>
<td>-0.015539 (-1.987) **</td>
</tr>
<tr>
<td>Mexico</td>
<td>-0.062653 (-2.947) **</td>
</tr>
<tr>
<td>Paraguay</td>
<td>-0.021497 (-2.018) **</td>
</tr>
<tr>
<td>Uruguay</td>
<td>-0.014256 (-2.385) **</td>
</tr>
<tr>
<td>Colombia</td>
<td>-0.0132233 (-1.968) **</td>
</tr>
<tr>
<td>Venezuela</td>
<td>-0.0018179 (-0.146)</td>
</tr>
<tr>
<td>Bolivia</td>
<td>-0.31822 (-7.757) **</td>
</tr>
<tr>
<td>Peru</td>
<td>-0.034256 (-2.108) **</td>
</tr>
<tr>
<td>Ecuador</td>
<td>0.0069977 (0.712)</td>
</tr>
</tbody>
</table>

Data from IFS from the IMF from Jan / 57 to Mar / 97
* = significant at 10% and ** = significant at 5%

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Table III.7: 2nd Error-Correction Model

\[ \Delta s_t = \alpha + \beta \left[ \Delta (p - p^*)_t \right] + \delta (s - p + p^*)_{t-1} \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated ( \delta ) (t-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>-0.089347 (-4.640) **</td>
</tr>
<tr>
<td>Brazil</td>
<td>-0.033536 (-3.179) **</td>
</tr>
<tr>
<td>Chile</td>
<td>-0.013038 (-1.910) *</td>
</tr>
<tr>
<td>Mexico</td>
<td>-0.082831 (-4.607) **</td>
</tr>
<tr>
<td>Paraguay</td>
<td>-0.016600 (-1.701) *</td>
</tr>
<tr>
<td>Uruguay</td>
<td>-0.012177 (-2.284) **</td>
</tr>
<tr>
<td>Colombia</td>
<td>-0.011845 (-1.800) *</td>
</tr>
<tr>
<td>Venezuela</td>
<td>-0.045349 (-4.415) **</td>
</tr>
<tr>
<td>Bolivia</td>
<td>-0.23931 (-7.588) **</td>
</tr>
<tr>
<td>Peru</td>
<td>-0.011825 (-1.183)</td>
</tr>
<tr>
<td>Ecuador</td>
<td>0.0020233 (0.230)</td>
</tr>
</tbody>
</table>

Data from IFS from the IMF from Jan / 57 to Mar / 97
* = Significant at 10% and ** = significant at 5%

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### Table III.8: The Half-Lives Using Coefficients Estimated From Two ECM Models on the Nominal Exchange Rate

<table>
<thead>
<tr>
<th>Countries</th>
<th>First ECM</th>
<th>Second ECM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated Coefficient on ( q_{-1} )</td>
<td>Half-Lives ( \frac{\ln(0.5)}{(\text{Coefficient})} ) / 12</td>
</tr>
<tr>
<td>Argentina #</td>
<td>-0.0191</td>
<td>3.02</td>
</tr>
<tr>
<td>Brazil</td>
<td>-0.024243</td>
<td>2.38</td>
</tr>
<tr>
<td>Chile</td>
<td>-0.015539</td>
<td>3.71</td>
</tr>
<tr>
<td>Mexico</td>
<td>-0.062653</td>
<td>0.92</td>
</tr>
<tr>
<td>Paraguay</td>
<td>-0.021497</td>
<td>2.68</td>
</tr>
<tr>
<td>Uruguay</td>
<td>-0.014256</td>
<td>4.05</td>
</tr>
<tr>
<td>Colombia</td>
<td>-0.013233</td>
<td>4.36</td>
</tr>
<tr>
<td>Venezuela #</td>
<td>-0.0018179</td>
<td>31.7</td>
</tr>
<tr>
<td>Bolivia</td>
<td>-0.31822</td>
<td>0.18</td>
</tr>
<tr>
<td>Peru ##</td>
<td>0.034256</td>
<td>1.68</td>
</tr>
<tr>
<td>Ecuador #</td>
<td>0.0069977</td>
<td>8.25</td>
</tr>
<tr>
<td>Average *</td>
<td>2.49</td>
<td></td>
</tr>
<tr>
<td>Average **</td>
<td>3.12</td>
<td></td>
</tr>
<tr>
<td>Total Average</td>
<td>2.80</td>
<td></td>
</tr>
</tbody>
</table>

# indicates that the coefficients used for calculation are not significant in the first ECM model.
## indicates that the coefficients used for calculation are not significant in the second ECM model.
* average using only countries with significant coefficient.
** average including all countries except Venezuela (first ECM model) and Ecuador (second ECM model).
*** Total Average = (Average * + Average **) / 2
<table>
<thead>
<tr>
<th>Countries</th>
<th>( \Delta(P - P^*) \rightarrow \Delta S )</th>
<th>F-stat</th>
<th>Reject Ho</th>
<th>( \Delta S \rightarrow \Delta(P - P^*) )</th>
<th>F-stat</th>
<th>Reject Ho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>4.86180 (0.00244)</td>
<td>Yes</td>
<td></td>
<td>64.5665 (0.00000)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>43.4462 (0.00000)</td>
<td>Yes</td>
<td></td>
<td>6.52646 (0.00025)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>4.16908 (0.00625)</td>
<td>Yes</td>
<td></td>
<td>0.67361 (0.56855)</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Colombia</td>
<td>2.74236 (0.04273)</td>
<td>Yes</td>
<td></td>
<td>5.97484 (0.00053)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Bolivia</td>
<td>59.0042 (0.00000)</td>
<td>Yes</td>
<td></td>
<td>17.8951 (5.6E-11)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>9.81035 (2.7E-06)</td>
<td>Yes</td>
<td></td>
<td>11.4114 (3.1E-07)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Paraguay</td>
<td>0.02434 (0.99486)</td>
<td>No</td>
<td></td>
<td>2.29705 (0.07688)</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Uruguay</td>
<td>1.16335 (0.32325)</td>
<td>No</td>
<td></td>
<td>1.23374 (0.29686)</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Peru</td>
<td>20.7173 (1.4E-12)</td>
<td>Yes</td>
<td></td>
<td>5.89773 (0.00059)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Ecuador</td>
<td>7.48652 (6.6E-05)</td>
<td>Yes</td>
<td></td>
<td>7.47757 (6.7E-05)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Venezuela</td>
<td>5.77078 (0.00070)</td>
<td>Yes</td>
<td></td>
<td>8.27328 (2.3E-05)</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

Data from IFS from the IMF from Jan / 57 to Mar / 97
Probability in parenthesis
Considering a 5% confidence interval to test Ho
Table III.10: Number of Lags and the Schwartz Criteria for Latin American Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Lags *</th>
<th>Maximum SBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>6 with trend</td>
<td>5056.4098</td>
</tr>
<tr>
<td>Bolivia</td>
<td>13 no trend</td>
<td>4936.2198</td>
</tr>
<tr>
<td>Brazil</td>
<td>13 with trend</td>
<td>4931.6698</td>
</tr>
<tr>
<td>Chile</td>
<td>13 no trend</td>
<td>5709.9498</td>
</tr>
<tr>
<td>Colombia</td>
<td>13 no trend</td>
<td>6755.0398</td>
</tr>
<tr>
<td>Ecuador</td>
<td>13 no trend</td>
<td>6443.2598</td>
</tr>
<tr>
<td>Mexico</td>
<td>13 no trend</td>
<td>6522.3898</td>
</tr>
<tr>
<td>Paraguay</td>
<td>13 no trend</td>
<td>6277.9698</td>
</tr>
<tr>
<td>Peru</td>
<td>13 with trend</td>
<td>4909.7098</td>
</tr>
<tr>
<td>Uruguay</td>
<td>13 with trend</td>
<td>5144.2498</td>
</tr>
<tr>
<td>Venezuela</td>
<td>13 no trend</td>
<td>6185.2098</td>
</tr>
</tbody>
</table>

* The choice of lag for each country was based on the maximum value for the SBC using the log likelihood function from the Johansen test for cointegration using lags from one to thirteen for each country.
Table III.11: Diagnostic Test for Eleven Latin American Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Order of System</th>
<th>Nominal Exchange Rate (a)</th>
<th>Domestic Price (p)</th>
<th>Foreign Price (p*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>AR (6)</td>
<td>bb,c</td>
<td>a,bb,cc,dd</td>
<td>aa,bb,cc,dd</td>
</tr>
<tr>
<td>Bolivia</td>
<td>AR (13)</td>
<td>aa,bb,cc,dd</td>
<td>aa,bb,cc,dd</td>
<td>a,bb,c,dd</td>
</tr>
<tr>
<td>Brazil</td>
<td>AR (13)</td>
<td>bb,cc,dd</td>
<td>bb,cc,dd</td>
<td>bb,cc</td>
</tr>
<tr>
<td>Chile</td>
<td>AR (13)</td>
<td>a,bb,</td>
<td>aa,bb,dd</td>
<td>bb,dd</td>
</tr>
<tr>
<td>Colombia</td>
<td>AR (13)</td>
<td>a,bb,</td>
<td>aa,bb,cc,dd</td>
<td>a,bb,cc</td>
</tr>
<tr>
<td>Ecuador</td>
<td>AR (13)</td>
<td>bb,</td>
<td>bb</td>
<td>bb,c</td>
</tr>
<tr>
<td>Mexico</td>
<td>AR (13)</td>
<td>bb,</td>
<td>bb,cc,dd</td>
<td>bb,cc</td>
</tr>
<tr>
<td>Paraguay</td>
<td>AR (13)</td>
<td>aa,bb,dd</td>
<td>bb,cc,dd</td>
<td>bb,cc</td>
</tr>
<tr>
<td>Peru</td>
<td>AR (13)</td>
<td>bb,dd</td>
<td>bb,dd</td>
<td>a,bb,cc</td>
</tr>
<tr>
<td>Uruguay</td>
<td>AR (13)</td>
<td>bb,dd</td>
<td>bb,cc,dd</td>
<td>bb</td>
</tr>
<tr>
<td>Venezuela</td>
<td>AR (13)</td>
<td>bb,d</td>
<td>aa,bb,dd</td>
<td>bb,cc</td>
</tr>
</tbody>
</table>

The Table reports significance levels for four diagnostic tests:

i) An f-statistic on one-to-seven lags for serial correlation

ii) Doornik and Hansen (1994) chi-square test for normality

iii) The f-form of the ARCH test


Significance level are denoted by the letters a,b,c and d for these four tests respectively.

