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Tests of Purchasing Power Parity in OECD Countries.

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Tests of Purchasing Power Parity in OECD Countries" submitted by Mehbooba Shamji in partial fulfilment of the requirements for the degree of Master of Arts.

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ABSTRACT.

Purchasing Power Parity has generated substantial theoretical and empirical interest since its formal conception. This thesis is an attempt to enhance present understanding of the PPP doctrine, as well as to shed some light on its validity (or lack of) among 16 OECD member countries vis a vis the US or Germany. Using Phillips and Perron's (1988) unit root tests, Engle and Granger's (1987) co-integration tests, as well as Zivot and Andrew's (1990) approach to test for a unit root after accounting for structural breaks, we examine the possibility of PPP. Based on these empirical contemplations, as well as on the empirical reviews of PPP, we were able to reject the PPP hypothesis for a majority of the countries of interest.

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To all that was lost ... and all that was gained.

CHAPTER I

INTRODUCTION.

A Swedish economist, Gustav Cassel once said that [Cassel (1918 pp. 413)]:

> "The general inflation which has taken place during the war has lowered this purchasing power in all countries, though in a different degree, and the rates of exchange should accordingly be expected to deviate from their old parities in proportion to the inflation of each country. At every moment the real parity is represented by this quotient between the purchasing power of the money in the one country and the other. I propose to call this parity '*purchasing power parity*'. As long as anything like free movement of merchandise and a somewhat comprehensive trade between the two countries takes place, the actual rate of exchange cannot deviate very much from this purchasing power parity."

And so began the *renewal* of the purchasing power parity (PPP) doctrine which states, in its simplest form, that arbitrage in the goods and services market will equate prices (denominated in the same currency of course) of identical commodities in different countries. We say 'renewal', because versions of PPP have been traced to as far back as 16th century Spain. More recent references, to some form or another of PPP, have been made by classical economists in the 19th century[1]. However, Gustav Cassel is considered the 'trail blazer' for the increased interest in PPP in this century, not only because he christened the concept, but also because he provided both a mathematical representation as well as empirical support for what was then a fairly new empirical concept[2].

Apparent from the quotation above, and crystal clear from Cassel's later works [Cassel (1921 pp. 38)],

> "The purchasing power parities represent the true equilibrium of the exchanges, and it is, of great practical value to know these parities. It is in fact to them we have to refer when we wish to get an idea of the real value of currencies whose exchanges are subject to arbitrary and sometimes wild fluctuations."

PPP is basically a theory of *exchange rate determination*. With

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[1] Refer to Frenkel [1978] or The New Palgrave, A Dictionary of Economics [pp. 1075 - 1077] for a brief, but concise review on the origins of the PPP doctrine as well as an extensive historical reference.

[2] Cassel presented a <u>successful</u> analysis, during World War I, on absolute PPP between Sweden and US.

the key words above being "equilibrium of the exchanges", if a PPP relationship does exist between two countries, then not only is the *PPP rate of exchange* a reliable predictor of future exchange rates, but most importantly it is an accurate one.

Understandably, there has been some doubt as to the validity of PPP as an accurate predictor of future exchange rates. Despite the fact that he remained a strong believer in the PPP doctrine, even Cassel, during his time, gradually recognized the tendency of exchange rates to deviate (in his opinion, ephemerally only) from the PPP rate of exchange[3]. The crux of the matter is in considering PPP as a scrupulous predictor. Samuelson could not have put it any better when he said [Samuelson (1964, pp.153)]:

> "Unless very sophisticated indeed, PPP is a misleading, pretentious doctrine, promising, what is rare in economics, detailed numerical prediction."

In recent years, empirical results have inclined even more strongly towards this conclusion. Before considering some of these results, it is of some interest to develop an understanding of some of the limitations faced by PPP as a

[3] See Cassel's: FOREIGN INVESTMENTS, Lectures of the Harris Foundation, Chicago, University of Chicago Press, 1928, pp. 16.

predictor of exchange rates.

As one of the foundations for price and exchange rate behaviour in an open economy, PPP is entrenched with price behaviour and all the limitations faced by statisticians when calculating price indices, like the consumer and wholesaler price index. Obviously the 'basket' of goods used, by both countries, to estimate a price index can not differ for effective comparison of purchasing powers, and yet in reality, they probably do. Some other weaknesses of price indices, for example the base year used, the weights used by each country to calculate the price index, the fact that some services are not tradeable on the international market (for instance a hair cut), and it's accuracy as an estimate of the 'true price index', are all discussed in more detail in the next chapter.

Impediments to international trade, like quotas, import duties, transportation costs, insurance costs, storage costs, etc, as well as information costs involved in the process of arbitrage, all affect the level to which arbitrage can erode away price differentials. Thus such external costs weaken the extent to which PPP can predict future exchange rates. Note though, that while the presence of such external costs prevent prices between countries from equalising, it does not necessarily mean that the market is inefficient, but rather that the price differential, at least, must equal to the transaction costs.

We have to keep in mind that exchange rates are influenced by international movements of capital as well, and so any structural change that may cause such movements, for instant an announcement of a change in monetary policy, will have an effect on the ability of PPP to predict exchange rates, since exchange rates react to such structural changes independent of relative prices.

Finally, to predict future exchange rates with PPP we need expected future prices (or equivalently, expected inflation). These expected prices are subject to statistical errors (due to the lack of a crystal ball), and are most likely going to differ from actual prices. This again would weaken PPP's ability to predict future exchange rates.

All these factors weaken the ability of PPP, as a theory, to efficiently estimate exchange rates. Based on this conclusion of poor proficiency, the appeal to determine if empirical (Note that the words empirical and graphical will be used interchangeably, unless stated otherwise) results are consistent with this conclusion, has been too strong to resist. To date there have been numerous papers testing the validity (or lack of) of the PPP theory. Very briefly we would like to review some of the empirical test results for PPP done to date, in particular those whose empirical content are similar to the content of this thesis. Some of these tests are highlighted in later chapters as well, where their relevance, we felt, would be most appreciated. The last chapter then concludes these results and relates them to all the findings from this thesis.

Fisher and Park (1991) tested for bilateral PPP among 11 major industrial countries (of which only one country, Sweden, is not included in the group of countries studied here), using monthly data from March 1973 to May 1988. Their results of most interest to this thesis were: support for PPP, for France and UK vis a vis the US, as well as support for Canada, France, Italy, Japan, Netherlands, Sweden, Switzerland and UK vis a vis Germany. What is of interest to note is that when Hakkio (1992, pp. 45, Chart 3, Panel A) used graphs to test the PPP relationship for UK vis a vis the US, using monthly data from January 1974 to August 1991, he did not find support for a PPP relationship. He did however, find graphical support for PPP (pp. 41 chart 1 panel A) using annual data from 1900 to 1990. Another person who found no evidence for the PPP relationship, for a similar group of countries comprising of Belgium, Canada, France, Germany, Italy, Japan, UK and US, was Mark (1990). He used monthly data from June 1973 to February 1988 (an almost identical sample size as Fisher and Park's) and found that, when regressing relative prices on nominal exchange rates, he could only reject the null of *no co-integration* for Belgium vis a vis Germany (pp. 122 table 4).

Frenkel (1981) also used graphical as well as empirical tests to investigate PPP for UK, France, Germany and the US. He used monthly data from June 1973 to July 1979 (pp. 677-679, figures 4-6 and table 7) to show divergencies from PPP graphically, and weak results, empirically. Note though that his results (using simple OLS regressions) with the deutschemark-based series were superior to those of the dollar-based. These results are consistent with Krugman (1978), who also used simple regressions to arrive at similar conclusions as Frenkel's.

Arrestingly though, Johnson (1990) found support for PPP between US and Canada using quarterly data from 1950:3 to 1986:4, a result contradictory to any of the previous empirical conclusions mentioned above. Lothian (1985) also found support for PPP, using *acceleration* of prices rather than price levels, for 20 OECD countries vis a vis the US. He used annual data from 1956 to 1980 and found graphical support (pp. 833 figure 4) for PPP, i.e. a one to one relationship, between exchange rates and acceleration of prices[4].

As will be seen later, this thesis discusses Perron's (1989) approach to test for one-time structural breaks in the real exchange rate, and the possibility of the formation of the EMS in 1979 as being one such break. This is because of the implications, of the EMS formation, on external costs as well as on the stability of exchange rates (due to increased stability of policies between member countries).

Considering some empirical work that is closely related

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[4] For more references, Macdonald and Taylor (1992 pp. 40-41) have provided a brief survey on some of the graphical and empirical work done to test the PPP hypothesis, briefly underlining the different empirical technics used.

to this, we have Chowdury and Sdogati (1993) who used two sub-samples, pre-EMS and post-EMS sample periods. Based on their ADF unit root test and co-integration test results, they concluded that PPP did not have support, prior to EMS for either the dollar or the deutschemark-based series, and did have support for PPP after EMS, but only for member countries and only vis a vis Germany (he examined PPP for France, Germany, Italy and USA).

MacDonald and Taylor (1991) also used tests for co-integration, but to test for *stability* in exchange rates between EMS member countries. They found evidence that exchange rates had stabilized between France, Italy and Germany since 1979. The implication of this is that if exchange rates have stabilized, then the PPP relationship is more likely to exist. More recently, Flynn and Boucher (1993) used Perron's (1989) approach (discussed in chapter IV) to account, exogenously, for one-time breaks in time series. In their case they were considering, in particular, the movement from fixed to flexible exchange rate era, for Canada and Japan vis a vis US. Even exogenously accounting for a one-time structural break, they found no support for PPP during the flexible exchange rate era for the Canada-US and Japan-US pairs, and only found support for Canada-US during the fixed exchange rate era.

It seems that though PPP has received mixed support, the tendency towards rejecting the PPP hypothesis has been stronger. Nevertheless, some results have been contradictory and therefore, despite all the numerous publications and their corresponding empirical cultivations, PPP has never ceased to be a topic of continuing interest. Under the circumstances though, we are compelled to differentiate our product in some manner.

We do this in a number of ways. First, most empirical achievements in the past have used ADF (1979, 1981) tests to test for unit roots in time series, we refrain from this and use Phillips-Perron (1988) unit root tests [as they appear in the program SHAZAM Version 6.2 (White et al, 1990)] instead. Secondly, while structural breaks have usually been accounted for exogenously using Perron's (1989) method, we use Zivot and Andrew's (1990) approach which accounts for breaks endogenously and is therefore superior. Finally, the group of countries to be studied here was chosen deliberately, to incorporate certain attractive features. The first two are discussed, in detail, in chapters II and IV respectively, so we will say no more about them at this point. However, the last consideration deserves some more elaboration.

In the last 45 years, economic integration has gained immense popularity. Starting from the Benelux customs (founded 1948) to the European Economic Community or EEC (1958), they have all had varying levels of implications towards restrictions on international trade among their member countries. When such an integration is triumphant, it leads to significant reduction in external costs, which in turn leads to stronger erosion of price differentials, through arbitrage in the goods and service markets of member countries. This, apparent from our previous discussion, which is also reinstated in the next chapter, is crucial to the PPP doctrine. The temptation, therefore, to study a group of countries already members of such a 'block' was too strong to resist, and what better group than one involving a majority of European states. This is because, not only are most of the major states already integrated, besides being in close proximity to each other, but also because most of the main players have 'grand' plans for a monetary union (in a few years) and all that having a common currency would entail.

We deemed the most logical choice to be countries who are members of the *organization for economic cooperation and development*, henceforth OECD. OECD comprises of a variety of integrated blocks, for example FTA and EEC, providing us with an assortment of countries to deal with, unlike if we used just one particular trading block. It is made up of 24 member countries who try to synchronize their policies with respect to major economic issues. For this thesis we study all the member countries for whom data was easily accessible[5].

The main purpose of this thesis then, is to investigate the possibility of a PPP relationship between the group of

[5] More detail on the data and its sources is provided in chapter III.

countries analyzed here, and to this end we use both empirical and graphical reasoning to arrive at our conclusions. To set this in motion, the following chapter discusses, in some detail, the three different concepts of PPP, taking into account both their theoretical as well as their empirical foundations, while effectively comparing and contrasting them. The chapter also ties in the limitations, discussed previously, with each of the PPP concepts that they affect directly. It then goes on to set up the framework for the empirical work to be done in this thesis, considering Phillips-Perron (1988) unit root tests as well as the Engle and Granger (1987) tests of co-integration.

The next step, after establishing the theoretical foundations of the test methods, is to examine the data required for the actual empirical work. The third chapter does precisely that, it provides a compact impression of the type of data that is used here: it's source, it's quality, it's quantity and, if any, it's transformations. Some descriptive statistics and graphical illustrations are also demonstrated in this chapter to provide clear perceptions of the data.

Having done that, we are in a position to perform the actual empirical work. All results from the Phillips-Perron unit root tests as well as the Engle-Granger co-integration tests are reported in chapter IV. Conclusions are then drawn on these results. Chapter IV will also consider the *theory* behind unit root tests, using Perron's (1989) approach as well as Zivot and Andrew's (1990) approach, for the real exchange rate once any existing one-time structural breaks in the data are accounted for. However, we provide test results for only Zivot and Andrew's approach: both graphical and empirical are displayed with the relevant conclusions drawn on these results.

The last chapter summarizes all the theoretical and empirical accomplishments of this thesis, congregating all conclusions that unfold as the thesis progresses, as well as all inferences that can be made based on empirical work done in the past.

CHAPTER II

PURCHASING POWER PARITY

INTEGRATION AND CO-INTEGRATION.

1. INTRODUCTION.

Purchasing Power Parity, as mentioned previously, is a concept as old as paper money itself and though it can be traced back to as far as the 16th Century, it's more recent popularity is due to Gustav Cassel after the first World War[6].

Reiterating what was established in the first chapter, PPP, by definition, provides a long run relationship between exchange rates and prices in an open economy. Technically, therefore, it provides an equilibrium value towards which the underlying currencies will converge, and hence PPP has some practical appeal for exchange rate determination.

In the short run, however, the PPP relationship is weak. Some economists believe it does not hold, while others [see, for example Hakkio (1992)[7]] believe that if deviations from the PPP rate of exchange are significantly large then the exchange rate will converge towards the PPP rate of exchange, even in the short run . Also if the inflation rates are in

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[6] This re-introduction of PPP occurred when Gustav Cassel studied alternative approaches for selecting official exchange rates at the end of WWI.

[7] Chart 1 panel B pp. 41, illustrate deviations of exchange rates from PPP and their movement towards PPP.

triple digits, then the currency value will tend to converge towards the PPP rate of exchange, even in the short run [see Copeland (1989)].

The next section tries to provide a theoretical understanding of the PPP relationship. It discusses, in some detail, all the different concepts of PPP, i.e. the law of one price, absolute PPP and relative PPP, as well as the inherent problems with these concepts. The third section then discusses empirical tests for PPP. There are a number of ways to test for the PPP relationship, however this section discusses only those empirical tests that are carried out in this thesis and whose results are then reported in chapter IV. The empirical tests, for PPP, looked at in this section are the Phillips-Perron (1988) unit root tests for the real exchange rate and co-integration tests based on the Engle and Granger (1987) approach. The last section of this chapter then concludes all that was said in this chapter and briefly introduces all that is to be done in the chapter III.

2. PPP, A THEORETICAL BACKGROUND.

As mentioned above, there are three concepts of PPP. The first is the *law of one price*, the second is *absolute PPP* and the third is *relative PPP*. The next three sub-sections consider each of these concepts individually.

2.1. The Law Of One Price.

The law of one price, the simplest concept of PPP, is based on the belief that identical goods in different countries should cost the same once denominated in the same currency. This condition only holds assuming that external costs such as transportation, taxes and tariffs are negligible enough to ignore, and that the commodities in question are homogenous. This last assumption ensures perfect substitutable, since we cannot compare prices for say crude oil in USA to refined oil in Norway, despite the fact that both products are oil they are not perfectly substitutable.

The logic behind this belief, that prices for identical goods must be equal, is that if prices for such goods differed between countries, and external costs were negligible, there would be potential for arbitrage. This arbitrage in the goods and services market, would erode away any price difference, i.e. an excess demand, by arbitrageurs, for the good where it is priced lower will increase its price, and an excess supply of the good in the country where prices are higher will *eventually* cause the price to fall, until the prices in both countries equate and there is no longer any potential for arbitrage. The operative word here is 'eventually', because the adjustment of prices is a time consuming process and hence explains why PPP is favoured more as a long term relationship rather than a short term one.

We can now quantify this relationship in the following manner: Let P and P^* be an identical commodity's price in the domestic and foreign country respectively, and S be the nominal spot exchange rate, where S is defined as the domestic price of one unit of foreign currency. Then the law of one price gives the following relationship:

[1] $$S = A \frac{P}{P^*}$$

where A is some arbitrary constant, suggesting that the exchange rate, a nominal variable, is a ratio of two nominal variables.

2.2. Absolute Purchasing Power Parity.

Having considered the law of one price, we are now in a position to introduce the concept of absolute PPP. A concept similar to the law of one price except instead of individual good prices, the PPP relationship is expressed in terms of *general* prices in the economy. Thus, by definition, absolute PPP states that general prices of two economies will be the same once converted to the same currency. Note that due to their availability, price indices are commonly used instead of general price levels. Consider the consumer price index (CPI), which is a weighted average of individual goods prices, where the weights are calculated according to expenditure shares:

$$CPI = \sum_{i=1}^{N} w_i \; P_i$$

where w_i is the expenditure share of good i, P_i is the price of good i, and the country's consumer price index is CPI.

Obviously, if the law of one price holds, between two countries, and the weights used to calculate CPI and CPI^*, where CPI^* is the foreign country's consumer price index, are the same, then absolute PPP holds as well. If however, the weights are not the same, then we require another restriction, in particular if one good's price changes, the contribution of this change to the CPI has to be offset by an opposite change in the price of some other good with not necessarily the same weight. Under such a circumstance, absolute PPP may still hold even if the law of one price does not, i.e., even if individual prices are not the same, general prices in the economy may equal. This makes absolute PPP superior to the concept of the law of one price.