One letter denotes significance at the 10% level, and two letters at the 5% level.
Table III.12: Testing for Cointegrating Relationships for Latin American Countries
Unadjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>$r = 0$</th>
<th>$r \leq 1$</th>
<th>$r \leq 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
</tr>
<tr>
<td>0</td>
<td>Argentina</td>
<td>46.96**</td>
<td>64.09**</td>
<td>10.81</td>
</tr>
<tr>
<td>1</td>
<td>Bolivia</td>
<td>27.93**</td>
<td>47.13**</td>
<td>18.95**</td>
</tr>
<tr>
<td></td>
<td>Brazil</td>
<td>18.54</td>
<td>37.57*</td>
<td>12.9</td>
</tr>
<tr>
<td></td>
<td>Chile</td>
<td>20</td>
<td>35.95**</td>
<td>15.72*</td>
</tr>
<tr>
<td></td>
<td>Colombia</td>
<td>15.75</td>
<td>20.85</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>Ecuador</td>
<td>27.15**</td>
<td>36.73**</td>
<td>8.581</td>
</tr>
<tr>
<td></td>
<td>Mexico</td>
<td>28.63**</td>
<td>48.09**</td>
<td>48.09**</td>
</tr>
<tr>
<td></td>
<td>Paraguay</td>
<td>25.4*</td>
<td>37.15**</td>
<td>10.79</td>
</tr>
<tr>
<td></td>
<td>Peru</td>
<td>25.55*</td>
<td>44.65**</td>
<td>12.92</td>
</tr>
<tr>
<td></td>
<td>Uruguay</td>
<td>22.02</td>
<td>38.11*</td>
<td>10.43</td>
</tr>
<tr>
<td></td>
<td>Venezuela</td>
<td>26.82**</td>
<td>37.5**</td>
<td>8.911</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have not been adjusted for degrees of freedom
Significance levels are based on Osterman-Lenum (1992)
where ** denotes significance at the 5% level and * denotes significance at the 10% level.
Table III.13: Testing for Cointegrating Relationships for Latin American Countries
Adjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>r = 0</th>
<th>r ≤ 1</th>
<th>Max</th>
<th>Trace</th>
<th>Max</th>
<th>Trace</th>
<th>Max</th>
<th>Trace</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
</tr>
<tr>
<td>1</td>
<td>Argentina</td>
<td>45.09**</td>
<td>61.54**</td>
<td>10.38</td>
<td>16.45</td>
<td>6.07*</td>
<td>6.07*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bolivia</td>
<td>25.45*</td>
<td>42.95**</td>
<td>17.27*</td>
<td>17.5*</td>
<td>0.2272</td>
<td>0.2272</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Brazil</td>
<td>17</td>
<td>34.44</td>
<td>11.82</td>
<td>17.44</td>
<td>5.62*</td>
<td>5.62*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Chile</td>
<td>18.35*</td>
<td>32.97*</td>
<td>14.42*</td>
<td>14.62</td>
<td>0.2036</td>
<td>0.2036</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Colombia</td>
<td>14.44</td>
<td>19.12</td>
<td>4.677</td>
<td>4.68</td>
<td>0.00380</td>
<td>0.00380</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Ecuador</td>
<td>24.89*</td>
<td>33.68*</td>
<td>7.867</td>
<td>8.784</td>
<td>0.9167</td>
<td>0.9167</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Mexico</td>
<td>26.26**</td>
<td>44.11**</td>
<td>17.22*</td>
<td>17.85*</td>
<td>0.6336</td>
<td>0.6336</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Paraguay</td>
<td>23.29*</td>
<td>34.07*</td>
<td>9.891</td>
<td>10.77</td>
<td>0.8818</td>
<td>0.8818</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Peru</td>
<td>23.26</td>
<td>40.65**</td>
<td>11.76</td>
<td>17.39</td>
<td>5.624*</td>
<td>5.624*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Uruguay</td>
<td>20.2</td>
<td>34.95*</td>
<td>9.566</td>
<td>14.75</td>
<td>5.184*</td>
<td>5.184*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Venezuela</td>
<td>24.59*</td>
<td>34.39*</td>
<td>8.172</td>
<td>9.795</td>
<td>1.624</td>
<td>1.624</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have been adjusted for degrees of freedom
Significance levels are based on Osterman-Lenum (1992)
where ** denotes significance at the 5% level and * denotes significance at the 10% level.

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Table III.14: Alfa (\(\alpha\)) Coefficients for Domestic Prices from the Johansen Cointegration Test:
A Comparison for OECD and Latin American Countries

<table>
<thead>
<tr>
<th>Countries</th>
<th>Alfa Coefficients for Domestic Prices (Absolute Value)</th>
<th>Allowing for One Cointegrating Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>OECD Countries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>0.0028620</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>0.00093120</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>0.00071707</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>0.00037521</td>
<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.0034176</td>
<td></td>
</tr>
<tr>
<td>Average for OECD</td>
<td>0.001660616</td>
<td></td>
</tr>
<tr>
<td>Latin America</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>0.023080</td>
<td></td>
</tr>
<tr>
<td>Bolivia</td>
<td>0.024675</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>0.0084377</td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>0.027025</td>
<td></td>
</tr>
<tr>
<td>Colombia</td>
<td>0.0026594</td>
<td></td>
</tr>
<tr>
<td>Ecuador</td>
<td>0.025656</td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>0.0072444</td>
<td></td>
</tr>
<tr>
<td>Paraguay</td>
<td>0.037495</td>
<td></td>
</tr>
<tr>
<td>Peru</td>
<td>0.069822</td>
<td></td>
</tr>
<tr>
<td>Uruguay</td>
<td>0.0078476</td>
<td></td>
</tr>
<tr>
<td>Venezuela</td>
<td>0.0017238</td>
<td></td>
</tr>
<tr>
<td>Average for Latin America</td>
<td>0.021424172</td>
<td></td>
</tr>
</tbody>
</table>

Coefficients used from the Johansen cointegration test from chapters 2 (OECD) and 3 (Latin America) from the \(\alpha\) matrix results.
Database from January of 1957 to March of 1997
International Financial Statistics CD-ROM
Table III.15: Testing the Restriction [1 -1 1] on the \( \beta \) Coefficients from the Johansen Cointegration Test
Allowing for At Least One Cointegrating Vector for Latin American Countries (1957-97)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Ho: Cointegrating Vector is Not Statistically Different from the Restriction ([1 -1 1]) for ( s, p ) and ( p^* )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>rank=1: ( \text{Chi}^2(2) = 13.062 \text{ [0.0015]} )**</td>
</tr>
<tr>
<td>Bolivia</td>
<td>rank=1: ( \text{Chi}^2(2) = 9.3229 \text{ [0.0095]} )<strong>, rank=2: ( \text{Chi}^2(5) = 28.273 \text{ [0.0000]} )</strong></td>
</tr>
<tr>
<td>Brazil</td>
<td>rank=1: ( \text{Chi}^2(2) = 11.145 \text{ [0.0038]} )**</td>
</tr>
<tr>
<td>Chile</td>
<td>rank=1: ( \text{Chi}^2(2) = 17.276 \text{ [0.0002]} )**</td>
</tr>
<tr>
<td>Colombia</td>
<td>rank=1: ( \text{Chi}^2(2) = 8.0506 \text{ [0.0179]} )*</td>
</tr>
<tr>
<td>Ecuador</td>
<td>rank=1: ( \text{Chi}^2(2) = 13.658 \text{ [0.0011]} )**</td>
</tr>
<tr>
<td>Mexico</td>
<td>rank=1: ( \text{Chi}^2(2) = 0.16419 \text{ [0.9212]} ), rank=2: ( \text{Chi}^2(5) = 18.936 \text{ [0.0020]} )**</td>
</tr>
<tr>
<td>Paraguay</td>
<td>rank=1: ( \text{Chi}^2(2) = 16.796 \text{ [0.0002]} )**</td>
</tr>
<tr>
<td>Peru</td>
<td>rank=1: ( \text{Chi}^2(2) = 16.183 \text{ [0.0003]} )**</td>
</tr>
<tr>
<td>Uruguay</td>
<td>rank=1: ( \text{Chi}^2(2) = 12.308 \text{ [0.0021]} )**</td>
</tr>
<tr>
<td>Venezuela</td>
<td>rank=1: ( \text{Chi}^2(2) = 13.038 \text{ [0.0015]} )**</td>
</tr>
</tbody>
</table>

The tests statistics is a Chi-Square
* is significant at the 5% level and ** at the 1% level
Data from the IFS CD-Rom (Jan 1957 to Apr 1997)
APPENDIX D

Tables – Chapter Four
Table IV.1: ADF Test on the Real Exchange Rate
With and without time trend
\[ \Delta q_t = \alpha + \beta t + \gamma q_{t-1} + \phi(L) \Delta q_{t-1} + \varepsilon_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>3</td>
<td>-1.6812</td>
<td>3</td>
<td>-2.0052</td>
</tr>
<tr>
<td>France</td>
<td>4</td>
<td>-2.5426</td>
<td>4</td>
<td>-2.5308</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>3</td>
<td>-2.4252</td>
<td>3</td>
<td>-2.5136</td>
</tr>
<tr>
<td>Germany</td>
<td>4</td>
<td>-2.4927</td>
<td>4</td>
<td>-2.4910</td>
</tr>
<tr>
<td>Japan</td>
<td>5</td>
<td>-1.8418</td>
<td>4</td>
<td>-2.9799</td>
</tr>
</tbody>
</table>

Level of Significance
- ADF Critical Values At 5%
- ADF Critical Values At 1%

* = significant at 5%  ** = significant at 1%

Critical values from MacKinnon [1991]

Real Exchange Rate: \( q = s + p^* - p \) (in natural log)

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.2: ADF Test on the First Difference of Nominal Exchange Rate
($\Delta S$) With and without time trend

\[ \Delta \Delta S_t = \alpha + \beta t + \gamma S_{t-1} + \phi(L) \Delta \Delta S_{t-1} + \epsilon_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>2</td>
<td>4.1081**</td>
<td>2</td>
<td>4.1063**</td>
</tr>
<tr>
<td>France</td>
<td>2</td>
<td>4.4565**</td>
<td>2</td>
<td>4.4821**</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2</td>
<td>4.3918**</td>
<td>2</td>
<td>4.4452**</td>
</tr>
<tr>
<td>Germany</td>
<td>2</td>
<td>4.6239**</td>
<td>2</td>
<td>4.5994**</td>
</tr>
<tr>
<td>Japan</td>
<td>4</td>
<td>3.9793**</td>
<td>4</td>
<td>3.9551*</td>
</tr>
</tbody>
</table>

**Level of Significance**
- At 5%
- At 1%

**ADF Critical Values**
- 2.89
- 3.46

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)

* = significant at 5%  ** = significant at 1%

Critical values from MacKinnon [1991]
Table IV.3: ADF Test on the First Difference of the Natural Log of Domestic Price (ΔP)
With and without time trend

\[ ΔΔP_t = α + β t + γ ΔP_{t-1} + φ(L) ΔΔP_{t-1} + ε_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>2</td>
<td>-1.8302</td>
<td>0</td>
<td>-4.9127**</td>
</tr>
<tr>
<td>France</td>
<td>1</td>
<td>-1.6857</td>
<td>1</td>
<td>-3.1274</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>4</td>
<td>-2.6421</td>
<td>4</td>
<td>-3.6604*</td>
</tr>
<tr>
<td>Germany</td>
<td>2</td>
<td>-3.2635*</td>
<td>2</td>
<td>-3.4754*</td>
</tr>
<tr>
<td>Japan</td>
<td>3</td>
<td>-3.4333*</td>
<td>3</td>
<td>-3.5094*</td>
</tr>
<tr>
<td>United States</td>
<td>1</td>
<td>-2.8191</td>
<td>1</td>
<td>-3.7630*</td>
</tr>
</tbody>
</table>

Level of Significance
- At 5%
- At 1%

ADF Critical Values
- 2.89
- 3.50

With Time Trend

* = significant at 5%  ** = significant at 1%

Critical values from MacKinnon [1991]

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)

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Table IV.4: ADF Test on the First Difference of a Moving Average of Domestic and US Real GDP Growth ($\Delta RG$ and $\Delta RGUS$)
With and without the time trend

\[ \Delta \Delta RG_t = \alpha + \beta t + \gamma \Delta RG_{t-1} + \phi(L) \Delta \Delta RG_{t-1} + \epsilon_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0</td>
<td>-4.7114**</td>
<td>0</td>
<td>-4.7091**</td>
</tr>
<tr>
<td>France</td>
<td>1</td>
<td>-4.4867**</td>
<td>1</td>
<td>-4.5572**</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1</td>
<td>-3.6452**</td>
<td>1</td>
<td>-3.6358*</td>
</tr>
<tr>
<td>Germany</td>
<td>3</td>
<td>-2.8261</td>
<td>3</td>
<td>-2.8020</td>
</tr>
<tr>
<td>Japan</td>
<td>4</td>
<td>-3.4968*</td>
<td>4</td>
<td>-3.4159*</td>
</tr>
<tr>
<td>United States</td>
<td>0</td>
<td>-5.1569**</td>
<td>0</td>
<td>-5.1434**</td>
</tr>
</tbody>
</table>

**Level of Significance**
- At 5%
- At 1%

**Critical values from MacKinnon [1991]**

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.5: ADF Test on the First Difference of the Discount Rate (\(\Delta DRAT\)) With and without the time trend

\[
\Delta DRAT_t = \alpha + \beta t + \gamma \Delta DRAT_{t-1} + \phi(L) \Delta DRAT_{t-1} + \epsilon_t
\]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0</td>
<td>-7.9973**</td>
<td>0</td>
<td>-7.9426**</td>
</tr>
<tr>
<td>France</td>
<td>4</td>
<td>-3.8231**</td>
<td>4</td>
<td>-3.8972*</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0</td>
<td>-10.620**</td>
<td>0</td>
<td>-10.622**</td>
</tr>
<tr>
<td>Germany</td>
<td>5</td>
<td>-6.0743**</td>
<td>5</td>
<td>-6.0502**</td>
</tr>
<tr>
<td>Japan</td>
<td>0</td>
<td>-12.730**</td>
<td>0</td>
<td>-12.642**</td>
</tr>
<tr>
<td>Level of Significance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADF Critical Values</td>
<td></td>
<td>-2.894</td>
<td></td>
<td>-3.505</td>
</tr>
<tr>
<td>ADF Critical Values</td>
<td></td>
<td>-3.461</td>
<td></td>
<td>-4.065</td>
</tr>
</tbody>
</table>

* = significant at 5%  ** = significant at 1%
Critical values from MacKinnon [1991]
Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.6: ADF Test on the First Difference of Real Interest Rate Differential ($\Delta r^*$)  
With and without the time trend  
$\Delta\Delta r^*_{t} = \alpha + \beta t + \gamma \Delta r^*_{t-1} + \phi(L) \Delta\Delta r^*_{t-1} + \varepsilon_t$

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF</th>
<th>k-max</th>
<th>t-ADF with trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>3</td>
<td>-7.3309**</td>
<td>3</td>
<td>-7.2837**</td>
</tr>
<tr>
<td>France</td>
<td>1</td>
<td>-8.4252**</td>
<td>1</td>
<td>-8.4222**</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>3</td>
<td>-7.3309**</td>
<td>3</td>
<td>-7.2837**</td>
</tr>
<tr>
<td>Germany</td>
<td>3</td>
<td>-4.3655**</td>
<td>3</td>
<td>-4.3346**</td>
</tr>
<tr>
<td>Japan</td>
<td>4</td>
<td>-4.3993**</td>
<td>4</td>
<td>-4.3659**</td>
</tr>
</tbody>
</table>

Level of Significance

<table>
<thead>
<tr>
<th>At 5%</th>
<th>At 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF Critical Values</td>
<td>-2.894</td>
</tr>
<tr>
<td>ADF Critical Values</td>
<td>-3.461</td>
</tr>
</tbody>
</table>

* = significant at 5%  ** = significant at 1%

Critical values from MacKinnon [1991]

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.7: OLS Regression of Nominal Exchange Rates and Relative Prices
Selected OECD Countries

\[ S = \alpha + \beta_1 P + \beta_2 P^* + \epsilon \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>( \alpha )</th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>Durbin Watson</th>
<th>Wald Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.94465</td>
<td>-0.26871</td>
<td>0.52803</td>
<td>0.123</td>
<td>180.13 **</td>
</tr>
<tr>
<td></td>
<td>(-7.449)</td>
<td>(-1.170)</td>
<td>(2.101)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>-0.78174</td>
<td>0.52794</td>
<td>-0.45851</td>
<td>0.185</td>
<td>65.991 **</td>
</tr>
<tr>
<td></td>
<td>(-1.418)</td>
<td>(1.915)</td>
<td>(-1.173)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>2.8449</td>
<td>-0.26875</td>
<td>-0.22157</td>
<td>0.143</td>
<td>65.402 **</td>
</tr>
<tr>
<td></td>
<td>(2.286)</td>
<td>(-0.426)</td>
<td>(-0.602)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>-0.78174</td>
<td>0.52794</td>
<td>-0.45851</td>
<td>0.185</td>
<td>65.991 **</td>
</tr>
<tr>
<td></td>
<td>(-1.418)</td>
<td>(1.915)</td>
<td>(-1.173)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>6.1489</td>
<td>1.4309</td>
<td>-1.7001</td>
<td>0.146</td>
<td>356.76 **</td>
</tr>
<tr>
<td></td>
<td>(8.551)</td>
<td>(4.113)</td>
<td>(-8.287)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All Variables are in natural log terms (S, P and P*)
t-value in parenthesis
** Indicates we can reject the null that the coefficients are jointly insignificant (equal to zero)
Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.8: ADF Test on Estimated Residuals from the OLS Regression of Nominal Exchange Rates and Relative Prices 2nd Step of Engel and Granger Procedure