As discussed previously, there are some inherent problems with using price indices and hence with the concept of absolute PPP. Even though we have only discussed CPI above, there are many other price indices, and using different indices to test absolute PPP may give different interpretations[8]. Another problem with price indices is the arbitrary choosing of a base year. In the case of consumer price indices, the CPI is equated to 100 for the base year, after which the remaining years CPI's are calculated according to the cost of the 'basket' in the base year, for example if say during the base year a representative basket of goods, for some hypothetical country, costs 10 000 units and the next year it costs 11 250 units, then the CPI in the following year is calculated as follows:

$$CPI_1 = \frac{P_1}{P_0} CPI_0$$

$$CPI_1 = \frac{11\ 250}{10\ 000} 100$$

$$CPI_1 = 112.50$$

As can obviously be seen, changing the base year and hence the base year cost, will effectively change the CPI reported for all the other years, and possibly the interpretation when testing for absolute PPP.

When using price indices of different countries to derive relative prices, the underlying assumption is that not only are the commodities, that make up the individual 'baskets', identical between countries, but that they are also tradeable.

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[8] Fisher and Park (1991) use both CPI and WPI (pp. 1480 table 1) to test co-integration and found results that were sometimes different. However, Chowdhury and Sdogati [1993, pp. 33] who also used WPI as well as CPI, found that their inferences did not change.

This can be a limiting assumption since commodities between baskets are more likely, than not, to differ, and that some services, for example car repair, hair cuts etc, can not be traded between countries.

Also interesting to note is that, even if the nature of commodities comprising the basket is not an issue, the available price indices are not necessarily *perfect* measures of the 'true price index'. This is due to (i) accounting differences (ii) different tax policies as well as different amounts of public good provision which create imperfections when calculating the cost of living (iii) problems arising from the fact that actual prices sometimes differ from listed prices due to advertisement gimmicks such as sample prices, discounts etc. This raises the question as to whether the use of the 'true price index' would provide more empirical support for PPP in both the short run and the long run. Under the circumstances though, the available price indices are the only 'yard sticks' that can be used, and what can not be discounted is that they are related to the unavailable 'true price index' and hence PPP still plays a significant role in exchange rate determination.

Despite these inherent problems with using price indices and ignoring external costs, which may be significant in magnitude, absolute PPP still has some appeal for exchange rate determination. It's relationship is explained as follows:

[2] $$S = \frac{P}{P^*}$$

here P and P* represent price indices for the domestic and foreign country, respectively, and the other variables are as before.

2.3. Relative Purchasing Power Parity.

This brings us to the final concept, i.e. the concept of relative PPP. This is similar to absolute PPP except it is in growth rates. Thus relative PPP portrays a relationship between exchange rates and *inflation* rates. More formally, relative PPP states that [Copeland (1989, pp 66)]

> "One country's inflation rate can only be higher (lower) to the extent that its exchange rate depreciates (appreciates)."

Therefore the relative PPP relationship is derived by first taking logarithms of the exchange rate and the price indices and rewriting equation [2] above as:

$$\ln S = \ln \frac{P}{P^*}$$

[3] $$= \ln P - \ln P^*$$

Let $s = \ln S$, $p = \ln P$ and $p^* = \ln P^*$, rewriting [3] in growth rates, yields:

$$\Delta \ln S = \Delta \ln P - \Delta \ln P^*$$

$$\Delta s = \Delta p - \Delta p^*$$

[4] $$\Delta s = \pi - \pi^*$$

where π is the domestic inflation rate and π^* is the foreign inflation rate.

Some economists feel that relative PPP is superior to absolute PPP because it is in growth rates, which eliminates the need to choose a base year[9]. Relative PPP also accounts for any external costs. This is desirable if such costs are significant enough to make absolute PPP weak, even in the long run, by failing to take them into consideration. To see this, consider if these costs were some fixed amount K, then equation [2] would be:

$$S = K \frac{P}{P^*}$$

Going through the same process, as we did to derive the relative PPP relationship, gives:

$$\Delta \ln S = \Delta \ln K + \Delta \ln P - \Delta \ln P^*$$

[9] See, for example, Hakkio (1992) and Copeland (1989).

$$\Delta s = 0 + \Delta p - \Delta p^*$$

$$\Delta s = \Delta p - \Delta p^*$$

$$\Delta s = \pi - \pi^*$$

which is the same as equation [4] since $\Delta \ln K = 0$. Hence with relative PPP, external costs do not pose a problem.

The bottom line here then is that if absolute PPP holds, relative PPP clearly holds too. However if absolute PPP fails to hold, relative PPP may still hold, i.e. even if the exchange rate is not equal to the exact ratio of the price indices, it may at least be *proportional* to it.

3. TEST METHODS.

In general, absolute PPP, as defined by equation [3] above, is tested [see Frenkel (1978) and Krugman (1978)] by estimating the regression

[5] $$\ln S_t = \alpha + \beta \ln P_t - \beta^* \ln P_t^* + u_t$$

and testing the null hypothesis that the coefficients of the logs of domestic and foreign prices are equal to unity, as implied by equation [3], i.e. $\beta = \beta^* = 1$. Alternatively, we can regress the relative price on the nominal exchange rate and estimate the equation

$$[6] \qquad \ln S_t = \alpha + \beta \ln(P_t/P_t^*) + u_t$$

and then test PPP by testing the hypothesis that $\beta = 1$.

Such tests, however, are based on the assumption that u_t is white noise. If (in the context of equation [6]) $\ln S_t$ and $\ln(P_t/P_t^*)$ are each integrated of order one [or I(1) in the terminology of Engle and Granger (1987)], then it is typically true that a linear combination of these variables will also be I(1). However, if a linear combination of these variables is integrated of order 0, i.e. I(0), then $\ln S_t$ and $\ln(P_t/P_t^*)$ are said to be *co-integrated* and, as will be discussed below in more detail co-integrated variables exhibit certain equilibrium or attraction properties. Note that if the variables are integrated of order one, but *not* co-integrated, then ordinary least squares yields misleading results. Thus, under the circumstances, it becomes important to test for co-integration.

3.1. Unit Root Tests

Prior to testing for co-integration, we need to test for unit roots in the autoregressive representation of each individual time series. Though in the past most econometric work was done without prior examination for any economic time series properties, it is now important, for both empirical and theoretical work in economics, to make some inferences about the generating process of time series[10]. One of the most important properties of an economic time series is whether it is stationary or not i.e. whether it is integrated of order 0 or not. If a time series X_t, is stationary it is said to have a *constant and finite mean and variance* at all points in time. Thus stationarity implies then, that the underlying generating process of such time series does not change over time. For most time series the generating process or mechanism is the economy itself, which is a dynamic process, leading to the conclusion that such time series could not be stationary.

With the conclusion above, we now require a method, not only to test for stationarity in a time series X_t, but a method to make the series stationary, if it is non-stationary in levels. Most series become stationary once their logged difference is taken. If a series has to be differenced d times before it becomes stationary, it is said to be integrated of order d, denoted I(d). More formally [Engle and Granger (1987, pp. 252)]

"A series with no deterministic component which has a stationary, invertible, ARMA representation

[10] Granger & Newbold (1977)

after differencing d times, is said to be ... ~I(d)".

If the series X_t is non-stationary in log levels and stationary in *first* difference, then it is said to contain a *single unit root*. Unit roots are important because they help to determine whether a trend is stochastic in nature, via the presence of a unit root, or deterministic, via the presence of a polynomial time trend.

Testing for unit roots is especially important in economics because, as Phillips and Perron (1988, pp. 335) have aptly put it,

> "...a unit root is often a theoretical implication of models which postulate the rational use of information that is available to economic agents."

Some of the common variables that postulates such use are prices and exchange rates, and therefore unit roots have significant importance for this thesis. There are a number of methods that can be used to test for unit roots. Some examples of the most common ones used are those introduced by Dickey and Fuller (1979, 1981) and those by Phillips and Perron (1988).

This thesis uses the Phillips-Perron (1988) test for unit roots, which is an approach that is robust to a wide variety of serial correlations and time dependent heteroskedasticities. It is an approach that is non-parametric in nature with respect to nuisance parameters and hence applies to a wider range of time series models as compared to other tests. The Phillips-Perron (1988) test also accommodates models with drift and trend. This is important for two reasons. The first reason is that the main competitor for the presence of a unit root is a time trend, so the accommodation of a trend variable allows us to discriminate between stationarity *due to* a deterministic trend and non-stationarity due to the presence of a unit root. Secondly, since a non-zero drift is a common occurrence in economic time series, the incorporation of a drift variable has practical applications as well.

Setting up the model, let us begin with the simple random walk model

[7] $$X_t = X_{t-1} + \xi_t$$

where $\xi_t \sim N(0, \sigma^2)$.

The mean of this series is $\frac{1}{t}\sum_{i=1}^{t}\xi_i$ and the variance is $t\sigma^2$ .As $t \to \infty$ the former becomes undefined and the latter approaches infinity as well. This proves that the variable X_t is non-stationary. Consider the first log difference instead

[8] $$X_t - X_{t-1} = \xi_t$$

Such a series has both mean and variance that are constant and finite since ξ_t is normally distributed with mean 0 and variance σ^2. Such a series would then be integrated of order 1.

Expanding on this model, we get the non-augmented Dickey Fuller regressions[11]:

[9] $$X_t = \alpha X_{t-1} + \mu_t$$

[10] $$X_t = \theta + \alpha X_{t-1} + \eta_t$$

[11] $$X_t = \theta + \beta\left(t - \frac{T}{2}\right) + \alpha X_{t-1} + \varepsilon_t$$

where equation [9] has neither drift nor trend, equation [10] has drift, but no trend and equation [11] has both drift and trend. Here T is the sample size.

Now that we have established the significance of testing for unit roots in time series, as well as the test statistic that will be used here to test for unit roots, we can

[11] Note that the ADF regressions are similar except that they have a number of lagged first differenced terms at the end of each regression.

consider, in the next sub-section, the presence of a unit root in $\ln S_t$ and $\ln(P_t/P_t^*)$, and its relationship to the PPP relationship via co-integration.

3.2. Co-integration Tests.

Determined in the first section of this chapter, was that the PPP rate of exchange is an *equilibrium* exchange rate that can be achieved given the lapse of sufficient time, thus the concept of equilibrium is an important one[12]. A vector X_t is said to be in equilibrium if there is a vector of parameters α such that $\alpha' X_t = 0$. Note however, that most times $\alpha' X_t = Z_t$, where Z_t is referred to as the equilibrium error.

The purpose of this thesis is then to test for the existence of such an equilibrium, as defined by PPP, for the exchange rates in question. Co-integration does precisely that by testing the long run consequences of a variable, to see if it achieves equilibrium or not. Co-integration between variables then implies that they tend to move together.

There are a number of methodologies that can be used to test for co-integration. This thesis uses the Engle and Granger approach (1987). A formal definition offered by Engle and Granger (1987, pp. 253) for co-integration is:

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[12] A discussion on how much elapsed time is sufficient to be defined as long term, with respect to PPP, is found in Hakkio (1992).

"The components of the vector X_t are said to be co-integrated of order d, b denoted $X_t \sim CI(d,b)$ if (i) all components of X_t are I(d) and (ii) there exists a vector α so that $\alpha' X_t = Z_t \sim I(d-b)$, $b > 0$. The vector α is called the co-integrating vector."

We will restrict our case to d=1 and b=1. The model specific to this thesis is then, that the vector $X_t = \{\ln S_t, \ln P_t/P_t^*\}$ and the equilibrium error Z_t is the log of the real exchange rate e_t, since e_t is a linear combination of the elements in X_t, with $\alpha = \{1, 1\}$.

Simplifying the above definition to this particular case, we can then find some evidence for a PPP relationship if the following three conditions hold:

(i) All elements of X_t are non-stationary in level,

(ii) Stationary in first difference and

(iii) be linearly combined to form a variable Z_t, such that Z_t is stationary in level.

The third condition requires Z_t, or in our particular case the real exchange rate, to be integrated of order 0, which implies that if Z_t has a zero mean it will rarely drift far from zero and will often cross the zero line i.e. an equilibrium will often be found. If all these conditions hold then X_t is said to be co-integrated, however if any of these conditions fail to hold then X_t is not co-integrated implying that Z_t will tend to wander widely, which would make a zero crossing and hence achieving an equilibrium, almost impossible. Implications for this model then is that, for the former case the model should be estimated in levels, while for the latter it should be estimated in first difference.

The actual empirical work in the Engle and Granger approach involves regressing relative prices on nominal exchange rates, to obtain a regression residual which is then tested for a unit root, whose presence will then determine whether to reject a null hypothesis of *no co-integration* (versus an alternative of co-integration). Note, however, that this approach has two shortcomings in general. In the particular case of this thesis, these limitations are not significant as discussed below.

The first limitation of the Engle & Granger approach is, that it does not take into account correctly the number of variables in the co-integrating regression (equation [5]), the model only deals well with a two variable model (since this thesis uses relative prices we do have a two variable model). Second, the Engle and Granger approach does not distinguish between one or more co-integrating vectors (again because of the particular model used in this thesis, there can only be one such vector). The approach (not used here) that does take care of both of these problems is Johansen's maximum likelihood approach [Johansen (1988)].

3.3. Unit Root Test for Real Exchange Rates.

Apparent from the discussion above, another test for the existence of the PPP relationship is the test for stationarity in log levels of the *real exchange rate*, or conversely to test for the presence of a unit root in the exchange rate.

The real exchange rate, by definition, is the price of foreign goods and services relative to domestic goods and services and is measured as follows:

[12] $$E = S \cdot \frac{P}{P^*}$$

where E is the real exchange rate, S is now the foreign price of one unit of domestic currency, and the other variables are as in equation [2]. The real exchange rate is important in the testing of PPP, because it measures short-run deviations from PPP and if it follows a random walk, i.e. contains a unit root, then PPP will not hold even in the long run. If, however, the real exchange rate is stationary then deviations from PPP may still occur, but the nominal exchange rate and relative price will eventually converge [see Chowdhury and Sdogati, (1993)]. Taking logs of equation [12] above, the real exchange rate becomes a *linear* combination of spot rates and relative prices i.e.

[13] $$e_t = s_t + p_t - p_t^*$$

where $e_t = \ln E_t$, $s_t = \ln S_t$, $p_t = \ln P_t$ and $p_t^* = \ln P_t^*$.

Based on equation [2] absolute PPP then implies that the log of the real exchange rate, e_t must equal zero. The relative PPP version of the above equation is in growth rates i.e.

[14] $$\Delta e_t = \Delta s_t + \Delta p_t - \Delta p_t^*$$

Only if the real exchange rate is stationary in levels, i.e. integrated of order 0, can the variables s_t, p_t and p_t^* [and hence $\ln S_t$ and $\ln(P_t^*/P_t)$] be co-integrated. Thus the presence of a unit root in the real exchange rate, which would indicate that e_t is I(1), would automatically rule out the possibility of the relevant variables being co-integrated, therefore not providing support for absolute PPP.

4. CONCLUSION.

This chapter has now established what the PPP relationship entails. It has theoretically looked at all the different concepts of PPP, i.e. the law of one price, absolute PPP and relative PPP, comparing and contrasting them as well as discussing some of the problems underlying these concepts.

We then went on to discuss some empirical considerations in the testing for PPP, in particular absolute PPP. The implications of certain time series properties to the PPP relationship, like the presence of unit roots and co-integration, were then considered. It was determined that the presence of a unit root (using Phillips-Perron approach) in the real exchange rate does not provide support for absolute PPP, while the presence of a unit root in nominal exchange rates and relative prices indicates that they could be co-integrated. The presence of co-integration (with the Engle and Granger approach), in its turn, then provides support for PPP.

The next step then, is to set up the framework for the actual empirical work involved. The following chapter provides extensive detail about the source and quality of the data used in this thesis, with graphical illustrations of real exchange rates, as well as tabulations of some descriptive statistics. The actual empirical results are then reported and discussed in greater detail in chapter IV.

CHAPTER III

DATA SERIES: SOURCES AND TYPES.

1. INTRODUCTION.

This chapter takes an in depth look into the data studied in this thesis using empirical methodologies whose theoretical foundations were discussed in the previous chapter. The next section individually discusses all the relevant data series: the dollar-based and deutschemark-based real and nominal exchange rates as well as the appropriate price indices. It also provides some graphical illustrations as well as tabulations of some useful descriptive statistics.

2. DATA.

The data studied here has been acquired from the OECD Main Economic Indicators. The data are recorded as quarterly entries from 1973:1 to 1992:1, for the following 17 OECD member countries:

Austria	Germany	Norway
Belgium	Greece	Spain
Canada	Ireland	Switzerland
Denmark	Italy	UK
Finland	Japan	USA.
France	Netherlands	

where the underlined countries, currencies represent 'base currencies'.

Since we have considered two base series, one with USA as the domestic country, and the other with Germany as the domestic country, we discuss below, in some detail, the dollar-based and deutschemark-based time series studied here i.e. the nominal exchange rate, relative prices and the real exchange rate.

The nominal exchange rate, as acquired from the OECD publications, is the dollar value of one unit of foreign currency. This publication, therefore, reports the nominal exchange rate as US cents per unit of foreign currency, which is then the dollar-based nominal exchange rate. Since most empirical work to date has been done using such direct quotes, this thesis uses *indirect quotes* i.e. by taking direct reciprocals, we convert the reported exchange rates, to the foreign currency price of a dollar.

Note that logarithms are then taken of all data series used here. This is because transforming to logs, while being a monotonic transformation, has the advantage of changing the multiplicative PPP equation (equation [2] above) to an additive equation (equation [3] above), allowing us to then proceed with empirical work based on regression equation [6] above.

Nominal exchange rates, with respect to the deutschemark, are found using implied cross rates. To see how this works, consider the following example, given the dollar-based nominal exchange rates (in levels) for Austria and Germany, i.e. $\frac{aus\$}{us\$}$ and $\frac{DM}{us\$}$ respectively, then the deutschemark-based Austrian nominal exchange rate can be found in the following manner

$$ER_{\frac{aus\$}{DM}} = \frac{\frac{aus\$}{us\$}}{\frac{DM}{us\$}}$$

In this manner the deutschemark-based nominal exchange rate can be calculated for all the countries mentioned above (with the exception of Germany of course).

Some descriptive statistics for the logs of quarterly nominal exchange rate series are provided in table 1, where the first two columns and the last two columns report the mean and standard deviation for the dollar-based and the deutschemark-based nominal exchange rates respectively.

Recall equation [2], which represents the absolute PPP relationship, and postulates that the nominal exchange rate S, should equal to the ratio of prices in the domestic country to prices in the foreign country. Since general prices are not easily available, price indices are used instead. Here, as mentioned previously, we are using the consumer price index.