\[ \Delta \epsilon_t = \alpha + \beta t + \gamma \epsilon_{t-1} + \phi(L) \Delta \epsilon_{t-1} + \mu_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF without the constant</th>
<th>k-max</th>
<th>t-ADF with the constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>3</td>
<td>-2.2960</td>
<td>3</td>
<td>-2.2874</td>
</tr>
<tr>
<td>France</td>
<td>4</td>
<td>-2.7597</td>
<td>4</td>
<td>-2.7285</td>
</tr>
<tr>
<td>Germany</td>
<td>4</td>
<td>-2.7092</td>
<td>4</td>
<td>-2.6976</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>3</td>
<td>-2.6697</td>
<td>3</td>
<td>-2.6550</td>
</tr>
<tr>
<td>Japan</td>
<td>4</td>
<td>-2.9631</td>
<td>4</td>
<td>-2.9426</td>
</tr>
<tr>
<td>Level of Significance</td>
<td>At 10%</td>
<td>At 5%</td>
<td></td>
<td>At 1%</td>
</tr>
<tr>
<td>ADF Critical Values</td>
<td>3.61</td>
<td>3.91</td>
<td></td>
<td>4.51</td>
</tr>
<tr>
<td>Without the Intercept</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADF Critical Values</td>
<td>3.89</td>
<td>4.20</td>
<td></td>
<td>4.80</td>
</tr>
<tr>
<td>With the Intercept</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Critical Values from Charemza and Deadman [1997]
Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.9: OLS Regression on Nominal Exchange Rates, Relative Prices, Domestic and US GDP Real Growth, Discount Rate, and Lagged Real Interest Rate Differential
Selected OECD Countries – 1975Q1 to 1995Q3

\[ s = \alpha + \beta_1 p + \beta_2 p^* + \beta_3 DRG + \beta_4 USRG + \beta_5 DRAT + \beta_6 r_{t-1} + \mu \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>( \alpha )</th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>( \beta_3 )</th>
<th>( \beta_4 )</th>
<th>( \beta_5 )</th>
<th>( \beta_6 )</th>
<th>Durbin Watson</th>
<th>Wald Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-1.4414</td>
<td>-0.65942</td>
<td>1.0760</td>
<td>15.576</td>
<td>-4.6167</td>
<td>-0.30790</td>
<td>-3.1144</td>
<td>0.437</td>
<td>359.75 **</td>
</tr>
<tr>
<td></td>
<td>(6.347)</td>
<td>(-3.208)</td>
<td>(4.785)</td>
<td>(5.612)</td>
<td>(-1.402)</td>
<td>(-1.084)</td>
<td>(-5.017)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>0.1835</td>
<td>2.5915</td>
<td>-3.1310</td>
<td>-20.591</td>
<td>5.4596</td>
<td>5.2862</td>
<td>-2.3625</td>
<td>0.574</td>
<td>523.92 **</td>
</tr>
<tr>
<td></td>
<td>(0.205)</td>
<td>(11.189)</td>
<td>(-11.311)</td>
<td>(-4.233)</td>
<td>(1.520)</td>
<td>(5.365)</td>
<td>(-2.278)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>-3.0635</td>
<td>-0.51377</td>
<td>0.98158</td>
<td>1.8222</td>
<td>31.629</td>
<td>0.28168</td>
<td>0.11985</td>
<td>0.462</td>
<td>178.75 **</td>
</tr>
<tr>
<td></td>
<td>(4.637)</td>
<td>(-1.139)</td>
<td>(1.538)</td>
<td>(0.365)</td>
<td>(5.005)</td>
<td>(0.332)</td>
<td>(0.086)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>2.1553</td>
<td>-0.01796</td>
<td>-0.37843</td>
<td>-1.8894</td>
<td>9.3805</td>
<td>0.18967</td>
<td>-6.3880</td>
<td>0.343</td>
<td>168.93 **</td>
</tr>
<tr>
<td></td>
<td>(1.423)</td>
<td>(-0.021)</td>
<td>(-0.770)</td>
<td>(-0.482)</td>
<td>(1.489)</td>
<td>(0.384)</td>
<td>(-6.473)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>4.1362</td>
<td>1.7769</td>
<td>-2.0167</td>
<td>13.291</td>
<td>-13.872</td>
<td>2.5441</td>
<td>-4.0657</td>
<td>0.315</td>
<td>369.29 **</td>
</tr>
<tr>
<td></td>
<td>(2.054)</td>
<td>(2.414)</td>
<td>(5.330)</td>
<td>(2.442)</td>
<td>(-2.369)</td>
<td>(1.391)</td>
<td>(-3.159)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* t-value in parenthesis
** Indicates we can reject the null that the coefficients are jointly insignificant (equal to zero)

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.10: ADF Test on Estimated Residuals from the OLS Regression of Nominal Exchange Rates, Relative Prices, Domestic and US Real Growth in GDP, Discount Rate, and Lagged Real Interest Rate Differential

2nd Step of Engel and Granger Procedure

\[ \Delta \mu_t = \alpha + \beta t + \gamma \mu_{t-1} + \phi(L) \Delta \mu_t + \nu_t \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>k-max</th>
<th>t-ADF without the constant</th>
<th>k-max</th>
<th>t-ADF with the constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>3</td>
<td>-3.6046</td>
<td>3</td>
<td>-3.6286</td>
</tr>
<tr>
<td>France</td>
<td>4</td>
<td>-4.0449</td>
<td>4</td>
<td>-4.0164</td>
</tr>
<tr>
<td>Germany</td>
<td>4</td>
<td>-2.9092</td>
<td>4</td>
<td>-2.9056</td>
</tr>
<tr>
<td>Japan</td>
<td>4</td>
<td>-3.3054</td>
<td>4</td>
<td>-3.2796</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2</td>
<td>-2.5472</td>
<td>2</td>
<td>-2.5128</td>
</tr>
</tbody>
</table>

Level of Significance

- ADF Critical Values with the Constant
  - At 10%: 4.90
  - At 5%: 5.22
  - At 1%: 5.85

- ADF Critical Values without the Constant
  - 5.17
  - 5.50
  - 6.14

Critical values from Charemza and Deadman [1997]
Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)

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Table IV.11: 1st Error-Correction Model

\[ \Delta s_t = \beta_0 + \beta_1(L)\Delta s_{t-1} + \beta_2(L)\Delta p_{t-1} + \beta_3(L)\Delta p^*_{t-1} + \beta_4q_{t-1} \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated ( \beta_4 ) (t-prob)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.038562 (0.1720)</td>
</tr>
<tr>
<td>France</td>
<td>-0.12194 (0.0071)**</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.066324 (0.0928) *</td>
</tr>
<tr>
<td>UK</td>
<td>-0.10830 (0.0141)**</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.053602 (0.0828) *</td>
</tr>
</tbody>
</table>

* = significant at 10% and ** = significant at 5%

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.12: 2nd Error-Correction Model
\[ \Delta s_t = \alpha + \beta_0 \left[ \Delta(p - p^*)_t \right] + \delta \left( s - p + p^* \right)_{t-1} \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated ( \delta ) (t-prob)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.026492 (0.2993)</td>
</tr>
<tr>
<td>France</td>
<td>-0.10294 (0.0117)**</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.066253 (-0.066)**</td>
</tr>
<tr>
<td>UK</td>
<td>-0.074183 (0.0807)*</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.022885 (0.4197)</td>
</tr>
</tbody>
</table>

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
* = Significant at 10% and ** = significant at 5%
Table IV.13: Half-Lives for the Two ECM Models on the Nominal Exchange Rate

<table>
<thead>
<tr>
<th>Countries</th>
<th>First EC Model</th>
<th>Second EC Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated Coefficient on q.t</td>
<td>[LN (0.6) / (Coefficient)] / 4</td>
</tr>
<tr>
<td>Canada # ##</td>
<td>-0.03856</td>
<td>4.49</td>
</tr>
<tr>
<td>France</td>
<td>-0.12194</td>
<td>1.42</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.06632</td>
<td>2.61</td>
</tr>
<tr>
<td>UK</td>
<td>-0.10830</td>
<td>1.60</td>
</tr>
<tr>
<td>Japan ##</td>
<td>-0.05360</td>
<td>3.23</td>
</tr>
<tr>
<td>Average *</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Average **</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>Total Average</td>
<td>2.45</td>
<td></td>
</tr>
</tbody>
</table>

# indicates that the coefficients used are not significant at the 10% level in the first EC model
## indicates that the coefficients used are not significant at the 10% level in the second EC model
* average including only countries with significant coefficients
** average including all the countries
*** Total Average = (Average * + Average **) / 2

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.14: 1st Error-Correction Model (With Real Factors)

\[ \Delta s_t = \beta_0 + \beta_1 \Delta s_{t-1} + \beta_2 \Delta p_{t-1} + \beta_3 \Delta p^*_{t-1} + \beta_4 \Delta DRG + \beta_5 \Delta USRG + \beta_6 \Delta DRAT + \beta_7 \Delta R^a_{t-1} + \beta_8 q_{t-1} \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated $\beta_3$ (t-prob)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.042017 (0.1770)</td>
</tr>
<tr>
<td>France</td>
<td>-0.073349 (0.1707)</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.025215 (0.5361)</td>
</tr>
<tr>
<td>UK</td>
<td>0.085256* (0.0781)</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.041894 (0.2639)</td>
</tr>
</tbody>
</table>

* = significant at 10% and ** = significant at 5%

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.15: 2nd Error-Correction Model (With Real Factors)
\[ \Delta s_t = \alpha + \beta_0 [\Delta(p - p^*)_t] + \beta_1 \Delta DRG + \beta_2 \Delta USRG + \beta_3 \Delta DRAT + \beta_4 \Delta m^{x-1} + \beta_5 (s - p + p^*)_{t-1} \]

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimated $\beta_5$ (t-prob)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.039676 (0.1978)</td>
</tr>
<tr>
<td>France</td>
<td>-0.081538* (0.0604)</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.018333 (0.6318)</td>
</tr>
<tr>
<td>UK</td>
<td>-0.061933 (0.1680)</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.020981 (0.5073)</td>
</tr>
</tbody>
</table>

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
* = Significant at 10% and ** = significant at 5%
Table IV.16: Half-Lives for the Two ECM Models on the Nominal Exchange Rate (With Real Factors)

<table>
<thead>
<tr>
<th>Countries</th>
<th>First EC Model Estimated Coefficient on q₁</th>
<th>First EC Model Half-Lives (Years) [LN (0.5) / (Coefficient)] / 4</th>
<th>Second EC Model Estimated Coefficient on q₁</th>
<th>Second EC Model Half-Lives (Years) [LN (0.5) / (Coefficient)] / 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>-0.042017</td>
<td>4.12</td>
<td>-0.039676</td>
<td>4.36</td>
</tr>
<tr>
<td>France</td>
<td>-0.073349</td>
<td>2.36</td>
<td>-0.081538*</td>
<td>2.12</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.025215</td>
<td>1.71</td>
<td>-0.018333</td>
<td>9.45</td>
</tr>
<tr>
<td>UK</td>
<td>-0.085256*</td>
<td>2.03</td>
<td>-0.061933</td>
<td>2.79</td>
</tr>
<tr>
<td>Japan</td>
<td>-0.041894</td>
<td>4.13</td>
<td>-0.020981</td>
<td>8.25</td>
</tr>
<tr>
<td>Average #</td>
<td>2.87</td>
<td>5.39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* significant at the 10% level
# includes all five countries

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)

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Table IV.17: Lag Numbers and the Schwartz Criteria for Selected OECD Countries Without Including Real Factors

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Lags •</th>
<th>Maximum SBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>5 with trend</td>
<td>1309.64</td>
</tr>
<tr>
<td>France</td>
<td>5 with trend</td>
<td>1316.45</td>
</tr>
<tr>
<td>Germany</td>
<td>5 with trend</td>
<td>1298.76</td>
</tr>
<tr>
<td>UK</td>
<td>5 with trend</td>
<td>1213.46</td>
</tr>
<tr>
<td>Japan</td>
<td>5 with trend</td>
<td>1248.88</td>
</tr>
</tbody>
</table>

- The choice of lag for each country was based on the maximum value for the SBC using the log likelihood function from the Johansen test for cointegration using lags from one to five for each country.

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.18: Diagnostic Test for Selected OECD Countries Without Including Real Factors

<table>
<thead>
<tr>
<th>Country</th>
<th>Order of System</th>
<th>Nominal Exchange Rate(s)</th>
<th>Domestic Price (p)</th>
<th>Foreign Price (p̂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>AR (5)</td>
<td></td>
<td>bb</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>AR (5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>AR (5)</td>
<td></td>
<td>bb</td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>AR (5)</td>
<td>a</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>AR (5)</td>
<td>a,d</td>
<td>b</td>
<td></td>
</tr>
</tbody>
</table>

The Table reports significance levels for four diagnostic tests:

ix) An f-statistic on one-to-five lags for serial correlation

x) Doornik and Hansen (1994) chi-square test for normality

xi) The $f$-form of the ARCH test


Significance levels are denoted by the letters a,b,c, and d for these four tests respectively.

One letter denotes significance at the 10% level, two letters at the 5% level and three letters at the 1% level.

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.19: Johansen Cointegration Test for Selected OECD Countries Without Including Real Factors
Unadjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>r = 0</th>
<th>r ≤ 1</th>
<th>r ≤ 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
</tr>
<tr>
<td>1</td>
<td>Canada</td>
<td>23.7</td>
<td>36.83</td>
<td>9.527</td>
</tr>
<tr>
<td>2</td>
<td>France</td>
<td>32.41**</td>
<td>53.01**</td>
<td>20.56*</td>
</tr>
<tr>
<td>3</td>
<td>Germany</td>
<td>26.18*</td>
<td>39.09*</td>
<td>11.88</td>
</tr>
<tr>
<td>4</td>
<td>UK</td>
<td>38.8**</td>
<td>66.15**</td>
<td>16.71</td>
</tr>
<tr>
<td>5</td>
<td>Japan</td>
<td>18.94</td>
<td>18.94</td>
<td>15.17</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have not been adjusted for degrees of freedom
Significance levels are based on Osterman-Lenum (1992),
where * denotes significance at the 5% level and ** denotes significance at the 1% level.

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### Table IV.20: Johansen Cointegration Test for Selected OECD Countries
Without including Real Factors
Adjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>$r = 0$ Max</th>
<th>$r = 0$ Trace</th>
<th>$r \leq 1$ Max</th>
<th>$r \leq 1$ Trace</th>
<th>$r \leq 2$ Max</th>
<th>$r \leq 2$ Trace</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Canada</td>
<td>19.75</td>
<td>30.69</td>
<td>7.939</td>
<td>10.94</td>
<td>3.001</td>
<td>3.001</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>27.07*</td>
<td>44.27**</td>
<td>17.17*</td>
<td>17.2</td>
<td>0.02378</td>
<td>0.02378</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>21.87</td>
<td>32.65</td>
<td>9.921</td>
<td>10.78</td>
<td>0.8569</td>
<td>0.8569</td>
</tr>
<tr>
<td></td>
<td>UK</td>
<td>32.33**</td>
<td>55.13**</td>
<td>13.93</td>
<td>22.8*</td>
<td>8.87**</td>
<td>8.87**</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>15.79</td>
<td>30.9</td>
<td>12.64</td>
<td>15.12</td>
<td>2.476</td>
<td>2.476</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have not been adjusted for degrees of freedom. Significance levels are based on Osterman-Lenum (1992), where * denotes significance at the 5% level and ** denotes significance at the 1% level.
Table IV.21: Testing the Restriction \([1 -1 1]\) on the \(\beta\) Coefficients from the Johansen Cointegration Test
Allowing for At Least One Cointegrating Vector for OECD Countries
(Floating Period)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Ho: Cointegrating Vector is Not Statistically Different from ([1 -1 1]) for (s, p) and (p^*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>rank=1: (\text{Chi}^2(2) = 8.4328) [0.0148] *</td>
</tr>
<tr>
<td>France</td>
<td>rank=1: (\text{Chi}^2(2) = 21.75) [0.0000] **</td>
</tr>
<tr>
<td>Germany</td>
<td>rank=1: (\text{Chi}^2(2) = 13.816) [0.0010] **</td>
</tr>
<tr>
<td>Japan</td>
<td>rank=1: (\text{Chi}^2(2) = 0.17868) [0.9145]</td>
</tr>
<tr>
<td>UK</td>
<td>rank=1: (\text{Chi}^2(2) = 17.52) [0.0002] **</td>
</tr>
<tr>
<td></td>
<td>rank=2: (\text{Chi}^2(5) = 34.232) [0.0000] **</td>
</tr>
</tbody>
</table>

The test statistics is a Chi-Squared
Data from IFS CD-Rom from Mar 1973 to Apr 1997
Table IV.22: The $\alpha$ Coefficients from the Johansen Cointegration Test for Selected OECD Countries Without Including the Real Factors

<table>
<thead>
<tr>
<th>Countries</th>
<th>$\alpha$ Coefficients for a Rank of One Variables ($s, p, \text{and } p^*$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Canada</strong></td>
<td></td>
</tr>
<tr>
<td>Nominal Exchange Rate</td>
<td>-0.15711</td>
</tr>
<tr>
<td>Domestic Price</td>
<td>-0.0066782</td>
</tr>
<tr>
<td>Foreign Price</td>
<td>0.018810</td>
</tr>
<tr>
<td><strong>France</strong></td>
<td></td>
</tr>
<tr>
<td>Nominal Exchange Rate</td>
<td>0.026652</td>
</tr>
<tr>
<td>Domestic Price</td>
<td>0.0077435</td>
</tr>
<tr>
<td>Foreign Price</td>
<td>-0.0039225</td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td></td>
</tr>
<tr>
<td>Nominal Exchange Rate</td>
<td>-0.19828</td>
</tr>
<tr>
<td>Domestic Price</td>
<td>-0.014109</td>
</tr>
<tr>
<td>Foreign Price</td>
<td>-0.016066</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td></td>
</tr>
<tr>
<td>Nominal Exchange Rate</td>
<td>-0.16776</td>
</tr>
<tr>
<td>Domestic Price</td>
<td>-0.0027743</td>
</tr>
<tr>
<td>Foreign Price</td>
<td>-0.015494</td>
</tr>
<tr>
<td><strong>United Kingdom</strong></td>
<td></td>
</tr>
<tr>
<td>Nominal Exchange Rate</td>
<td>0.0027560</td>
</tr>
<tr>
<td>Domestic Price</td>
<td>0.0020740</td>
</tr>
<tr>
<td>Foreign Price</td>
<td>-0.00060420</td>
</tr>
</tbody>
</table>

Cointegration analysis for 1974 Q4 to 1997 Q1
Table IV.23: Lag Numbers and the Schwartz Criteria for Selected OECD Countries Including Real Factors
(Domestic and Foreign Real Growth in GDP, and the Discount Rate)

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Lags •</th>
<th>Maximum SBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>5 with trend</td>
<td>2809.45</td>
</tr>
<tr>
<td>France</td>
<td>5 with trend</td>
<td>2808.85</td>
</tr>
<tr>
<td>Germany</td>
<td>5 with trend</td>
<td>2568.76</td>
</tr>
<tr>
<td>UK</td>
<td>5 with trend</td>
<td>2639.75</td>
</tr>
<tr>
<td>Japan</td>
<td>5 with trend</td>
<td>2658.10</td>
</tr>
</tbody>
</table>

- The choice of lag for each country was based on the maximum value for the SBC using the log likelihood function from the Johansen test for cointegration using lags from one to five for each country.