The consumer price index, as recorded in the OECD

TABLE 1. MEAN AND STANDARD DEVIATION FOR THE DOLLAR-BASED AND DEUTSCHEMARK-BASED NOMINAL EXCHANGE RATE SERIES FROM 1973:1 TO 1992:1.

	DOLLAR-BASED		DEUTSCHEMARK-BASED	
COUNTRY	Mean	Standard Deviation	Mean	Standard Deviation
Austria	-1.8770	0.1932	1.9604	0.0158
Belgium	-0.9474	0.2017	2.8901	0.1412
Canada	-4.4494	0.1041	-0.6120	0.2280
Denmark	-2.6824	0.2081	1.1551	0.1940
Finland	-3.1403	0.1616	0.6972	0.1817
France	-2.8810	0.2356	0.9565	0.2445
Germany	-3.8375	0.1918	-	-
Greece	-0.3236	0.6789	3.5139	0.7679
Ireland	-5.0996	0.2383	-1.2621	0.2713
Italy	2.3843	0.3390	6.2217	0.3856
Japan	0.7237	0.2894	4.5612	0.1819
Netherlands	-3.7446	0.1823	0.0928	0.0321
Norway	-2.7843	0.1650	1.0532	0.2149
Spain	-0.0500	0.3506	3.7875	0.3897
Switzerland	-3.9345	0.2500	-0.0971	0.1156
UK	-5.1890	0.1859	-1.3516	0.2326
USA	-	-	3.8375	0.1918

NOTES: These statistics are for quarterly log level data from 1973:1 to 1992:1.

publications, has 1980 as the base year and consequently a cpi of 100. All the other year's price indices are found in the manner demonstrated in section 2, chapter II above. The price indices used in the empirical work in the following chapter are not seasonally adjusted quarterly entries.

We use these individual cpi's to calculate *relative* price indices are calculated, since it is relative prices that are of interest to this thesis (as per regression equation [6]). With USA as the base country, relative prices are calculated as the CPI for the foreign country in question divided by the CPI for USA. Similarly relative price indices, with Germany as the base country, are calculated as the CPI for the foreign country divided by the CPI for Germany as in the case of the US based relative price indices.

Table 2 reports similar statistics for relative prices as it did for nominal exchange rates in table 1. The first two columns report the mean and standard deviation for relative prices with respect to USA as the base country, while the last two columns report these statistics for the series with respect to Germany.

As mentioned in section 3 of chapter II, the real exchange rate, defined as foreign prices relative to domestic prices, represents short-run deviations from PPP. Hence consideration must be given to it's behaviour. The real exchange rate is calculated as in equation [13], except since we use relative prices a more relevant form for this series

TABLE 2. MEAN AND STANDARD DEVIATION FOR THE DOLLAR-BASED AND DEUTSCHEMARK-BASED RELATIVE PRICE INDEX SERIES FROM 1973:1 TO 1992:1.

COUNTRY	DOLLAR-BASED		DEUTSCHEMARK-BASED	
	Mean	Standard Deviation	Mean	Standard Deviation
Austria	0.0509	0.1089	-0.0310	0.0568
Belgium	-0.0181	0.0573	-0.1000	0.1231
Canada	-0.0267	0.0503	-0.1086	0.2062
Denmark	-0.0675	0.0797	-0.1494	0.2362
Finland	-0.0816	0.1170	-0.1635	0.2709
France	-0.1220	0.1075	-0.2039	0.2629
Germany	0.0819	0.1610	-	-
Greece	-0.2998	0.6210	-0.3817	0.7746
Ireland	-0.2191	0.2348	-0.3010	0.3903
Italy	-0.2596	0.3186	-0.3415	0.4768
Japan	0.0689	0.1367	-0.0130	0.0703
Netherlands	0.0448	0.1291	-0.0371	0.0481
Norway	-0.0350	0.1081	-0.1169	0.2574
Spain	-0.2327	0.3275	-0.3146	0.4857
Switzerland	0.1019	0.1664	0.0120	0.0315
UK	-0.0929	0.1709	-0.1748	0.3267
USA	-	-	-0.0819	0.1610

NOTES: These statistics are for quarterly log level data from 1973:1 to 1992:1.

is:

$$\ln E_t = \ln S_t + \ln(P_t/P_t^*) \qquad [15]$$

where E_t is the real exchange rate, S_t the nominal exchange rate, P_t the domestic price index and P_t^*, the foreign price index.

Table 3, as with the previous two tables, reports the mean and standard deviation of the real exchange rate for both the dollar-based series (first two columns) and the deutschemark-based series (last two columns).

Since stationarity in the log levels of the real exchange rate provides support for PPP (implying that real exchange rates do represent deviations from PPP), we felt that graphical illustrations of the real exchange rate would be useful to determine if the series exhibit any upward or downward trend properties or if they are stationary[13]. Figures 1 to 4 depict both the dollar-based real exchange rate and the deutschemark-based real exchange rate for each country (as shown, with the exception of USA and Germany for whom only one series each is available and hence their individual series have been graphed together in figure 2.C.). Each series is graphed on a different Y-axis. The dollar-based series is

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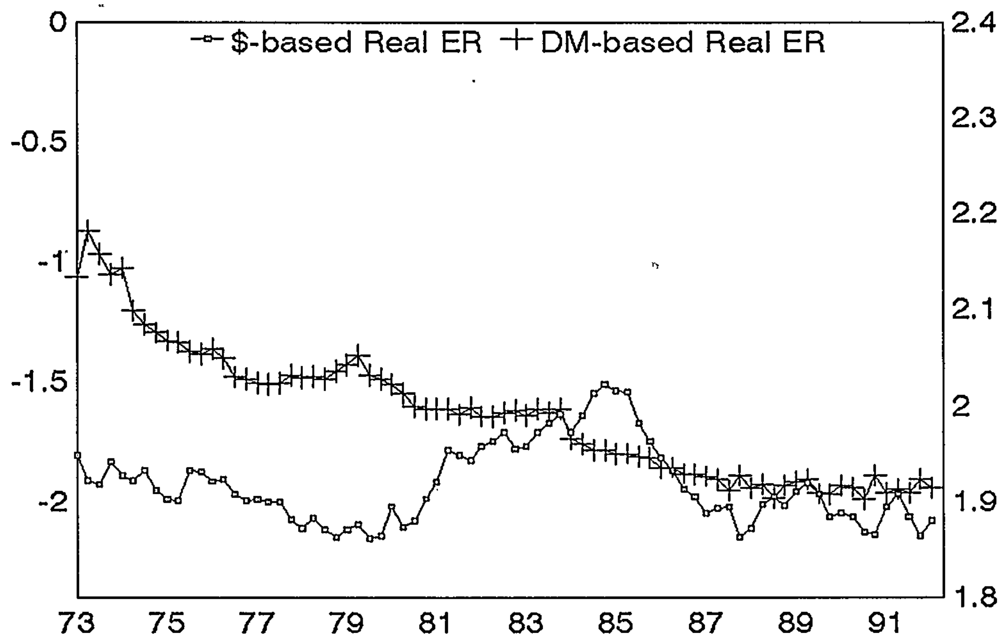
[13] Hakkio (1991) and Mark (1990) use the same idea, where the former uses graphs of the nominal exchange rate and the PPP rate, while the latter uses graphs of nominal exchange rates and relative prices.

TABLE 3. MEAN AND STANDARD DEVIATION FOR THE DOLLAR-BASED AND DEUTSCHEMARK-BASED REAL EXCHANGE RATE SERIES FROM 1973:1 TO 1992:1.

COUNTRY	DOLLAR-BASED		DEUTSCHEMARK-BASED	
	Mean	Standard Deviation	Mean	Standard Deviation
Austria	-1.9279	0.1670	1.9915	0.0681
Belgium	-0.9293	0.2094	2.9901	0.0526
Canada	-4.4227	0.0811	-0.5034	0.1516
Denmark	-2.6149	0.1804	1.3044	0.0543
Finland	-3.0587	0.1513	0.8607	0.1222
France	-2.7590	0.1677	1.1604	0.0454
Germany	-3.9194	0.1772	-	-
Greece	-0.0238	0.1585	3.8956	0.0702
Ireland	-4.8805	0.1335	-0.9612	0.1413
Italy	2.6439	0.1636	6.5634	0.1174
Japan	0.6548	0.1968	4.5742	0.2035
Netherlands	-3.7894	0.1760	0.1299	0.3138
Norway	-2.7493	0.1318	1.1701	0.0760
Spain	0.1827	0.1990	4.1021	0.1278
Switzerland	-4.0364	0.1686	-0.1170	0.1059
UK	-5.0961	0.1591	-1.1768	0.1659
USA	-	-	3.9194	0.1772

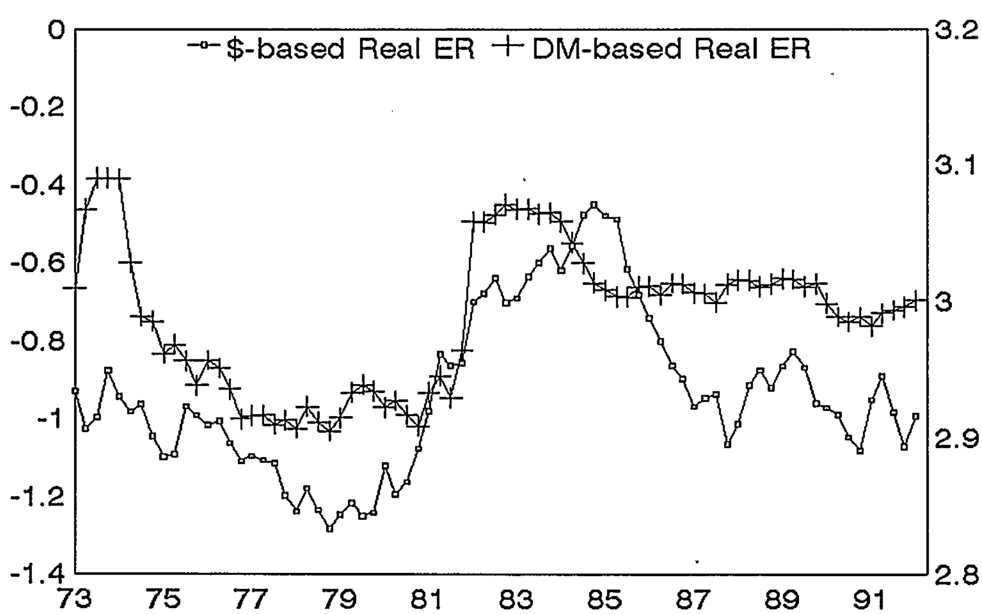
NOTES: These statistics are for quarterly log level data from 1973:1 to 1992:1.

Figure 1.A. Dollar-based & Deutschemark-based Real Exchange Rates for Austria.



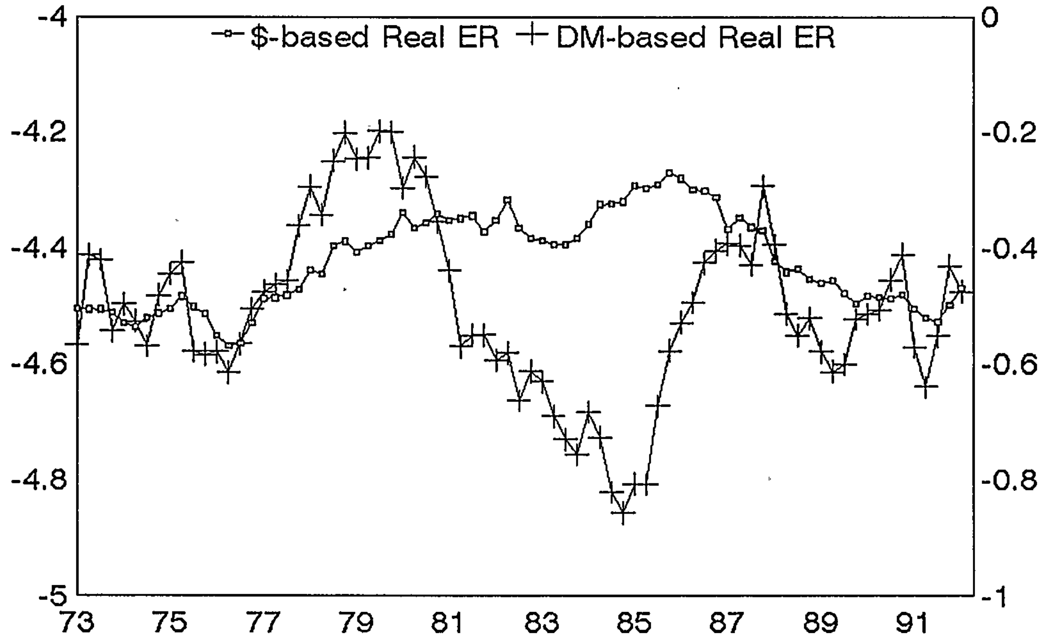
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 1.B. Dollar-based & Deutschemark-based Real Exchange Rates for Belgium.



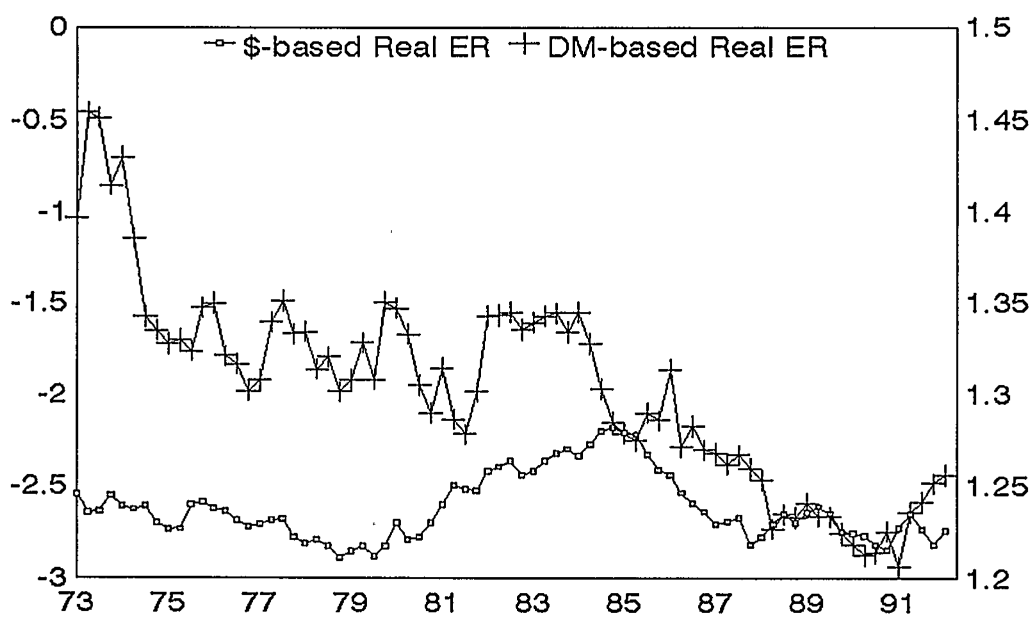
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 2.A. Dollar-based & Deutschemark-based Real Exchange Rates for Canada.



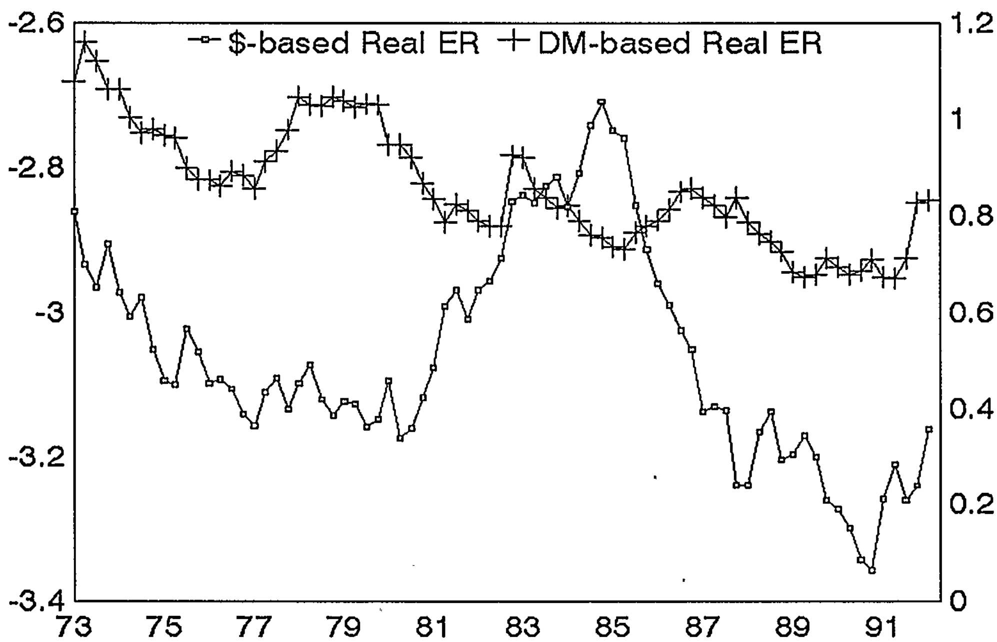
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 2.B. Dollar-based & Deutschemark-based Real Exchange Rates for Denmark.



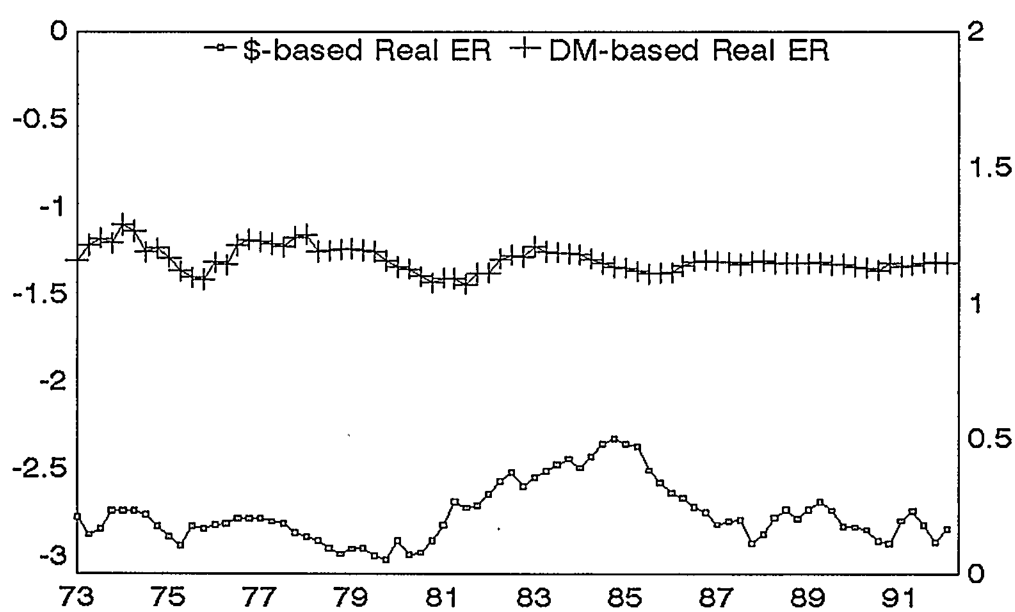
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 3.A. Dollar-based & Deutschemark-based Real Exchange Rates for Finland.