Data from the IFS CD-ROM (1973 Q2 to
Table IV.24: Diagnostic Test for Selected OECD Countries
Including Real Factors
(Domestic and Foreign Real Growth in GDP, and the Discount Rate)

<table>
<thead>
<tr>
<th>Country</th>
<th>Order of System</th>
<th>Nominal Exchange Rate (s)</th>
<th>Domestic Price (p)</th>
<th>Foreign Price (p*)</th>
<th>Real Growth in GDP</th>
<th>Real Growth in US GDP</th>
<th>Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>AR (5)</td>
<td>a,</td>
<td>aa</td>
<td>aa</td>
<td>b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>AR (5)</td>
<td>b,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>AR (5)</td>
<td>b,</td>
<td>aa</td>
<td>bb</td>
<td>aa,bb,</td>
<td>bb,</td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>AR (5)</td>
<td>a,</td>
<td></td>
<td></td>
<td>a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>AR (5)</td>
<td>aa, a</td>
<td></td>
<td></td>
<td>a, bb,</td>
<td>bb,</td>
<td>aa,bb</td>
</tr>
</tbody>
</table>

The Table reports significance levels for four diagnostic tests:

i) An f-statistic on one-to-five lags for serial correlation
ii) Doornik and Hansen (1994) chi-square test for normality
iii) The f-form of the ARCH test

Significance level are denoted by the letters a, b, c and d for these four tests respectively. One letter denotes significance at the 10% level, two letters at the 5% level and three letters at the 1% level.

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.25: Johansen Cointegration Test for Selected OECD Countries Including Real Factors
(Domestic and Foreign GDP Real Growth, and the Discount Rate)
Unadjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>( r = 0 )</th>
<th>( r \leq 1 )</th>
<th>( r \leq 2 )</th>
<th>( r \leq 3 )</th>
<th>( r \leq 4 )</th>
<th>( r \leq 5 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max Trace</td>
<td>Max Trace</td>
<td>Max Trace</td>
<td>Max Trace</td>
<td>Max Trace</td>
<td>Max Trace</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Max Trace</td>
<td>Max Trace</td>
<td>Max Trace</td>
<td>Max Trace</td>
<td>Max Trace</td>
<td>Max Trace</td>
</tr>
<tr>
<td>Canada</td>
<td>71.05**</td>
<td>222.9**</td>
<td>58.98**</td>
<td>151.9**</td>
<td>53.08**</td>
<td>92.89**</td>
<td>20.3</td>
</tr>
<tr>
<td>France</td>
<td>67.11**</td>
<td>184.9**</td>
<td>53.82**</td>
<td>117.7**</td>
<td>25.76</td>
<td>63.93**</td>
<td>20.78</td>
</tr>
<tr>
<td>Germany</td>
<td>55.45**</td>
<td>164.4**</td>
<td>44.22**</td>
<td>109**</td>
<td>27.74</td>
<td>64.77**</td>
<td>18.73</td>
</tr>
<tr>
<td>UK</td>
<td>53.68**</td>
<td>159.7**</td>
<td>32.58</td>
<td>106**</td>
<td>24.14</td>
<td>73.4**</td>
<td>21.43</td>
</tr>
<tr>
<td>Japan</td>
<td>68.25**</td>
<td>191.8**</td>
<td>43.89**</td>
<td>123.5**</td>
<td>40.81**</td>
<td>79.62**</td>
<td>24.92*</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have not been adjusted for degrees of freedom
Significance levels are based on Osterman-Lenum (1992)
where ** denotes significance at the 1% level and * denotes significance at the 5% level.
Table IV.26: Johansen Cointegration Test for Selected OECD Countries Including Real Factors (Domestic and US GDP Real Growth, and the Discount Rate)
Adjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>r = 0</th>
<th>r ≤ 1</th>
<th>r ≤ 2</th>
<th>r ≤ 3</th>
<th>r ≤ 4</th>
<th>r ≤ 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
</tr>
<tr>
<td>0</td>
<td>Canada</td>
<td>43.72*</td>
<td>137.2**</td>
<td>36.3</td>
<td>93.46**</td>
<td>32.67*</td>
<td>57.16*</td>
</tr>
<tr>
<td>1</td>
<td>France</td>
<td>41.62</td>
<td>114.7**</td>
<td>33.38</td>
<td>73.03</td>
<td>15.98</td>
<td>39.65</td>
</tr>
<tr>
<td>2</td>
<td>Germany</td>
<td>34.39</td>
<td>102*</td>
<td>27.43</td>
<td>67.6</td>
<td>17.21</td>
<td>40.18</td>
</tr>
<tr>
<td>3</td>
<td>UK</td>
<td>33.04</td>
<td>98.26</td>
<td>20.05</td>
<td>65.22</td>
<td>14.85</td>
<td>45.17</td>
</tr>
<tr>
<td>4</td>
<td>Japan</td>
<td>42</td>
<td>118**</td>
<td>27.01</td>
<td>76.01*</td>
<td>25.12</td>
<td>49</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have been adjusted for degrees of freedom
Significance levels are based on Osterman-Lenum (1992)
where ** denotes significance at the 1% level and * denotes significance at the 5% level.
Table IV.27: Testing the Restriction $[1 -1 1]$ on the $\beta$ Coefficients from the Johansen Cointegration Test including Three Real Factors (Domestic and US GDP Real Growth, and the Discount Rate) Allowing for At Least One Cointegrating Vector for OECD Countries (Floating Period)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Ho: Cointegrating Vector is Not Statistically Different from $[1 -1 1]$ for $s$, $p$ and $p^*$</th>
</tr>
</thead>
</table>
| Canada    | rank=1: Chi$^2$(2) = 6.2011 [0.0450] *  
           | rank=2: Chi$^2$(4) = 30.443 [0.0000] **  
           | rank=3: Chi$^2$(6) = 59.274 [0.0000] ** |
| France    | rank=1: Chi$^2$(2) = 32.201 [0.0000] ** |
| Germany   | rank=1: Chi$^2$(2) = 0.62368 [0.7321] |
| Japan     | rank=1: Chi$^2$(2) = 3.6353 [0.1624]  
           | rank=2: Chi$^2$(4) = 38.12 [0.0000] ** |
| UK        | rank=1: Chi$^2$(2) = 0.11907 [0.9422] |

The test statistics is a Chi-Squared
* indicates significance at the 5% level and ** at the 1% level
Data from IFS CD-Rom from Mar 1973 to Apr 1997
Table IV.28: The $\alpha$ Coefficients from the Johansen Cointegration Test for Selected OECD Countries Including Three Real Factors (Domestic and US GDP Real Growth, and the Discount Rate)

<table>
<thead>
<tr>
<th>Countries</th>
<th>$\alpha$ Coefficients for a Rank of One Including Real Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nominal Exchange Rate</td>
</tr>
<tr>
<td></td>
<td>-0.026854</td>
</tr>
<tr>
<td></td>
<td>Domestic Price</td>
</tr>
<tr>
<td></td>
<td>0.00061042</td>
</tr>
<tr>
<td></td>
<td>Foreign (US) Price</td>
</tr>
<tr>
<td></td>
<td>-0.0077415</td>
</tr>
<tr>
<td></td>
<td>Domestic Real GDP Growth</td>
</tr>
<tr>
<td></td>
<td>-0.0014086</td>
</tr>
<tr>
<td></td>
<td>US Real GDP Growth</td>
</tr>
<tr>
<td></td>
<td>-0.0041644</td>
</tr>
<tr>
<td></td>
<td>Discount Rate</td>
</tr>
<tr>
<td></td>
<td>-0.017084</td>
</tr>
<tr>
<td>France</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nominal Exchange Rate</td>
</tr>
<tr>
<td></td>
<td>-0.0069993</td>
</tr>
<tr>
<td></td>
<td>Domestic Price</td>
</tr>
<tr>
<td></td>
<td>-0.0018744</td>
</tr>
<tr>
<td></td>
<td>Foreign (US) Price</td>
</tr>
<tr>
<td></td>
<td>-0.0014803</td>
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<td></td>
<td>Domestic Real GDP Growth</td>
</tr>
<tr>
<td></td>
<td>0.00055760</td>
</tr>
<tr>
<td></td>
<td>US Real GDP Growth</td>
</tr>
<tr>
<td></td>
<td>0.0037389</td>
</tr>
<tr>
<td></td>
<td>Discount Rate</td>
</tr>
<tr>
<td></td>
<td>-0.0038656</td>
</tr>
<tr>
<td>Germany</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nominal Exchange Rate</td>
</tr>
<tr>
<td></td>
<td>0.00014084</td>
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<tr>
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<td>Domestic Price</td>
</tr>
<tr>
<td></td>
<td>3.3312e-006</td>
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<tr>
<td></td>
<td>Foreign (US) Price</td>
</tr>
<tr>
<td></td>
<td>-1.0875e-005</td>
</tr>
<tr>
<td></td>
<td>Domestic Real GDP Growth</td>
</tr>
<tr>
<td></td>
<td>-3.2415e-005</td>
</tr>
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<td></td>
<td>US Real GDP Growth</td>
</tr>
<tr>
<td></td>
<td>1.5021e-005</td>
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<tr>
<td></td>
<td>Discount Rate</td>
</tr>
<tr>
<td></td>
<td>-0.00090921</td>
</tr>
<tr>
<td>Japan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nominal Exchange Rate</td>
</tr>
<tr>
<td></td>
<td>0.015785</td>
</tr>
<tr>
<td></td>
<td>Domestic Price</td>
</tr>
<tr>
<td></td>
<td>0.026999</td>
</tr>
<tr>
<td></td>
<td>Foreign (US) Price</td>
</tr>
<tr>
<td></td>
<td>-0.0034454</td>
</tr>
<tr>
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<td>Domestic Real GDP Growth</td>
</tr>
<tr>
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<td>0.0013783</td>
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<tr>
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<td>US Real GDP Growth</td>
</tr>
<tr>
<td></td>
<td>-0.00024165</td>
</tr>
<tr>
<td></td>
<td>Discount Rate</td>
</tr>
<tr>
<td></td>
<td>-0.014673</td>
</tr>
<tr>
<td>United Kingdom</td>
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</tr>
<tr>
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<td>Nominal Exchange Rate</td>
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<tr>
<td></td>
<td>-0.0042730</td>
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<tr>
<td></td>
<td>Domestic Price</td>
</tr>
<tr>
<td></td>
<td>-0.0089795</td>
</tr>
<tr>
<td></td>
<td>Foreign (US) Price</td>
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<td>-0.0070874</td>
</tr>
<tr>
<td></td>
<td>Domestic Real GDP Growth</td>
</tr>
<tr>
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<td>0.0031692</td>
</tr>
<tr>
<td></td>
<td>US Real GDP Growth</td>
</tr>
<tr>
<td></td>
<td>0.0041246</td>
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<tr>
<td></td>
<td>Discount Rate</td>
</tr>
<tr>
<td></td>
<td>0.013286</td>
</tr>
</tbody>
</table>

Cointegration analysis for 1976 Q2 to 1995 Q3
Table IV.29: Diagnostic Test for Selected OECD Countries Including Four Real Factors
(Domestic and US GDP Real Growth, the Discount Rate and Real Interest Rate Differential)

<table>
<thead>
<tr>
<th>Country</th>
<th>Order of System</th>
<th>Nominal Exchange Rate (s)</th>
<th>Domestic Price (p)</th>
<th>Foreign Price (p*)</th>
<th>Real Growth in GDP</th>
<th>Real Growth in US GDP</th>
<th>Discount Rate</th>
<th>Real Interest Rate Differential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>AR (5)</td>
<td>a,</td>
<td>aa</td>
<td>aa,</td>
<td>bb,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>AR (5)</td>
<td>a,</td>
<td>aa</td>
<td>a,</td>
<td>aa,</td>
<td>a,</td>
<td>a,b,</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>AR (5)</td>
<td>b,</td>
<td>aa</td>
<td>a,bb,</td>
<td>aa,</td>
<td>a,bb,</td>
<td>bb,</td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>AR (5)</td>
<td>aa,</td>
<td>aa</td>
<td>aa,</td>
<td>a,</td>
<td>a,</td>
<td>bb,</td>
<td>aa,bb,</td>
</tr>
<tr>
<td>Japan</td>
<td>AR (5)</td>
<td>aa,</td>
<td>a</td>
<td>a,</td>
<td>bb,</td>
<td>aa,bb,</td>
<td>a,</td>
<td></td>
</tr>
</tbody>
</table>

The Table reports significance levels for four diagnostic tests:

v) An f-statistic on one-to-seven lags for serial correlation
vi) Doornik and Hansen (1994) chi-square test for normality
vii) The f-form of the ARCH test

Significance level are denoted by the letters a, b, c and d for these four tests respectively.

One letter denotes significance at the 10% level, two letters at the 5% level and three letters at the 1% level.

Data from the IFS CD-ROM (1973 Q2 to 1997 Q1)
Table IV.30: Johansen Cointegration Test for Selected OECD Countries Including Real Factors
(Domestic and Foreign GDP Real Growth, the Discount Rate and Real Interest Rate Differential)
Unadjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>r = 0</th>
<th>r ≤ 1</th>
<th>r ≤ 2</th>
<th>r ≤ 3</th>
<th>r ≤ 4</th>
<th>r ≤ 5</th>
<th>r ≤ 6</th>
<th>r ≤ 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
</tr>
<tr>
<td>Canada</td>
<td>82.82**</td>
<td>277.3**</td>
<td>70.78**</td>
<td>194.5**</td>
<td>56.12**</td>
<td>123.7**</td>
<td>28.75</td>
<td>67.61**</td>
</tr>
<tr>
<td>France</td>
<td>93.85**</td>
<td>263.4**</td>
<td>63.72**</td>
<td>169.5**</td>
<td>45.22**</td>
<td>105.8**</td>
<td>29.44</td>
<td>60.6*</td>
</tr>
<tr>
<td>Germany</td>
<td>62.99**</td>
<td>212.6**</td>
<td>53.3**</td>
<td>149.6**</td>
<td>30.33</td>
<td>96.35**</td>
<td>27.52</td>
<td>66.02**</td>
</tr>
<tr>
<td>UK</td>
<td>71.92**</td>
<td>212.2**</td>
<td>48.17*</td>
<td>140.3**</td>
<td>27.86</td>
<td>92.15**</td>
<td>22.22</td>
<td>64.29**</td>
</tr>
<tr>
<td>Japan</td>
<td>83.87**</td>
<td>271.9**</td>
<td>58.8**</td>
<td>188**</td>
<td>42.89**</td>
<td>129.2**</td>
<td>41.57**</td>
<td>86.33**</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have not been adjusted for degrees of freedom.
Significance levels are based on Osterman-Lenum (1992).
where ** denotes significance at the 1% level and * denotes significance at the 5% level.
Table IV.31: Johansen Cointegration Test for Selected OECD Countries Including Real Factors
(Domestic and Foreign GDP Real Growth, the Discount Rate and Real Interest Rate Differential)
Adjusted Trace and Max Eigenvalue Statistics

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>r = 0</th>
<th>r ≤ 1</th>
<th>r ≤ 2</th>
<th>r ≤ 3</th>
<th>r ≤ 4</th>
<th>r ≤ 5</th>
<th>r ≤ 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
<td>Max</td>
<td>Trace</td>
</tr>
<tr>
<td></td>
<td>45.65</td>
<td>152.9**</td>
<td>39.02</td>
<td>107.2*</td>
<td>30.94</td>
<td>68.21</td>
<td>15.85</td>
<td>37.27</td>
</tr>
<tr>
<td></td>
<td>52.27*</td>
<td>146.7*</td>
<td>35.49</td>
<td>94.43</td>
<td>25.18</td>
<td>58.94</td>
<td>16.4</td>
<td>33.75</td>
</tr>
<tr>
<td></td>
<td>35.08</td>
<td>118.4</td>
<td>29.68</td>
<td>83.35</td>
<td>16.89</td>
<td>53.66</td>
<td>15.33</td>
<td>36.77</td>
</tr>
<tr>
<td></td>
<td>39.65</td>
<td>117</td>
<td>26.56</td>
<td>77.36</td>
<td>15.36</td>
<td>50.8</td>
<td>12.25</td>
<td>35.44</td>
</tr>
<tr>
<td></td>
<td>46.23</td>
<td>149.9**</td>
<td>32.42</td>
<td>103.7</td>
<td>23.64</td>
<td>71.23</td>
<td>22.91</td>
<td>47.59</td>
</tr>
</tbody>
</table>

Trace and max eigenvalues have been adjusted for degrees of freedom
Significance levels are based on Osterman-Lenum (1992)
where ** denotes significance at the 1% level and * denotes significance at the 5% level
Table IV.32: Testing the Restriction $[1 \ -1 \ 1]$ on the $\beta$ Coefficients from the Johansen Cointegration Test Including Four Real Factors (Domestic and US GDP Real Growth, Discount Rate and Real Interest Rate Differential) Allowing for At Least One Cointegrating Vector for OECD Countries (Floating Period)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Ho: Cointegrating Vector is Not Statistically Different from $[1 \ -1 \ 1]$ for $s$, $p$ and $p^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>rank=1: $\chi^2(2) = 13.146 \ [0.0014]$ ** &lt;br&gt;rank=2: $\chi^2(4) = 24.979 \ [0.0001]$ **</td>
</tr>
<tr>
<td>France</td>
<td>rank=1: $\chi^2(2) = 19.3 \ [0.0001]$ **</td>
</tr>
<tr>
<td>Germany</td>
<td>rank=1: $\chi^2(2) = 0.28428 \ [0.8675]$</td>
</tr>
<tr>
<td>Japan</td>
<td>rank=1: $\chi^2(2) = 25.828 \ [0.0000]$ **</td>
</tr>
<tr>
<td>UK</td>
<td>rank=1: $\chi^2(2) = 9.1556 \ [0.0103]$ *</td>
</tr>
</tbody>
</table>