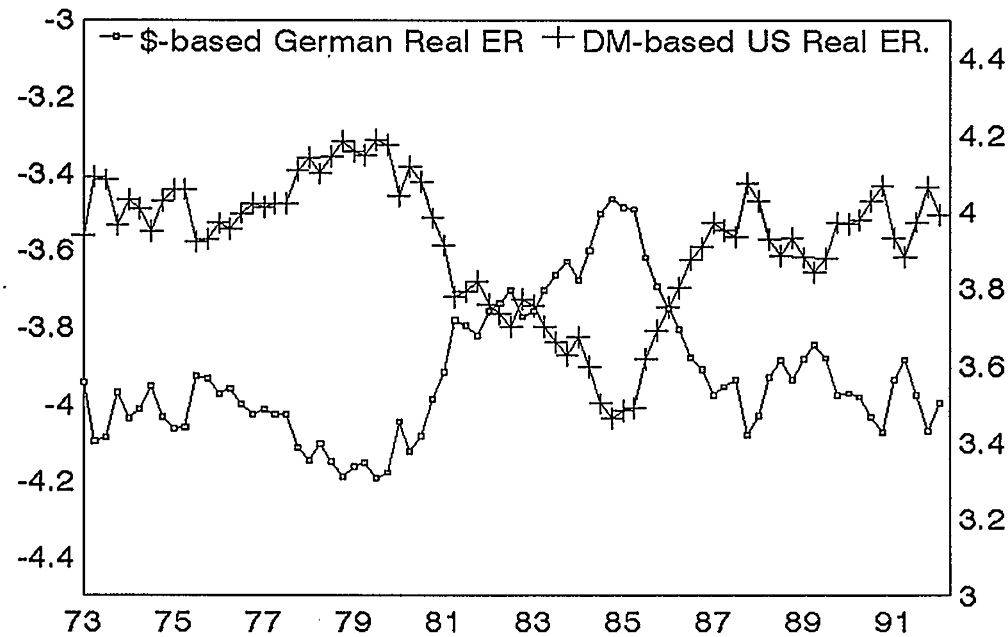
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 3.B. Dollar-based & Deutschemark-based Real Exchange Rates for France.



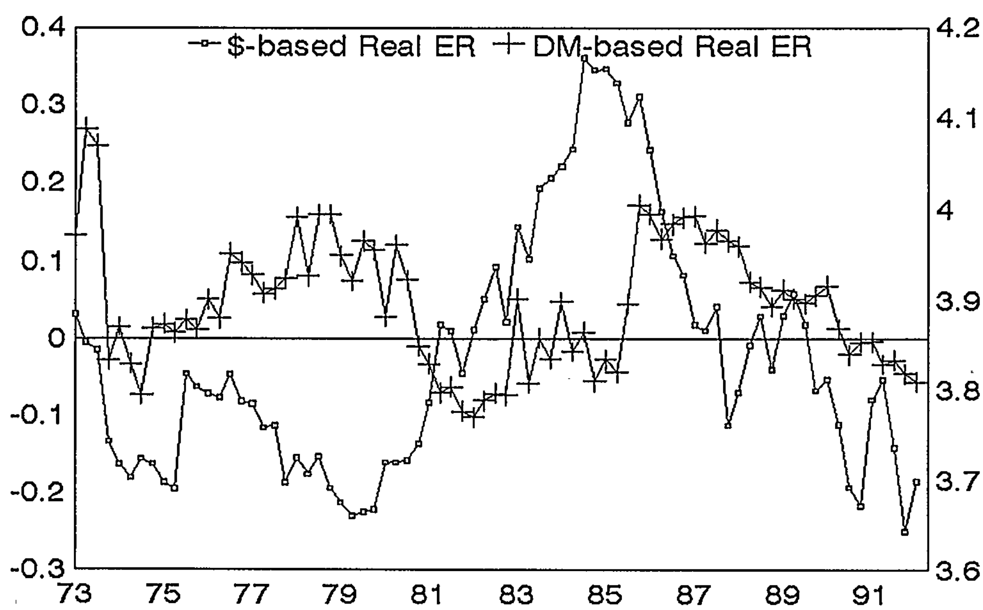
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 4.A. Real Exchange Rates: Dollar-based for Germany & DM-based for US.



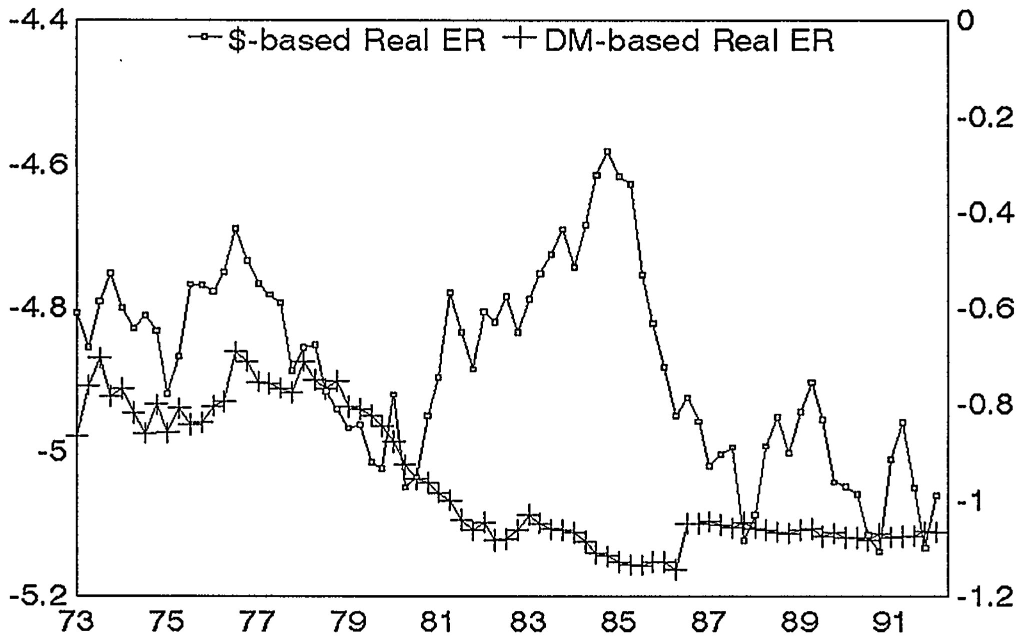
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 4.B. Dollar-based & Deutschemark-based Real Exchange Rates for Greece.



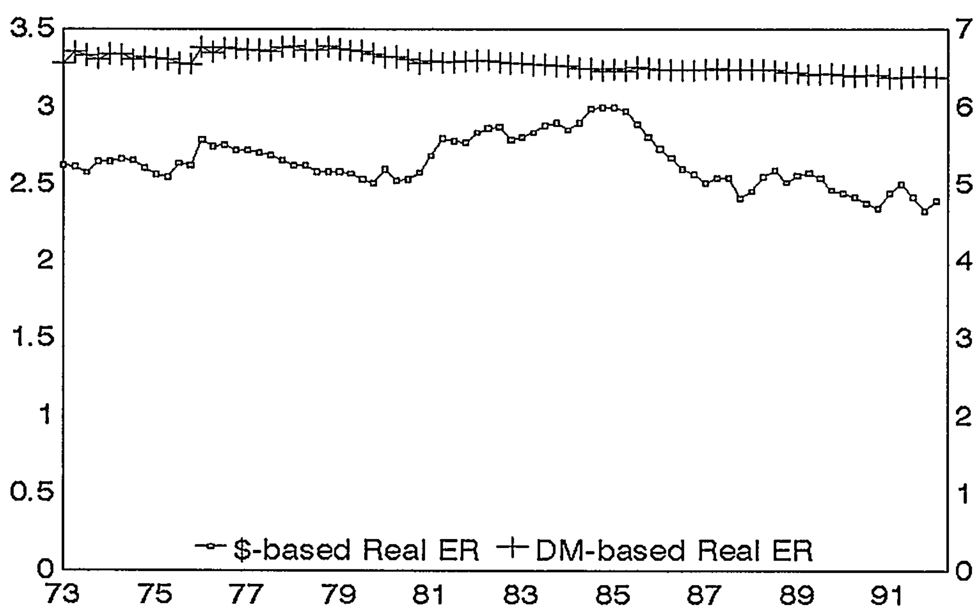
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 5.A. Dollar-based & Deutschemark-based Real Exchange Rates for Ireland.



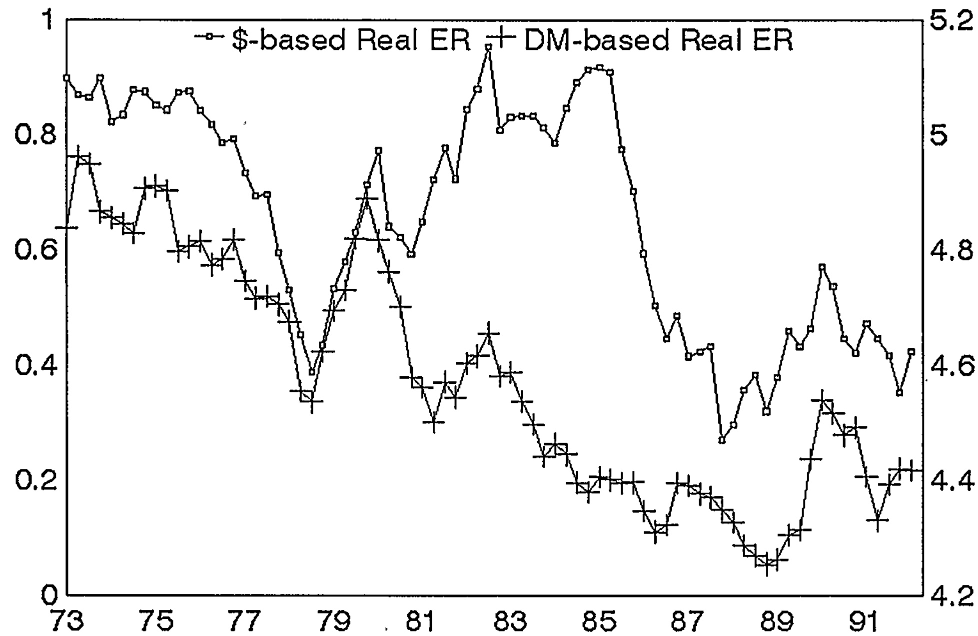
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 5.B. Dollar-based & Deutschemark-based Real Exchange Rates for Italy.



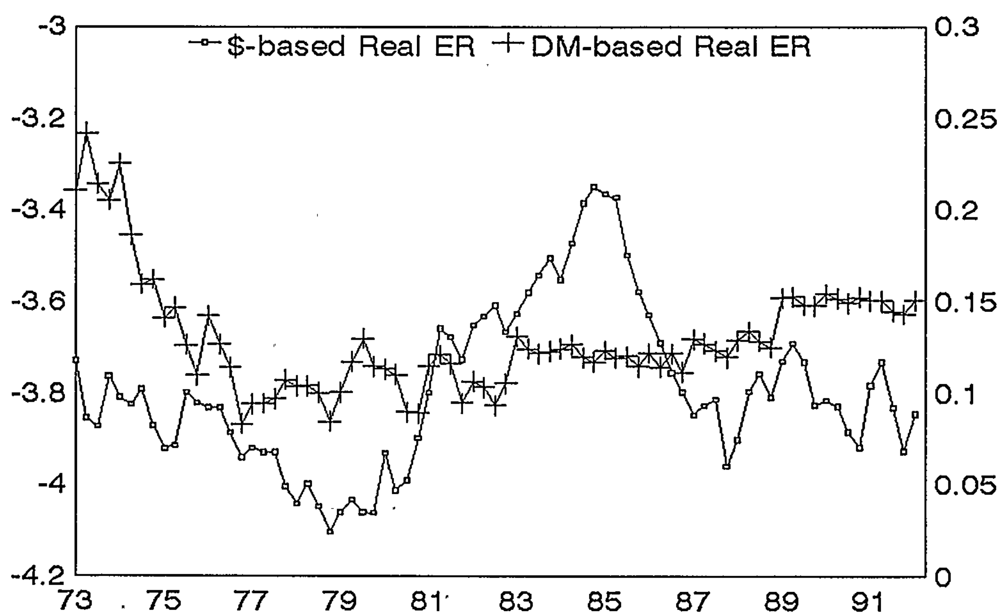
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 6.A. Dollar-based & Deutschemark-based Real Exchange Rates for Japan.



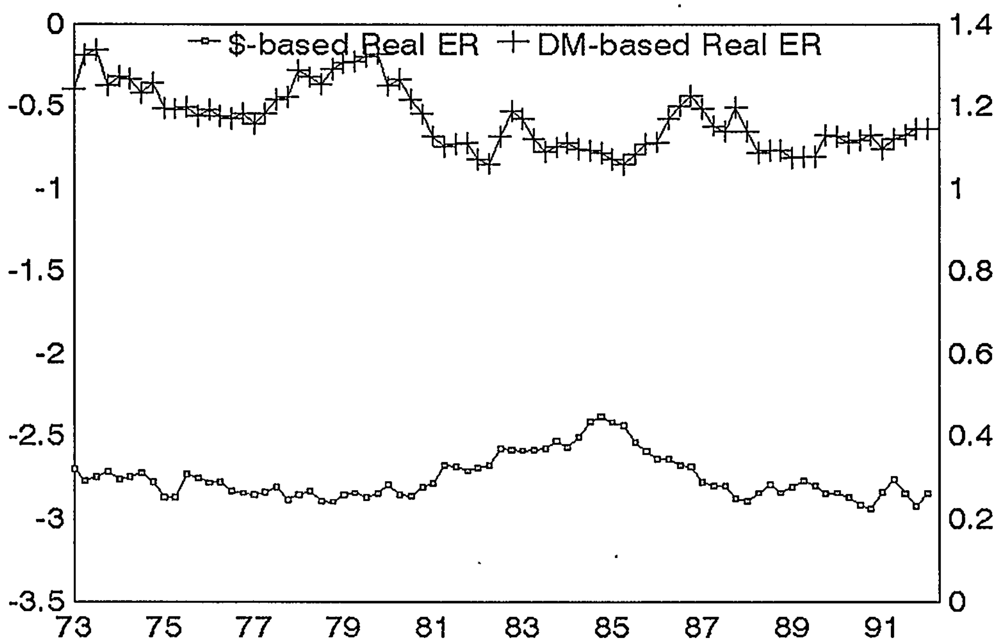
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 6.B. Dollar-based & Deutschemark-based Real Exchange Rates for Netherlands.



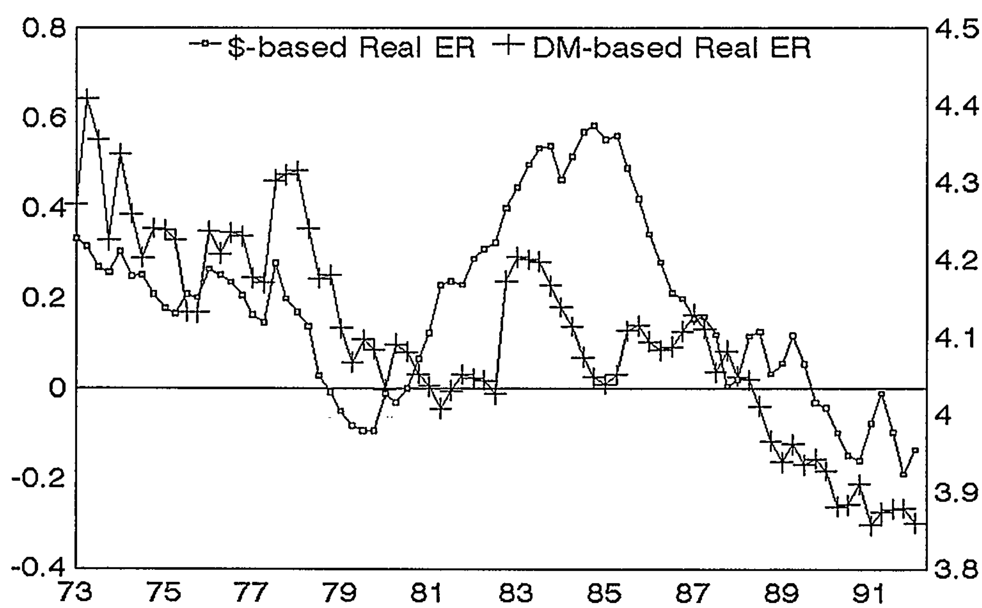
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 7.A. Dollar-based & Deutschemark-based Real Exchange Rates for Norway.



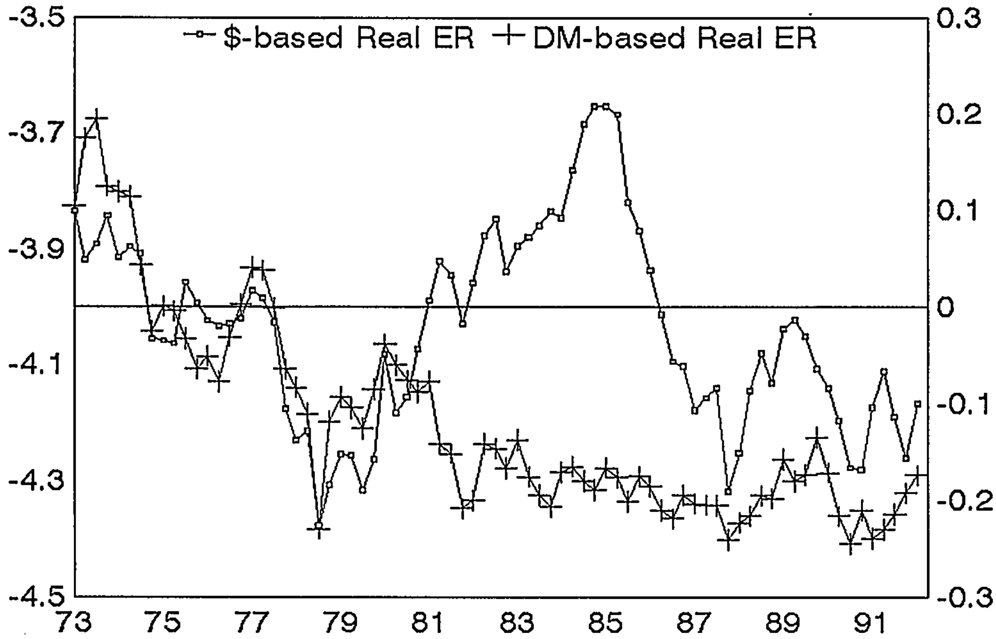
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 7.B. Dollar-based & Deutschemark-based Real Exchange Rates for Spain.



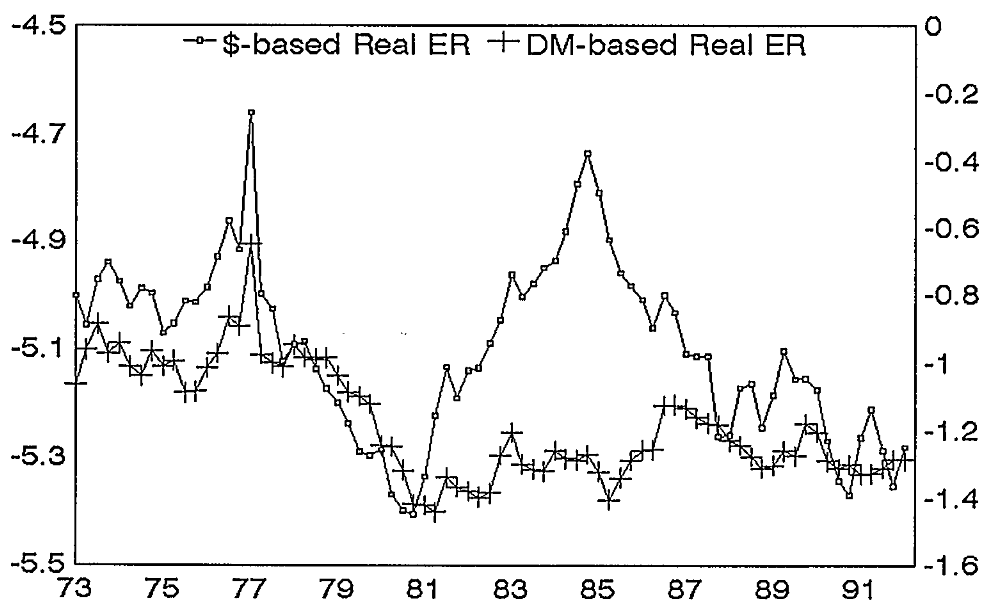
Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 8.A. Dollar-based & Deutschemark-based Real Exchange Rates for Switzerland.



Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

Figure 8.B. Dollar-based & Deutschemark-based Real Exchange Rates for UK.



Notes: Sample period, quarterly data: 1973:1 - 1992:1. All series are in logs.

graphed on the left Y-axis (henceforth Y1) and the deutschemark-based real exchange rate is on the right Y-axis (Y2). The implications of these graphs will be incorporated in chapter IV.

3. CONCLUSION.

We have provided in this chapter, considerable detail about the type of data used in this thesis, as well as some descriptive statistics and graphical illustrations to provide an intuitive understanding of the data being studied here. The following chapter reports the empirical results from testing for PPP, based on the test methodologies discussed in the previous chapter. We provide unit root test results for all three time series, i.e. nominal exchange rates, relative price indices and real exchange rates, as well as co-integration test results for those countries whose first two series are integrated of order 1. We go on to test the real exchange rate for properties that may provide support for the PPP relationship as per our previous discussion. We also present results from unit root tests for the real exchange rate, that account for one-time structural breaks.

CHAPTER IV

PPP: ESTIMATION RESULTS.

1. INTRODUCTION.

Having considered, in chapter II, the theoretical foundations of PPP, and the methodology involved in testing for PPP, and having established an important step for empirical work, with our discussion on the data series in chapter III, we are now in a position to perform empirical tests to determine the presence (or lack of) of a PPP relationship between the countries of interest.

This chapter briefly summarizes the test methodologies discussed previously, presenting their results (as generated by SHAZAM), and making conclusions about PPP based on these results. The next section considers these methodologies, individually looking at each of the tests involved for the dollar-based and the deutschemark-based time series, i.e. the sub-sections report the unit root test results for the nominal exchange rates and relative prices, the co-integration results, the unit root test results for the real exchange rate and briefly analyses the possibility (or lack of) graphical support for PPP based on the stationarity of real exchange rates (as per figures 1 - 8).

The third section then considers the interesting possibility of support for PPP, between countries, once structural breaks are accounted for.

2. EMPIRICAL RESULTS FROM TESTS OF ABSOLUTE PPP.

This section, as mentioned previously, presents all the empirical results from testing for absolute PPP. The first sub-section tests for a unit root in the nominal exchange rate and in the relative price index. Dependent on the results of this sub-section, the second sub-section then tests for co-integration of the nominal exchange rate and the relative price index, the third sub-section then tests for the presence of a unit root in the real exchange rate and ties in graphical support (or lack of) for PPP based on the depictions of the real exchange rates.

2.1. Unit Root Tests: Nominal Exchange Rates and Relative Prices.

As per our discussion in chapter II, the regressions used to test the null hypothesis of a unit root are equations [9] - [11]. In this thesis however, we only use regression [11], which we state here again for convenience purposes:

$$X_t = \theta + \beta(t - \frac{T}{2}) + \alpha X_{t-1} + \varepsilon_t$$

This regression has both trend and drift, the significance of which was discussed in section 3, chapter II.

Based on this regression, the dollar-based and deutschemark-based nominal exchange rates and relative prices were tested for the presence of a unit root using the 'coint' command, with the Phillips-Perron (1988), option in Shazam. Table 4 reports the results for the dollar-based series. The first two columns test for stationarity in log levels of the time series i.e. test to see if the series are integrated of order 0, if not then the last two columns test for stationarity in first differences, i.e. test to see if the series are integrated of order 1 or equivalently test to see if the series contain a unit root. Similarly for the deutschemark-based time series, table 5 shows test results for stationarity in log levels (first two columns), and if not, then for stationarity in growth rates (last two columns).

The critical values, for 100 observations are as given in the notes to the tables. These critical values are the same as those for the Dickey-Fuller tests, despite the fact that the Phillips-Perron (1988) tests cover a wider range of time series specification. This is because, in limit, the distribution of the 'new' transformed statistic (as per our discussion in the second chapter) is the same as the test statistic for the Dickey-Fuller test.

As seen from table 4, the dollar-based nominal exchange rates for all 16 countries are non-stationary in level, but stationary in first differences. Relative prices are also

TABLE 4. PHILLIPS - PERRON UNIT ROOT TESTS FOR THE DOLLAR-BASED NOMINAL EXCHANGE RATE AND RELATIVE PRICE INDEX FOR THE SAMPLE PERIOD 1973:1 TO 1992:1.

Regression: $\ln X_t = \alpha + \beta(t - T/2) + \ln X_{t-1} + \epsilon_t$

	Dollar - Based			
Country	$\ln S_t$	$\ln(P_t^*/P_t)$	$\Delta \ln S_t$	$\Delta \ln(P_t^*/P_t)$
Austria	-1.8081	-1.2396	-7.8184*	-8.5477*
Belgium	-1.4548	-1.7678	-7.4843*	-4.4934*
Canada	-0.8330	-1.7812	-7.8026*	-5.6965*
Denmark	-1.3090	-0.9237	-7.3600*	-8.9085*
Finland	-1.5728	-2.7826	-7.2535*	-9.2906*
France	-1.1036	-0.4389	-7.2121*	-5.2832*
Germany	-1.7895	-0.6489	-8.0100*	-6.0272*
Greece	-1.7536	-1.2610	-7.6054*	-10.068*
Ireland	-1.4127	-0.1831	-7.2296*	-7.0951*
Italy	-1.0830	-0.0935	-7.2484*	-6.5316*
Japan	-2.0570	-4.1504*	-7.1113*	-
Netherlands	-1.6601	-2.1635	-7.5719*	-6.7938*
Norway	-1.8956	-2.1149	-7.8866*	-6.6404*
Spain	-0.6222	-0.6218	-6.7348*	-6.8355*
Switzerland	-2.1032	-0.1071	-7.8219*	-5.2369*
UK	-2.1209	-2.0927	-9.2798*	-7.1146*
USA	-	-	-	-

NOTES: Sample period, quarterly data. The critical values at the 90% level are -3.16 for log levels and -3.17 for log first difference. Significant results are marked with an asterisk.

found to be non-stationary in levels, with the exception of Japan, and stationary in first difference. We can conclude therefore that all the countries of interest have nominal exchange rates that contain a single unit root. Relative prices, on the other hand, are all integrated of order 1 with the exception of Japan's relative price index. These are useful results pertaining to the test for co-integration in the next sub-section.

For the deutschemark-based series, the results are a little bit more daunting (table 5). The nominal exchange rates for Austria, Japan and UK are found to be *stationary in log levels* i.e. not to contain a unit root, while the relative price index for Japan is also found to be stationary in log levels. The rest of the series for the remaining countries however, do contain a unit root.

For those countries whose nominal exchange rate as well as relative prices are found to contain a unit root, the next sub-section can now explore the possible existence of a PPP relationship using co-integration technics based on Engle and Granger. For those countries whose exchange rate and/or relative price are found to be stationary in levels, the PPP relationship has already failed as per the discussion on co-integration in chapter II.

Summarizing these results, we see that for the dollar-based series, we can not test for co-integration between Japan's nominal exchange rate and relative price index. For

TABLE 5. PHILLIPS - PERRON UNIT ROOT TESTS FOR THE DEUTSCHEMARK-BASED NOMINAL EXCHANGE RATE AND RELATIVE PRICE INDEX FOR THE SAMPLE PERIOD 1973:1 TO 1992:1.

Regression: $\ln X_t = \alpha + \beta(t - T/2) + \ln X_{t-1} + \epsilon_t$

	Deutschemark - Based			
Country	$\ln S_t$	$\ln(P_t^*/P_t)$	$\Delta \ln S_t$	$\Delta \ln(P_t^*/P_t)$
Austria	-3.2489*	-1.8987	-	-10.891*
Belgium	-1.0531	-0.8257	-6.7160*	-6.2167*
Canada	-2.1185	0.8318	-7.8702*	-6.7072*
Denmark	-0.7151	1.4919	-8.9664*	-9.1499*
Finland	-2.3166	-2.1522	-8.4011*	-12.460*
France	-1.6660	2.9621	-8.5979*	-6.7213*
Germany	-	-	-	-
Greece	-2.2755	-1.7255	-10.493*	-10.553*
Ireland	-2.4799	1.0593	-9.9206*	-7.3300*
Italy	-1.8397	1.9772	-12.904*	-6.4824*
Japan	-3.3012*	-7.8169*	-	-
Netherlands	-2.9183	-2.1226	-12.955*	-10.189*
Norway	-2.3395	-1.2892	-7.8586*	-7.3993*
Spain	-1.1941	0.4897	-8.9462*	-7.4532*
Switzerland	-1.3769	-0.3085	-9.3862*	-6.9498*
UK	-3.2569*	-1.4342	-	-6.5829*
USA	-1.7895	-0.6449	-8.0100*	-6.0272*

NOTES: Sample period, quarterly data. The critical values at the 90% level are -3.16 for log levels and -3.17 for log first difference. Significant results are marked with an asterisk.

the deutschemark-based series, we can not test for co-integration between Austria's, Japan's and UK's data series.

2.2. Co-integration Test Results.

Once we have determined which series are integrated of order one, i.e. tested for the presence of a unit root in the components of the vector $X_t = \{\ln S_t, \ln(P_t^*/P_t)\}$, we are now in a position to test if these components are co-integrated. As mentioned previously the Engle and Granger approach is used. Recall that co-integration basically involves the testing for a unit root in the residuals from regressing the price index on the nominal exchange rate. The difference from convention co-integration tests is that again we test for a unit root, in the residuals, using Phillips and Perron's robust approach.

Table 6 reports these co-integration results, for those countries whose both, nominal exchange rates and relative price indices are integrated of order one (as per table 4 and 5). The first column reports the co-integration results for the dollar-based series, while the second column reports those for the deutschemark-based series.

As seen from these results in table 6 for the dollar-based series (first column) all the countries whose data are tested for co-integration, fail to reject the null hypothesis of no co-integration i.e. neither of the Engle and Granger test statistics are significant. For deutschemark-based time

TABLE 6. ENGLE AND GRANGER CO-INTEGRATION TESTS.

Regression: $\ln S_t = \alpha + \beta \ln(P_t^*/P_t) + u_t$

Country	Dollar-based Engle & Granger co-integration results.	Deutschemark-based Engle & Granger co-integration results.
Austria	-1.9371	-
Belgium	-1.4982	-1.6090
Canada	-0.9044	-2.1374
Denmark	-2.0970	-2.9997
Finland	-1.6415	-2.2064
France	-2.2995	-3.5073*
Germany	-1.8949	-
Greece	-1.6321	-3.2275
Ireland	-3.1334	-3.3155
Italy	-2.6209	-3.8469*
Japan	-	-
Netherlands	-1.6859	-3.9129*
Norway	-1.8769	-2.8379
Spain	-1.6755	-3.2110
Switzerland	-2.1335	-3.4270
UK	-2.2270	-
USA	-	-1.8949

NOTES: Sample period, quarterly data. The 10% critical value for the co-integration results is -3.50. All significant results are marked with an asterisk.

series (second column) we are able to reject the null for France, Italy and Netherlands, suggesting that these countries' series are co-integrated, providing evidence for the PPP relationship[14].

2.3. Real Exchange Rates: Unit Root Tests Results.

Another test for the PPP relationship, as determined before, is the test for stationarity in the log levels of the real exchange rate. Recall that the real exchange rate is a linear combination of the nominal exchange rate and the relative price (equation [15]). If the exchange rate is not stationary, in levels, then the PPP relationship can not exist, based on our previous discussion on co-integration and on the fact that the real exchange rate represents deviations from PPP.

Table 7 reports the Phillips-Perron (1988) test results for stationarity in log level dollar-based and deutschemark-based real exchange rate for all 16 countries. As seen from these results, for the dollar-based series (first two columns) all countries real exchange rates are found to be *non-*

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[14] Fisher & Park (1991) have tested for co-integration for a subset of the group of countries covered in this thesis. They found evidence of co-integration for France in the Dollar-based series and for Canada, Italy, Japan, Netherlands, Switzerland and UK for the deutschemark-based series. They used monthly data from 1973 March to 1988 May. Mark (1990) did some similar empirical work with respect to dollar and deutschemark-based series, but found little evidence of co-integration.

TABLE 7. PHILLIPS - PERRON UNIT ROOT TESTS FOR THE DOLLAR-BASED AND DEUTSCHEMARK-BASED REAL EXCHANGE RATE FOR THE SAMPLE PERIOD 1973:1 TO 1992:1.

Regression: $\ln E_t = \alpha + \beta(t - T/2) + \ln E_{t-1} + \epsilon_t$

	Dollar - Based		Deutschemark - Based	
Country	$\ln E_t$	$\Delta \ln E_t$	$\ln E_t$	$\Delta \ln E_t$
Austria	-1.6989	-7.6920*	-2.5825	-12.484*
Belgium	-1.4753	-7.4630*	-1.8710	-6.9749*
Canada	-0.9475	-7.3799*	-2.0470	-7.9498*
Denmark	-1.5247	-7.3841*	-2.9298	-9.9135*
Finland	-1.6283	-7.2091*	-2.0145	-7.8007*
France	-1.4756	-7.3332*	-3.3355*	-
Germany	-1.5993	-8.1020*	-	-
Greece	-1.5191	-8.7531*	-3.1464	-11.250*
Ireland	-2.2146	-8.1782*	-2.0417	-10.179*
Italy	-1.4298	-7.4612*	-3.8638*	-
Japan	-2.1586	-7.2269*	-2.5955	-7.1739*
Netherlands	-1.7604	-7.6225*	-2.4857	-11.095*
Norway	-1.7401	-7.9297*	-2.7767	-8.5392*
Spain	-0.9596	-6.6773*	-3.0952	-10.071*
Switzerland	-1.9842	-7.8203*	-2.4875	-9.1517*
UK	-2.1949	-9.5161*	-2.5689	-10.650*
USA	-	-	-1.9117	-7.8598*

NOTES: Data is quarterly. Critical value at the 90% level is -3.16 for log levels and -3.17 for log first difference. Significant results are marked with an asterisk.

stationary in log levels and stationary in first difference. The implications from this are as follows: first, based on our previous discussion on co-integration, a linear combination of the interested variables is not I(0) and second, the presence of a unit root implies that the real exchange rate follows a random walk and thus represents deviations from PPP. Both these implications fail to provide support for PPP for the dollar-based series. For the deutschemark-based time series (column 3) we are able to find stationarity, for France and Italy, providing some support for PPP (this is partly consistent with our results from the previous sub-section).

Our conclusions, based on these stationarity tests of the real exchange rate, are also supported by the graphical illustrations of the real exchange rate provided in the previous chapter (figures 1 - 8). For those real exchange rates that are found to contain a unit root, their graphs depict upward or downward trends or both.

3. UNIT ROOT TESTS FOR REAL EXCHANGE RATES WITH STRUCTURAL BREAKS.

3.1. Setting Up The Framework.

A consideration when testing for the presence of a unit root in a time series, is that if the time series contains one or more structural breaks, it will mirror unit root behaviour and therefore render unit root tests as ineffective [see for example, Perron (1989), Flynn and Boucher (1993) and Serletis (1992)]. This problem can be overcome by accounting for structural breaks.

One way of doing this is by considering, *exogenously*, some potential one-time breaks. Perron (1989) does precisely that, his method basically involves detrending the time series for structural breaks, i.e. allowing for a one-time change in the intercept or the slope of the trend function, and then testing the detrended series for the presence of a unit root. Perron justifies his methodology by arguing that most macroeconomic time series, once accounted for structural changes in the trend function, are trend stationary and that significant changes, like the formation of the EMS for example, would have lasting effects on these series. Thus modelling such breaks exogenously would remove their influence from the trend function and lead to the rejection of the unit root null[15].