The test statistics is a Chi-Squared
* indicates significance at the 5% level and ** at the 1% level
Data from IFS CD-Rom from Mar 1973 to Apr 1997
Figure 1: Monthly Exchange Rate of UK (Jan 57 to Mar 97) in Natural Log

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Figure 2: Monthly Real Exchange Rate of UK (Jan 57 to Mar 97) in Natural Log
Figure 3: Monthly Exchange Rate of Canada (Jan 57 to Mar 97) in Natural Log

Monthly Exchange Rate of Canada in Natural Log (Jan 1957 to Mar 97)

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Figure 4: Monthly Real Exchange Rate of Canada (Jan 57 to Mar 97)
In Natural Log

Monthly Real Exchange Rate of Canada in Natural Log
(Jan 1957 to Mar 1997)
Figure 5: Monthly Exchange Rate of France (Jan 57 to Mar 97) in Natural Log

Monthly Exchange Rate of France in Natural Log
(Jan 57 to Mar 97)

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Figure 6: Monthly Real Exchange Rate of France (Jan 57 to Mar 97) in Natural Log
Figure 7: Monthly Exchange Rate of Germany (Jan 57 to Mar 97) in Natural Log
Figure 8: Monthly Real Exchange Rate of Germany (Jan 57 to Mar 97) in Natural Log

Monthly Real Exchange Rate of Germany in Natural Log - (Jan 57 to Mar 97)
Figure 9: Monthly Exchange Rate of Japan (Jan 57 to Mar 97) in Natural Log
Figure 10: Monthly Real Exchange Rate of Japan (Jan 57 to Mar 97) in Natural Log

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APPENDIX F

Figures – Chapter Three
Figure 11: Monthly Exchange Rate of Argentina (Jan 57 to Mar 97) in Natural Log

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Figure 12: Monthly Real Exchange Rate of Argentina (Jan 57 to Mar 97) in Natural Log

Monthly Real Exchange Rate of Argentina in Natural Log (Jan 57 to Mar 97)

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Figure 13: Monthly Exchange Rate of Bolivia (Jan 57 to Mar 97) in Natural Log

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Figure 14: Monthly Real Exchange Rate of Bolivia (Jan 57 to Mar 97) in Natural Log
Figure 15: Monthly Exchange Rate of Brazil (Jan 57 to Mar 97) in Natural Log
Figure 16: Monthly Real Exchange Rate of Brazil (Jan 57 to Mar 97) in Natural Log

Monthly Real Exchange Rate of Brazil in Natural Log
(Jan 57 to Mar 97)

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Figure 17: Monthly Exchange Rate of Chile (Jan 57 to Mar 97) in Natural Log
Figure 18: Monthly Real Exchange Rate of Chile (Jan 57 to Mar 97) in Natural Log

[Graph showing the monthly real exchange rate of Chile in natural log from January 1957 to March 1997]
Figure 19: Monthly Exchange Rate of Colombia (Jan 57 to Mar 97) in Natural Log
Figure 20: Monthly Real Exchange Rate of Colombia (Jan 57 to Mar 97) in Natural Log

Monthly Real Exchange Rate of Colombia in Natural Log
(Jan 57 to Mar 97)

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Figure 21: Monthly Exchange Rate of Ecuador (Jan 57 to Mar 97) in Natural Log

Lawrence M. Seifert

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Figure 22: Monthly Real Exchange Rate of Ecuador (Jan 57 to Mar 97) in Natural Log

Monthly Real Exchange Rate of Ecuador in Natural Log
(Jan 57 to Mar 97)

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Figure 23: Monthly Exchange Rate of Mexico (Jan 57 to Mar 97) in Natural Log

Monthly Exchange Rate of Mexico in Natural Log
(Jan 57 to Mar 97)

LNEXCMEX
Figure 24: Monthly Real Exchange Rate of Mexico (Jan 57 to Mar 97) in Natural Log
Figure 25: Monthly Exchange Rate of Paraguay (Jan 57 to Mar 97) in Natural Log
Figure 26: Monthly Real Exchange Rate of Paraguay (Jan 57 to Mar 97) in Natural Log
Figure 27: Monthly Exchange Rate of Peru (Jan 57 to Mar 97) in Natural Log
Figure 28: Monthly Real Exchange Rate of Peru (Jan 57 to Mar 97) in Natural Log

Monthly Real Exchange Rate of Peru in Natural Log (Jan 57 to Mar 97)

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Figure 29: Monthly Exchange Rate of Uruguay (Jan 57 to Mar 97) in Natural Log
Figure 30: Monthly Real Exchange Rate of Uruguay (Jan 57 to Mar 97) in Natural Log

Monthly Real Exchange Rate of Uruguay in Natural Log
(Jan 57 to Mar 97)

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Figure 31: Monthly Exchange Rate of Venezuela (Jan 57 to Mar 97) in Natural Log

Monthly Exchange Rate of Venezuela in Natural Log
(Jan 57 to Mar 97)

LNEXCVENEZ
Figure 32: Monthly Real Exchange Rate of Venezuela (Jan 57 to Mar 97) in Natural Log

Monthly Real Exchange Rate of Venezuela in Natural Log
(Jan 57 to Mar 97)

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The Dornbusch (Overshooting) Model of 1976

Capital Mobility and Expectations:

\[ r = r^* + x \] \hspace{2cm} (1)

\[ x = \theta (\bar{e} - e) \] \hspace{2cm} (2)

The Money Market:

\[ p - m = \phi y + \lambda r^* + \lambda \theta (\bar{e} - e) \] \hspace{2cm} (3)

\[ \bar{p} = m + (\lambda r^* - \phi y) \] \hspace{2cm} (4)

where

\[ x \] is the expected rate of depreciation of the domestic currency
\[ m \] is the log of the nominal quantity of money
\[ p \] is the log of the price level
\[ y \] is the log of real income
\[ r^* \] is the given world rate of interest
\[ r \] is the domestic interest rate
\[ e \] is the log of the current nominal exchange rate
\[ \bar{e} \] is the log of the long-run nominal exchange rate
\( \bar{p} \) is the log of the long-run equilibrium price level

Substituting (4) in (3):

\[
e = \bar{e} - (1/\lambda \theta) (p - \bar{p})
\]  

(5)

The Goods Market:

\[
\ln D = \mu + \delta(e - p) + \gamma y - \sigma r
\]  

(6)

where \( D \) denotes the demand for domestic output and \( \mu \) is a shift parameter.

The rate of change in the domestic price is given by:

\[
\dot{p} = \pi \ln (D / Y) = \pi [\mu + \delta(e - p) + (\gamma - 1)y - \sigma r]
\]  

(7)

The long-run equilibrium exchange rate implied by (7) is:

\[
\bar{e} = \bar{p} + (1 / \delta) [\sigma r^* + (1 - \gamma) y - \mu]
\]  

(8)

Equation (7) can be simplified using equation (8) and the idea that interest differences equal expected depreciation:

\[
r - r^* = \theta (\bar{e} - e)
\]  

(9)

Therefore, (7) becomes:
\[ \dot{p} = -\pi \frac{[(\delta + \sigma\theta)]}{\theta\lambda + \delta}(p - \bar{p}) = -\nu (p - \bar{p}) \]  

(10)

where \( \nu = \pi \frac{[(\delta + \sigma\theta)]}{\theta\lambda + \delta} \)

The time path of the exchange rate will be given by:

\[ e(t) = e - \frac{1}{\lambda\theta} (p_0 - \bar{p}) \exp (-v_t) = e + (e_0 - e) \exp (-v_t) \]  

(11)

In the steady state, we have that:

\[ \dot{m} = \dot{y} = 0 \]  

(12)

where \( \cdot \) indicates changes over time

Therefore, the expression for the rate of change in the domestic price in the steady state is:

\[ \dot{p} = \delta (e - p_r - \bar{q}) = 0 \]  

(13)

where

\[ \bar{q} \text{ is the long-run equilibrium level of the real exchange rate} \]

\[ p_r = p - p^* \]

We know that the Dornbusch model was designed to explain the implications of temporary demand-side shocks (such as monetary shocks) for the short-run movements of nominal exchange rates and relative prices, given that goods prices are sticky in the short-run. In the long-run, the model assumes
PPP, (constant long-run real exchange rate). Equation (3) implies a relationship between the nominal exchange rate and prices, which is called the QQ schedule. Equation (13) describes the rate of change in the domestic price in the steady state. With this we have the two curves we need to explain what is the effect of a one-time change in the long-run real exchange rate.

The idea here is that a one-time increase in the long-run real exchange rate will shift the QQ schedule upwards but at the same time the it will shift down the schedule of the change in prices in the steady state as we can see through equation (13). Since there is no movement in relative prices \( p_r = p - p^* = \text{constant} \) due to sticky prices, the system will jump from point \( E_1 \) to \( E_2 \) in the graph below where the nominal exchange rate will jump from \( e_1 \) to \( e_2 \) instantaneously. The graphical representation using the Dombusch [1976] overshooting model would be:
Figure 1: The Dornbusch Model With a One-Time Change in the Long-Run Real Exchange Rate

$E_1 = \text{initial equilibrium}$

$E_2 = \text{new equilibrium}$