The problem with using Perron's method to test the unit root null against the trend stationary alternative, for a time series with breaks, is that the breaks are *exogenously* determined. This has connotations of all the problems

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[15] Flynn and Boucher [1993], after implementing Perron's method with monthly data, of dollar-based time series for Canada and Japan, for fixed and flexible exchange rate era, found evidence against PPP for all except Canada-US during the fixed exchange rate era.

associated with 'pre-testing'[16]. Taking this into consideration, Zivot and Andrew (1990) have argued that the correct procedure to deal with structural breaks in a time series is to treat them, *endogenously*, as an outcome of the estimation procedure. Thus they transform Perron's conditional (on a structural change at a known time) unit root test into an unconditional unit root test, where the null hypothesis of a unit root with drift and trend is tested against the alternative hypothesis of trend stationarity with a one-time break in the intercept and slope of the trend function at an unknown point in time.

3.2. Empirical Results.

Based on two factors that became apparent from our discussions in previous chapters, one that testing for time series properties like unit roots is important for any empirical work, and two that the presence (or lack of) of a unit root in the real exchange rate has significant implications for the PPP relationship, we felt it prudent to test the real exchange rate for a unit root while making allowances for structural breaks.

Taking into consideration the weaknesses of Perron's methodology, this thesis uses Zivot and Andrew's approach to test the unit root null against the trend stationary

[16] For more detail refer to Christiano [1988]

alternative with the following augmented regression:

$$lnE_t = \hat{\mu} + \hat{\theta}\, DU_t(\hat{\lambda}) + \hat{\beta} t + \hat{\gamma}\, DT_t(\hat{\lambda}) + \hat{\alpha}\, lnE_{t-1} + \sum_{j=1}^{k} \eta_j \Delta lnE_{t-j} + \hat{e}_t$$

where

$\hat{\lambda}$ represents the break fraction or break point ($=T_b/T$, where T is the sample size)

$DU_t(\hat{\lambda})$ is a dummy variable for the intercept such that

$$\begin{aligned} DU_t(\hat{\lambda}) &= 0 \text{ when } t < \lambda T \\ &= 1 \text{ when } t > \lambda T \end{aligned}$$

$DT_t(\hat{\lambda})$ is a dummy variable for the time trend such that

$$\begin{aligned} DT_t(\hat{\lambda}) &= 0 \text{ when } t < \lambda T \\ &= t \text{ when } t > \lambda T \end{aligned}$$

and the other variables are as before.

The k regressors are added to eliminate possible nuisance parameter dependencies, and k is chosen assuming correlation with the data i.e. starting backward at some $k = \bar{k}$, choose k such that the t-statistic on the last included lag in the autoregression, $t_{\hat{\eta}_k}$, is greater than 1.6[17] in absolute terms,

[17] 1.6 approximately corresponds to a 95% level for a two- tailed t-test.

and that $t_{\hat{\eta}_k}$ (in absolute terms) for higher order regressions is less than 1.6. For every country, with both the dollar-based and the deutschemark-based real exchange rate, $\bar{k}$ is set at 12. If the first t-statistic to be greater than 1.6 is for the autoregression with 12 lags, then the t-statistic on the last lag for the next autoregression (k = 13) will be examined, to verify that its magnitude is less than 1.6. In this manner the appropriate number of lags, k, will be found for every choice of λ, ranging from 2/T to (T-1)/T.

Testing the unit root null hypothesis, once the appropriate no. of lags, k, is found , is then equivalent to testing the null $\hat{\alpha} = 1$. The break fraction, λ, is chosen to minimize the one-sided t-statistic for testing $\hat{\alpha} = 1$. This minimum t-statistic, $t_{\hat{\alpha}}(\hat{\lambda})$, is then compared to the "break point" critical value derived and reported by Zivot and Andrew (1990, Table 4A). The unit root null hypothesis is rejected if $t_{\hat{\alpha}}(\hat{\lambda})$ is greater than this critical value.

Tables 8 and 9 report these break points (second column) that minimize the one-sided t-statistics for the dollar-based and deutschemark-based real exchange rate series respectively. As can be seen from these tables, none of the break points correspond with the formation of the EMS with the exception of UK for whom we can not reject the null anyway, implying that accounting for the formation of the EMS does not change the

TABLE 8. TESTS FOR A UNIT ROOT IN THE DOLLAR-BASED REAL EXCHANGE RATE USING ZIVOT AND ANDREW's (1990) PROCEDURE.

$$Regression:\ \ln E_t = \hat{\mu} + \hat{\theta} DU_t(\hat{\lambda}) + \hat{\beta} t + \hat{\gamma} DT_t(\hat{\lambda}) + \hat{\alpha} \ln E_{t-1} + \sum_{j=1}^{k} \eta_j \Delta \ln E_{t-j} + \hat{e}_t$$

Country	T	$\hat{T}_B$	k	$\hat{\mu}$	$\hat{\theta}$	$\hat{\beta}$	$\hat{\gamma}$	$\hat{\alpha}$	$S(\hat{e})$
Austria	77	1989:2	12	-0.717 (-3.7)	0.107 (0.3)	0.002 (2.6)	-0.003 (-0.6)	0.662 (-3.7)	0.06
Belgium	77	1989:2	12	-0.446 (-4.3)	0.177 (0.4)	0.004 (3.8)	-0.004 (-0.8)	0.664 (-4.4)	0.06
Canada	77	1984:2	11	-2.540 (-4.7)	0.309 (4.3)	0.003 (4.0)	-0.006 (-4.4)	0.447 (-4.7)	0.02
Denmark	77	1981:1	3	-0.530 (-3.7)	0.177 (3.3)	-0.001 (-0.5)	-0.002 (-1.4)	0.802 (-3.6)	0.06
Finland	77	1981:1	8	-0.572 (-3.9)	0.084 (1.8)	-0.001 (-0.9)	-0.001 (-0.4)	0.807 (-3.9)	0.04
France	77	1980:4	4	-0.517 (-3.7)	0.123 (2.6)	-0.001 (-0.8)	-0.001 (-0.5)	0.815 (-3.7)	0.05
Germany	77	1984:2	12	-2.039 (-3.7)	0.563 (3.5)	0.004 (3.1)	-0.010 (-3.7)	0.521 (-3.6)	0.06
Greece	77	1983:3	4	-0.056 (-2.2)	0.366 (3.7)	0.001 (1.5)	-0.006 (-3.6)	0.690 (-4.0)	0.05
Ireland	77	1983:3	8	-2.637 (-4.3)	0.300 (3.3)	-0.002 (-2.1)	-0.004 (-2.5)	0.444 (-4.3)	0.05
Italy	77	1984:2	12	1.584 (4.1)	0.708 (4.2)	0.003 (3.1)	-0.013 (-4.5)	0.373 (-4.3)	0.05
Japan	77	1981:1	4	0.284 (4.0)	0.090 (1.8)	-0.005 (-2.6)	0.001 (0.6)	0.717 (-4.4)	0.06
Netherlands	77	1980:4	4	-0.782 (-3.6)	0.117 (2.3)	-0.001 (-0.9)	0.000 (-0.1)	0.795 (-3.6)	0.06
Norway	77	1981:2	7	-0.622 (-3.5)	0.136 (2.5)	0.000 (0.0)	-0.002 (-1.3)	0.780 (-3.4)	0.05
Spain	77	1980:3	8	0.090 (2.2)	0.078 (1.5)	-0.004 (-2.0)	0.001 (0.7)	0.836 (-3.8)	0.05
Switzerland	77	1982:1	4	-1.157 (-3.7)	0.180 (2.5)	-0.002 (-1.0)	-0.002 (-1.0)	0.708 (-3.7)	0.07
UK	77	1977:2	12	-3.013 (-4.2)	0.860 (1.7)	0.066 (2.0)	-0.066 (-2.0)	0.580 (-4.4)	0.07

NOTES: Sample, quarterly data from 1973:1 to 1992:1, adjusted for the value of k. T-statistics are in parenthesis and critical values at the *1% **5% +10% levels are -5.57, -5.08 and -4.82 respectively. Significant values are as marked.

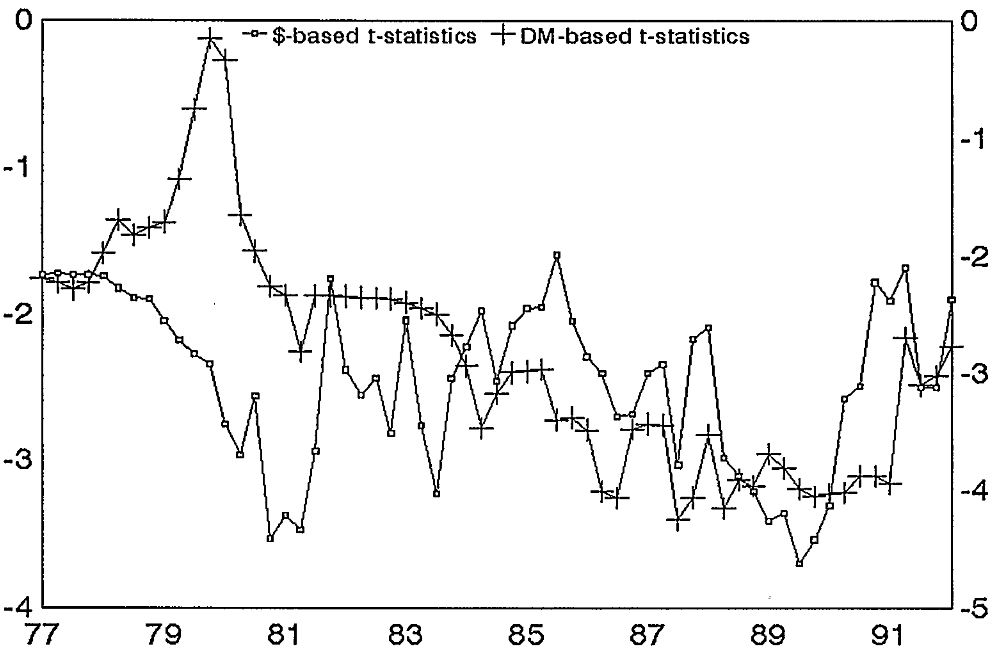
TABLE 9. TESTS FOR A UNIT ROOT IN THE DEUTSCHEMARK-BASED REAL EXCHANGE RATE USING ZIVOT AND ANDREW's (1990) PROCEDURE.

Regression: $\ln E_t = \hat{\mu} + \hat{\theta} DU_t(\hat{\lambda}) + \hat{\beta} t + \hat{\gamma} DT_t(\hat{\lambda}) + \hat{\alpha} \ln E_{t-1} + \sum_{j=1}^{k} \eta_j \Delta \ln E_{t-j} + \hat{e}_t$

Country	T	$\hat{T}_B$	k	$\hat{\mu}$	$\hat{\theta}$	$\hat{\beta}$	$\hat{\gamma}$	$\hat{\alpha}$	$S(\hat{e})$
Austria	77	1987:2	12	1.729 (4.23)	-0.096 (-3.4)	-0.002 (-4.2)	0.001 (3.5)	0.178 (-4.2)	0.01
Belgium	77	1981:4	7	1.328 (6.4)	0.063 (4.1)	-0.001 (-1.6)	0.000 (-0.1)	0.552 (-6.5+)	0.01
Canada	77	1983:2	8	-0.225 (-3.2)	-0.170 (-2.2)	0.002 (1.1)	0.001 (0.6)	0.573 (-4.0)	0.06
Denmark	77	1977:1	0	0.473 (4.6)	-0.025 (-2.2)	-0.004 (-4.1)	0.003 (3.6)	0.676 (-4.5)	0.02
Finland	77	1983:2	12	1.016 (4.7)	-0.059 (-1.6)	-0.002 (-2.4)	-0.001 (-0.7)	-0.014 (-4.7)	0.03
France	77	1980:3	12	1.822 (6.5)	-0.095 (-4.0)	-0.001 (-1.5)	0.001 (1.3)	-0.505 (-6.3+)	0.01
Greece	77	1985:3	8	2.056 (4.7)	0.175 (2.8)	-0.002 (-3.3)	-0.002 (-1.5)	0.484 (-4.7)	0.03
Ireland	77	1980:1	4	-0.165 (-3.0)	-0.072 (-3.2)	0.000 (-0.3)	0.000 (0.4)	0.787 (-3.3)	0.03
Italy	77	1987:1	11	4.662 (7.8)	-0.042 (-0.8)	-0.005 (-8.0)	0.001 (1.4)	0.321 (-7.7+)	0.02
Japan	77	1988:2	5	2.675 (4.0)	-0.753 (-3.2)	-0.006 (-4.0)	0.012 (3.4)	0.461 (-4.0)	0.04
Netherlands	77	1989:1	8	0.042 (3.9)	0.096 (2.0)	0.000 (2.8)	-0.001 (-1.8)	0.522 (-4.0)	0.04
Norway	77	1983:1	8	0.773 (5.0)	-0.099 (-3.1)	-0.001 (0.9)	0.001 (1.2)	0.378 (-5.1**)	0.03
Spain	77	1985:1	11	3.022 (3.9)	0.171 (2.6)	-0.004 (-3.4)	-0.002 (-1.6)	0.303 (-3.9)	0.04
Switzerland	77	1983:2	12	0.038 (1.0)	-0.272 (-3.5)	-0.006 (-2.8)	0.005 (3.1)	-0.361 (-3.8)	0.03
UK	77	1979:1	0	-0.302 (-3.6)	-0.137 (-3.1)	-0.001 (-0.6)	0.001 (0.7)	0.671 (-4.2)	0.06
USA	77	1984:2	12	2.039 (3.7)	-0.563 (-3.5)	-0.004 (-3.1)	0.010 (3.7)	0.521 (-3.6)	0.06

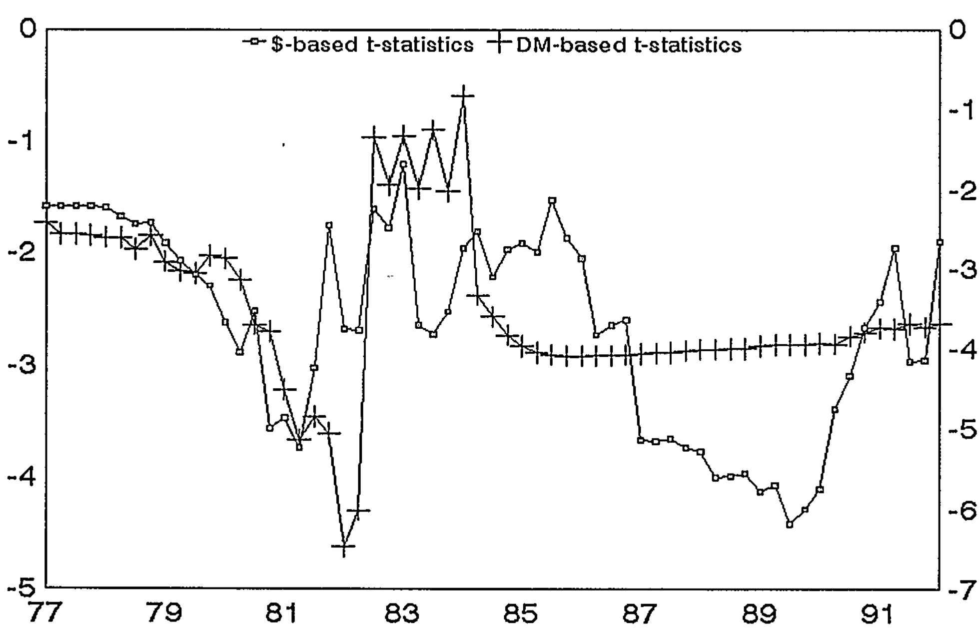
NOTES: Sample, quarterly data from 1973:1 to 1992:1, adjusted for the value of k. T-statistics are in parenthesis and critical values at the *1% **5% +10% levels are -5.57, -5.08 and -4.82 respectively. Significant values are as marked.

Figure 9.A. Austria: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



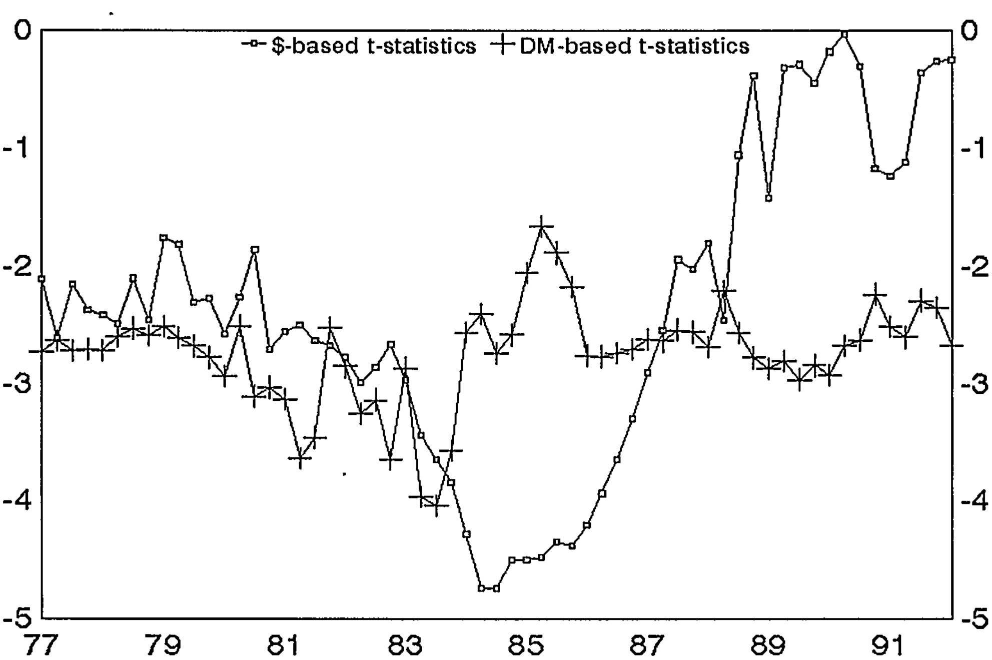
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 9.B. Belgium: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



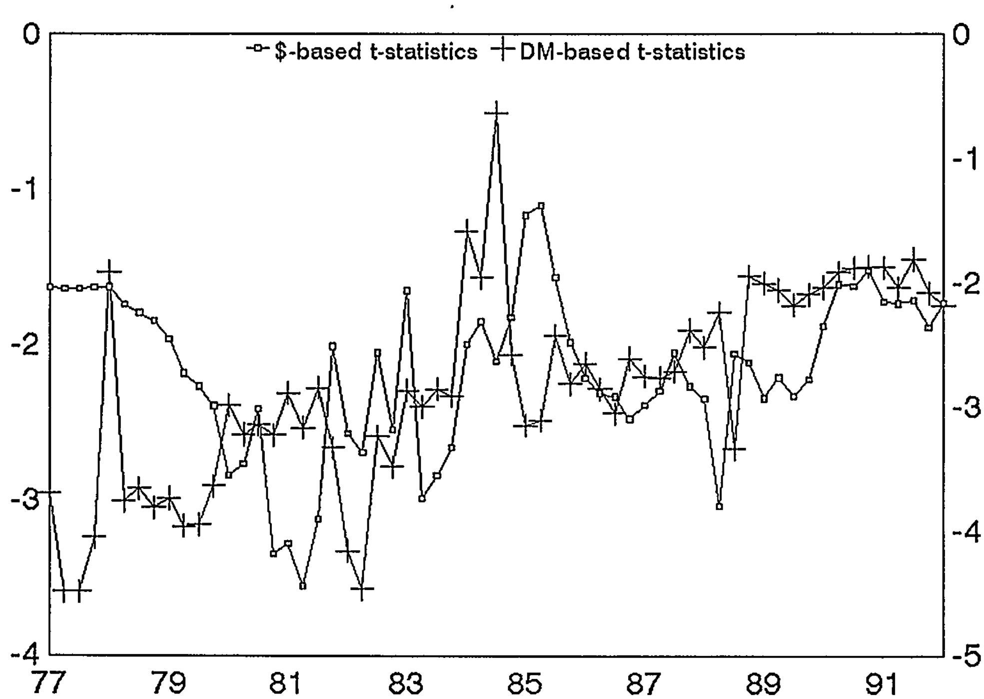
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the' value of k.

Figure 10.A. Canada: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



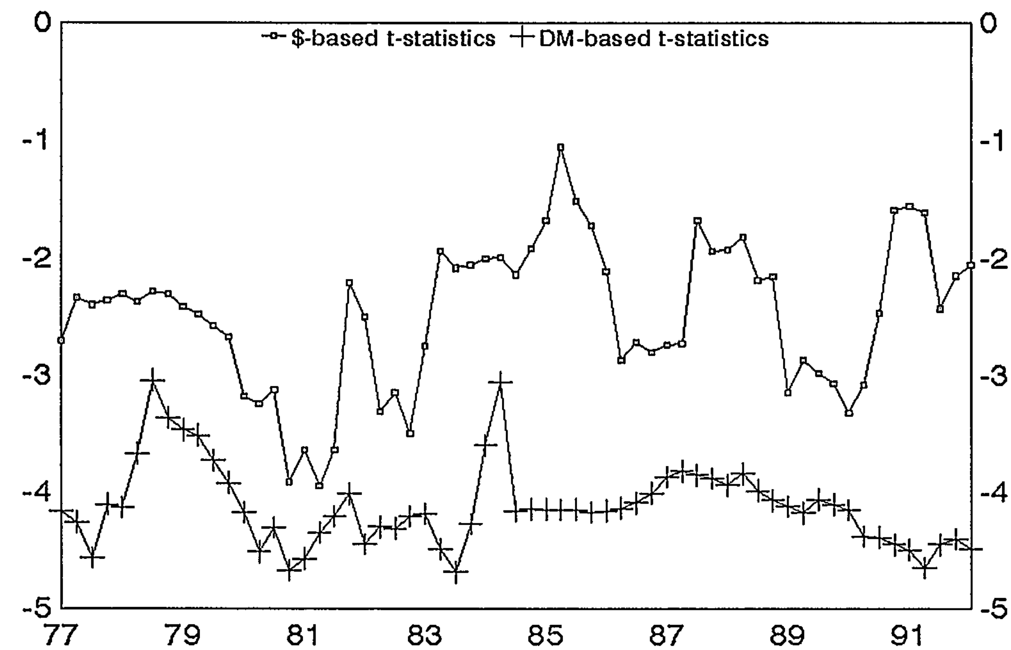
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 10.B. Denmark: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



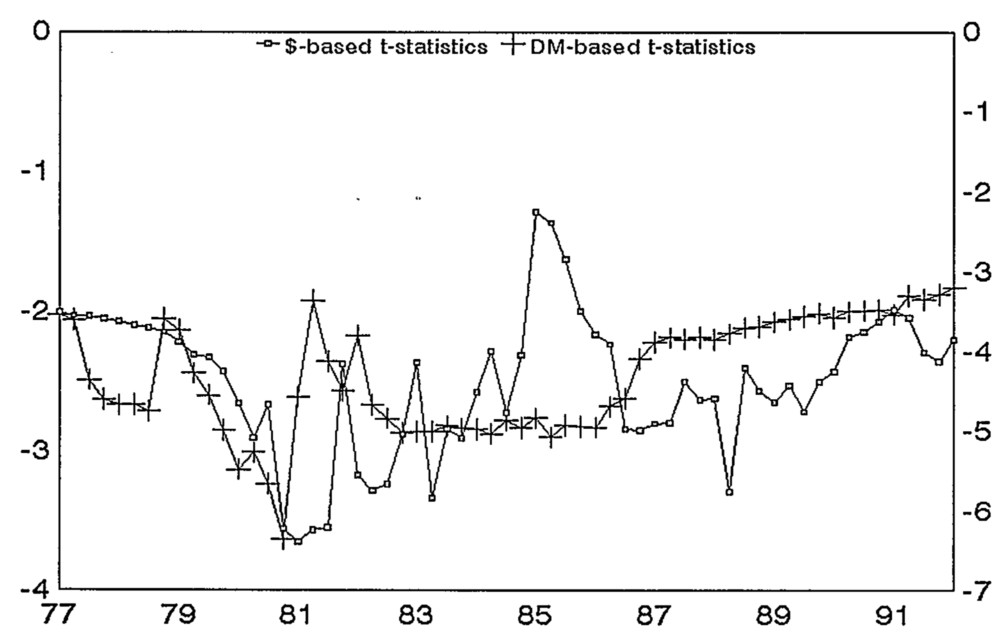
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 11.A. Finland: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



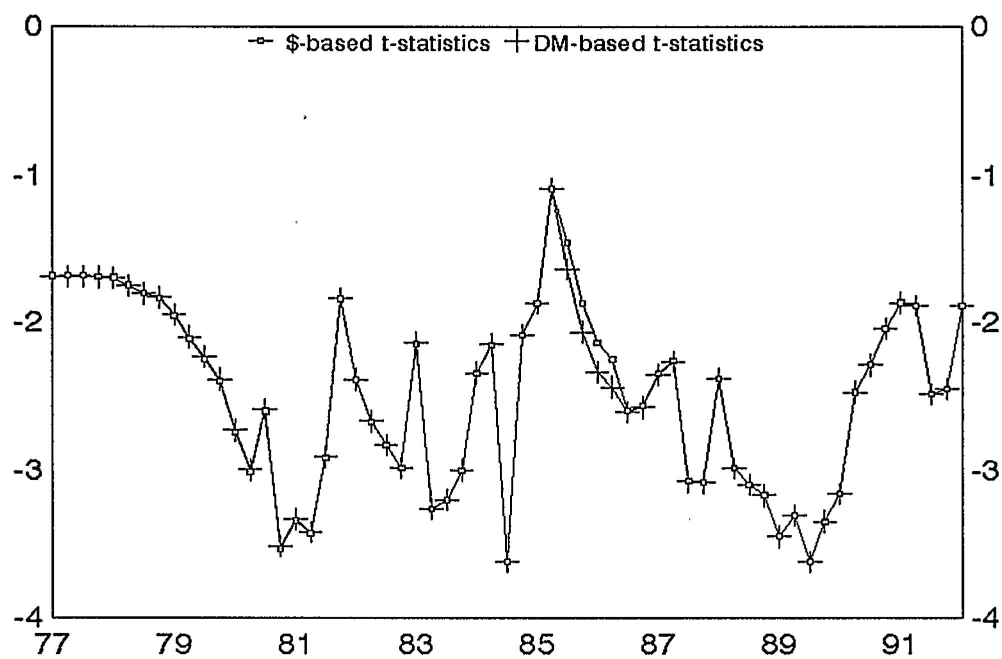
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 11.B. France: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



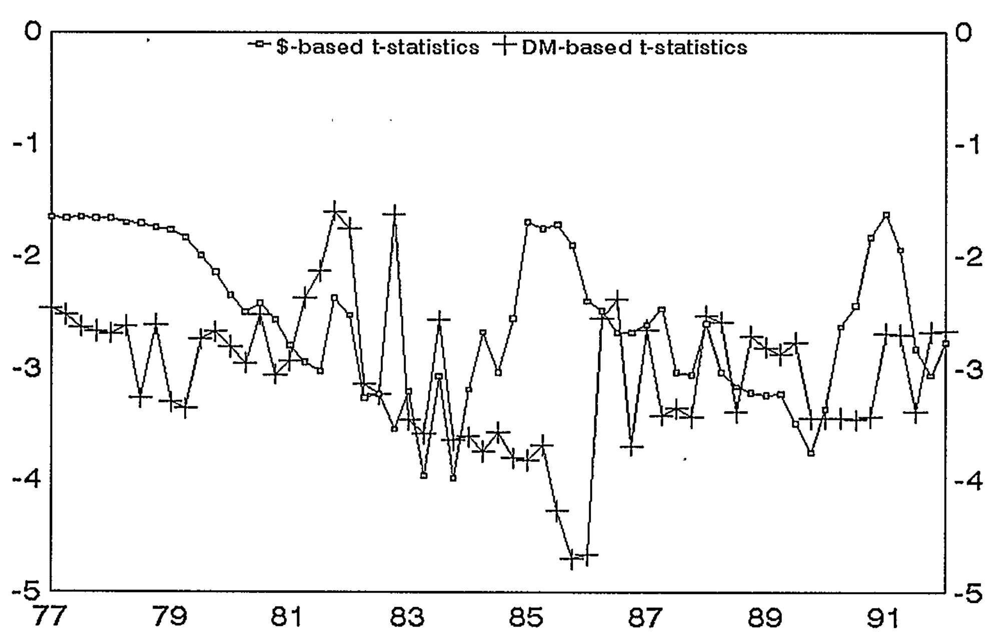
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 12.A: Germany Dollar-Based & USA Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



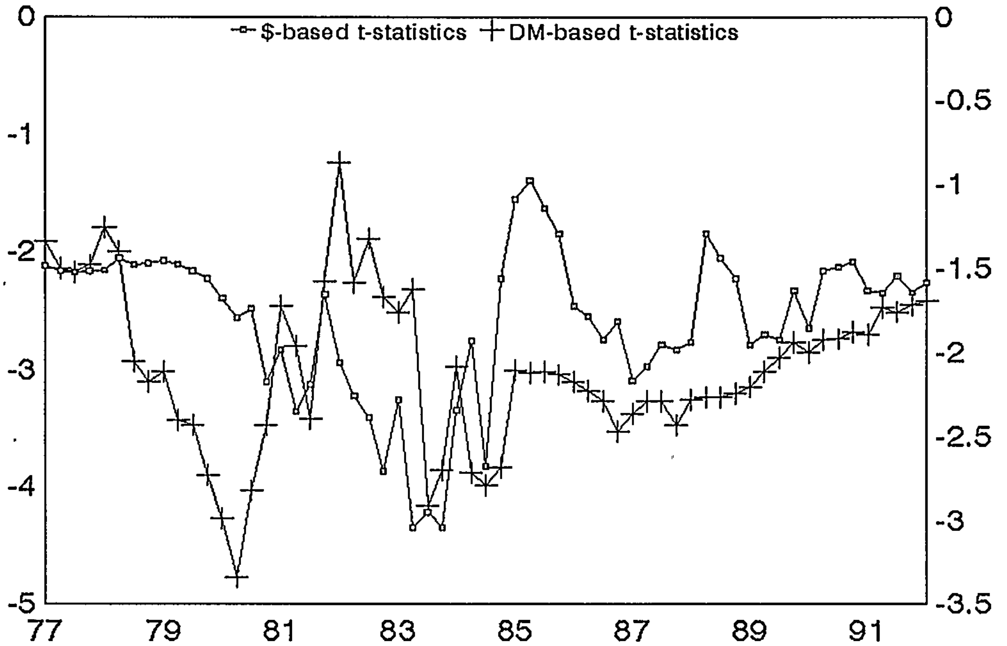
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 12.B. Greece: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



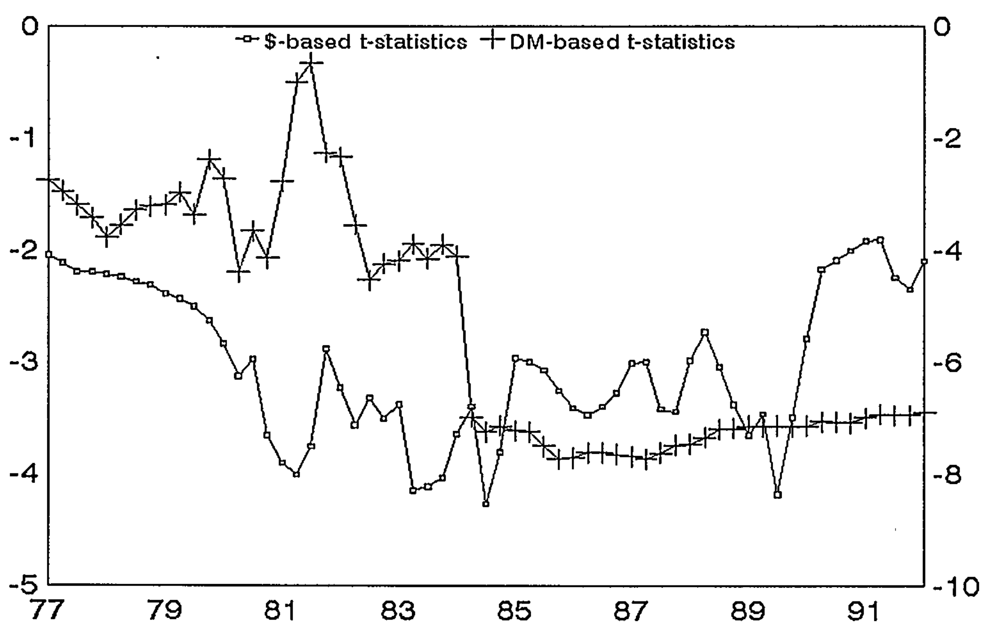
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 13.A. Ireland: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



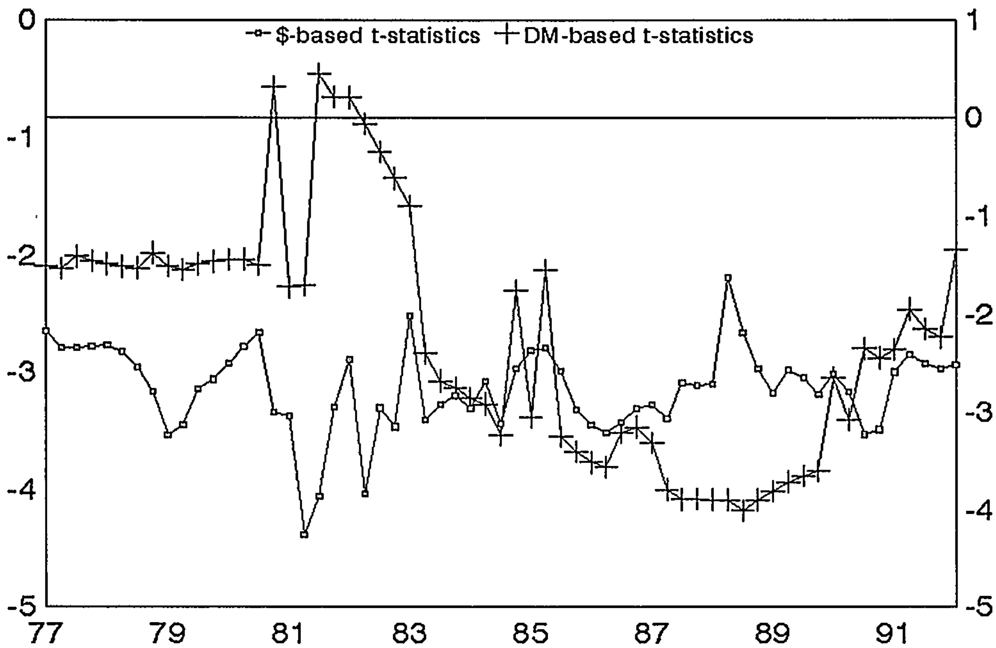
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 13.B. Italy: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



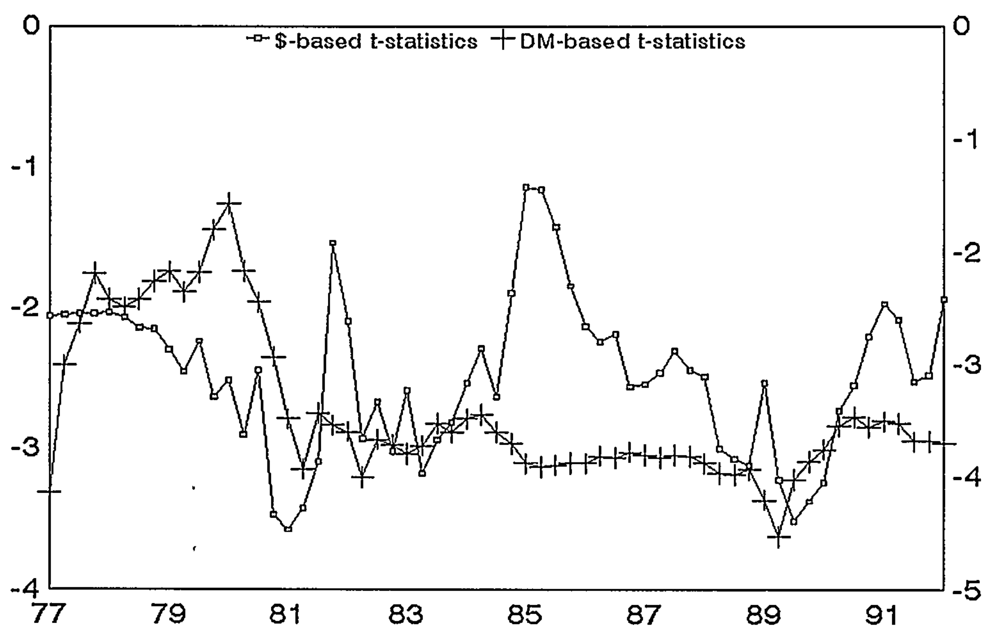
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 14.A. Japan: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



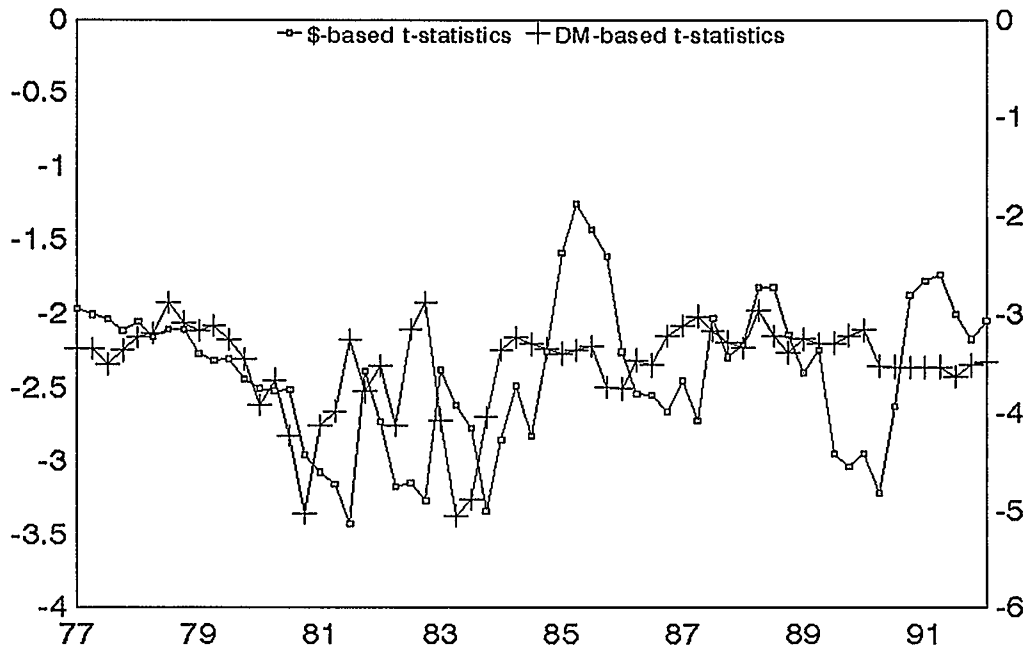
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 14.B. Netherlands: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistic.



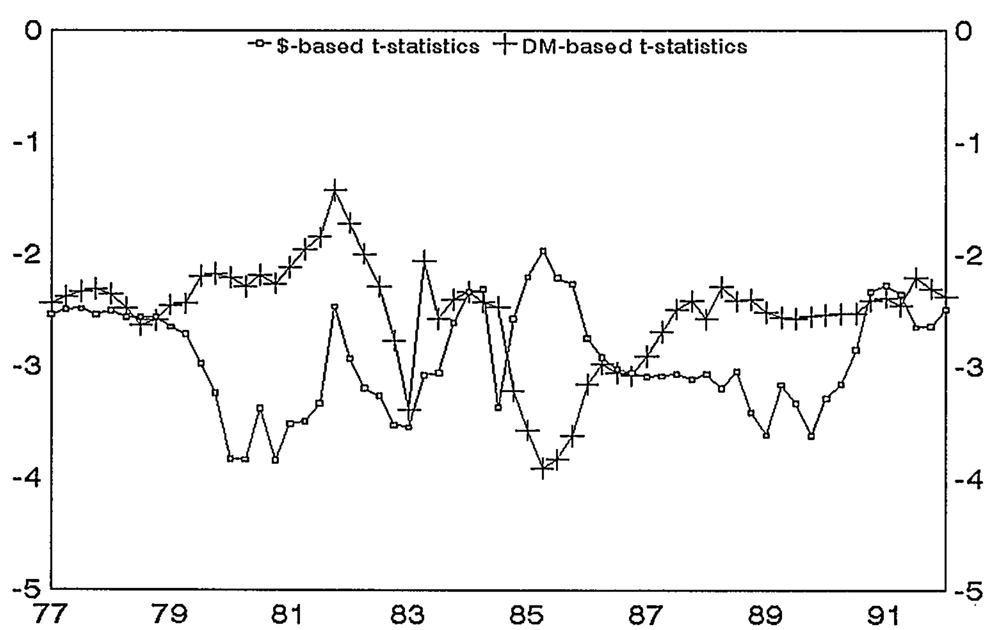
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 15.A. Norway: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



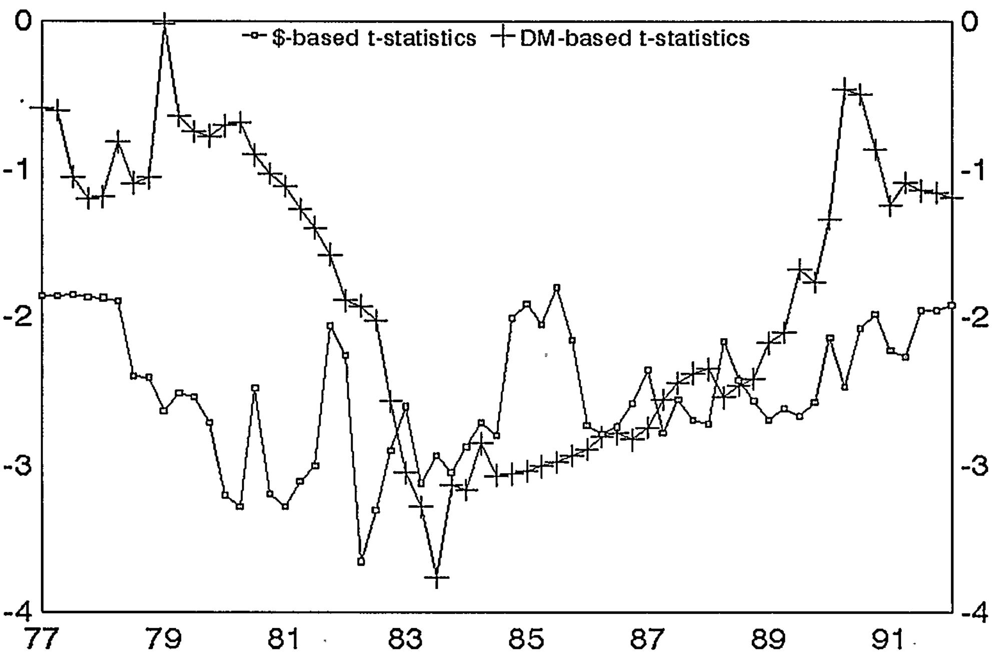
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 15.B. Spain: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



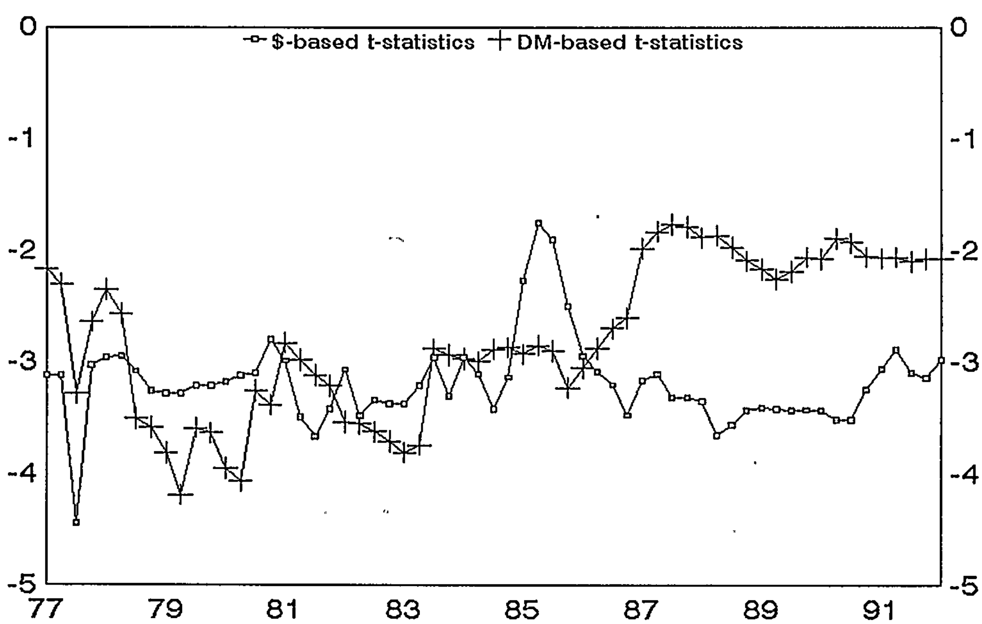
Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted to the value of k.

Figure 16.A. Switzerland: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics



Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

Figure 16.B. UK: Dollar-Based & Deutschemark-Based Real Exchange Rate Plots of T-Statistics.



Notes: Sample period, quarterly data: 1973:1 - 1992:1, adjusted for the value of k.

implication of a unit root[18].

Considering the dollar-based series t-statistics (table 8, eighth column) we see that our results are consistent with the Phillips-Perron (1988) unit root tests for the real exchange rate when not accounting for structural breaks i.e. even when the existence of a one-time break is accounted for we can not reject the unit root null for either of the countries. For the deutschemark-based real exchange rate series t-statistics (table 9, eighth column) we see that we still reject the unit root null for both France and Italy [as per the Phillips-Perron (1988) unit root tests], at the 10% significance level, as well as rejecting the null for Belgium and Norway. The minimum break points, for these countries for which we can reject the unit root null, range from early 80's to late 80's as can also be seen from figures 9 - 16 (minimum points) which contain time plots of the estimated t-statistics for testing $\hat{\alpha} = 1$ for both the dollar-based and deutschemark-based real exchange rates.

4. CONCLUSIONS.

Concluding our results from this chapter, we found that for the dollar-based series, every country's relative price

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[18] Recall that Chowdhury and Sdogati (1993), using Perron's approach, found support for PPP for EMS countries after the formation of the EMS, leading them to conclude that EMS played a significant role.

index and nominal exchange rate contained a unit root, with the exception of Japan whose relative price index was found to be stationary in levels. For the deutschemark-based series, the nominal exchange rates for Austria, Japan and UK as well as the relative price for Japan, were found to be stationary in log levels. The remaining countries' time series were all integrated of order one, i.e., they all contained a unit root. Based on these results, testing for co-integration with the dollar-based series, we did not find support for the PPP relationship for any of the countries, while testing for co-integration with the deutschemark-based series did find support for the PPP relationship for France, Italy and Netherlands.

The unit root test in the real exchange rate confirmed the lack of support for a PPP relationship with dollar-based series i.e. all countries' real exchange rates were found to contain a unit root or equivalently found to be non-stationary in log levels. For the deutschemark-based time series, the results supported the PPP relationship for France and Italy (but not for Netherlands) as per the previous co-integration tests.

Taking into account the presence of any one-time structural breaks in the dollar-based and deutschemark-based real exchange rates, we were still unable to reject the unit root null for the former and only able to reject the unit root null for two additional countries for the latter, despite the substantial increase in the estimated t-statistics, as compared to the t-ratios from the Phillips-Perron unit root test of the real exchange rate.

These results seem to suggest that absolute PPP does not exist, even in the long run, for a majority of OECD member countries vis a vis the US. With Germany however, support is found for a subset of the sample of countries used in this thesis. What is interesting to note is that this subset of countries are all EMS member countries (just like Germany). However, from the previous section, this is not an indication that the formation of the EMS (March 1979) provides an explanation for the unusual support for the PPP relationship between EMS member countries.

CHAPTER V

SYNOPSIS.

Historically, despite it's immense appeal as an equilibrating mechanism for prices and exchange rates, PPP has lacked *unanimous* support, not only empirically, but also theoretically. This is something that was apparent from our previous discussion in chapter I, on the limitations faced by PPP as well the strong tendency of previous empirical work to reject the PPP hypothesis. Also apparent was that, despite the lack of unanimity, most previous empirical work has leaned more strongly towards lack of support for PPP among a majority of countries, especially vis a vis the US. Our results have added strength to this conviction.

The first chapter initially presented some historical background of the PPP doctrine, after which it contemplated all the theoretical shortcomings of PPP. Considered there, in some detail, was the (im)practicality of assuming that prices between different countries, once denoted in the same currency and given a sufficient lapse of time, would eventually equate due to arbitrage. Considerations looked at there were: the type of price index used and the method used to determine it, significantly large external costs, information costs, the role of asset markets in altering exchange rates independent of relative prices, impediments to international trade and the accuracy of forecasting future prices.

Having provided a brief overview of the limitations of the PPP theory, chapter I went on to discuss the possibility of empirical support for the PPP doctrine, calling on other empirical publications to determine if, despite its many limitations, PPP has found empirical support in the past. Here we implemented research, done prior to this thesis, from a variety of sources whose empirical configurations were closely related to some of the empirical content of this thesis.

After undergoing a brief overview of the nature of support for PPP as a theory, as well as empirically, chapter I progressed to justify the utilization of OECD member countries as the countries of interest for this thesis, basing this justification on the increased interest in European countries due to their incessant integration. Once this was established, the road was paved to begin laying foundations for all empirical and graphical work to be done in this thesis.

Chapter II discussed in some detail the three different concepts of PPP i.e. the law of one price, absolute PPP and relative PPP. In the process it established the concept of absolute PPP on whose basis all empirical work was carried out for this thesis. Once the concepts were established, the chapter provided intimate details about the theory behind the empirical tests which were used here and whose results were reported in chapter IV. Thus chapter II considered the need to test for, and the implications of the presence of time properties (in particular the presence of a unit root); the method used to test for a unit root in nominal exchange rates and relative prices and the foundation behind this Phillips-Perron test for unit roots; and the methodologies for testing the existence of a PPP relationship. The latter refers to tests for co-integration between nominal exchange rates and relative prices using the Engle and Granger approach, as well as the tests for stationarity in the real exchange rate.

Having set the theoretical foundations, not only for the PPP concept to be concentrated on in this thesis, but also for the test methods to be relied on, empirical estimation was then pursued in chapters III and IV. The former considered, in sufficient detail, the data employed in this thesis: it's sources, quality, quantity and transformations, providing descriptive statistics for all series, as well as graphical illustrations of the real exchange rate. All this detail was aimed at providing as concise a description, of the data series used in this thesis, as possible. The latter then presented results from all the empirical work carried out in this thesis. Chapter IV reported the Phillips-Perron unit root test for the nominal exchange rate and the relative price, to determine the possible existence of a unit root in these series. If so, then the Engle and Granger co-integration test results were reported to determine if the nominal exchange rate and relative price were co-integrated, the presence of which would provide evidence of a PPP relationship.

Also reported were the Phillips-Perron unit root tests of the real exchange rates, to confirm the possibility (or lack of) of stationarity in the real exchange rate and hence provide support (or not) for the PPP relationship. The chapter also provided sufficient details on the theory behind other methodologies to test for PPP, methodologies like Perron's approach which exogenously accounts for one-time structural breaks, such as the formation of EMS, and Zivot and Andrew's approach which also accounts for such breaks, but does so endogenously. This was crucial for this thesis because of the nature of our data.

As mentioned previously majority of the countries of interest here are involved, with each other, in some trading block or another, whose establishment may have possibly led to more stability in exchange rates and hence increased the probability of the existence of a PPP relationship between them. Therefore testing for this possibility had practical appeal. For this thesis only the empirical results for Zivot and Andrews was reported because, as was mentioned previously, it is an approach that is superior to Perron's approach.

Summarising the conclusions drawn from all the empirical and graphical estimation done in this thesis, we saw from our Phillips-Perron unit root test, and Engle-Granger co-integration test results reported in chapter IV, that we could only conclude, that when structural breaks are not accounted for there was lack of support for PPP for any of the dollar-based series, but support for PPP with deutschemark-based series for only France, Italy and Netherlands, during the period of interest.

Based on our Phillips-Perron unit root test results for the real exchange rate, again we did not find support for PPP for any dollar-based series, and support for PPP, vis a vis Germany, for only France and Italy, but not for Netherlands. These inferences were confirmed by the graphical illustrations of the real exchange rate i.e. for those countries whose exchange rates were non-stationary in levels, their exchange rates depicted either an upward or a downward trend, or both.

When endogenously accounting for the possibility of a one-time structural break in the real exchange rate, using the Zivot and Andrew's approach, we found that, as per our previous PPP tests, we could not find support (reject the unit root null) for PPP with any of the dollar-based series. However, for the deutschemark-based real exchange rate series, while we still found support for PPP for France and Italy we were also able to reject the unit root null, and hence find support for PPP, for Belgium and Norway. Thus accounting for a one-time break, changed our inferences about the existence of PPP for some non-EMS member countries who previously (when a one-time break was not accounted for) had had no support.

As a finale, we summarize the calibre of support for PPP, among a variety of countries' monies, based on empirical work done prior to and in this thesis. Based on our discussion in chapter I and on our results from this thesis, we can conclude that for the approximate sample period of interest (the recent flexible exchange rate era), our results are consistent with those that have been before, with the exception of Fisher and Park (1991) for a subset of our group of countries, and Johnson (1990) for Canada-US pair. Note that we do not mention Hakkio's (1992) results as contradictory to ours, because he only found support for PPP between UK and US with annual data and for a large sample size, with monthly data (for approximately the same sample size as ours) he was unable to find graphical support for PPP.

Despite all the implication that the formation of the EMS increased support for PPP [Chowdury and Sdogati (1993)], Zivot and Andrew's test results here showed that none of the countries for whom we rejected the unit root null, had break points in 1979, the year the EMS was founded.

Obvious from our empirical review above and in chapter I, evidence for PPP seems dependent on certain factors, some of which are: sample size used, increment intervals used, sample period being considered, type of empirical tests used, whether graphical support is used or empirical and the consistency between them, the type of graphical support used, i.e., one can plot real exchange rates; or PPP rate with nominal exchange rates; or real with nominal exchange rates etc to derive visual evidence (or lack of) of PPP.

Despite the tendency of empirical contemplations to bend towards weak support for PPP, the weakness may not necessarily lie with the PPP theory, but rather with the way Gustav Cassel defined it. And as long as there lacks a more refined and empirically effective definition of PPP, the doctrine will always remain of analytical interest.

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