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What Do We Really Know About Real Exchange Rates?

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Editorial

On April 3 -4, 1998 the Oesterreichische Nationalbank hosted a joint Euroconference with the CEPR on „Real Exchange Rates: Recent Theories and Evidence“. A number of papers presented at this conference is being made available to a broader audience in the Working Paper series of the Bank. This volume contains the second of these papers. The first paper was issued as Working Paper 27.

ABSTRACT

This paper seeks to provide a comprehensive overview of the recent literature on the economics of real exchange rates. In particular, the paper attempts to provide answers to the following questions: to what extent are real exchange rates mean reverting and how may the degree of observed mean reversion be explained?; do real exchange rates have a business cycle component and, in particular, are they related to real interest differentials?; how important are real, relative to nominal shocks, in driving real exchange rates?; is the systematic component of the real exchange rate related to factors such as productivity, net foreign asset accumulation, national savings imbalances and terms of trade effects?

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Note: The views expressed in this Working Paper are strictly those of the authors and do not, in any way, commit the Oesterreichische Nationalbank nor the CEPR.

1. Introduction[1]

This paper attempts to provide a comprehensive overview of the recent literature on the economics of real exchange rates. Since the rapid growth of this literature has been due to the development and application of econometric and statistical techniques, rather than to any new theoretical developments, the main focus of this paper is empirical. One way of motivating the material discussed here is to refer to the observed close correlation between real and nominal exchange rates during the recent floating experience, as illustrated in Figure 1. Indeed, it has become something of a stylised fact that the correlation between real and nominal exchange rates is very close to unity. Given the evident variability of real exchange rates, the immediate implication of this is that PPP cannot hold continuously and, in particular, in the short-run. But does it hold at all, and especially in a long-run context? There is some evidence to suggest that it does not, so one important theme in any discussion of real exchange rates concerns trying to quantify the importance of relative prices in explaining nominal exchange rate movements. As we shall see, much of this debate focuses on the magnitude of mean reversion in real exchange rates and, in particular, explaining why it is so slow. A related issue concerns unravelling the sources of the close correlation between real and nominal rates. Do nominal exchange rates drive real rates, or does causality run in the opposite direction?

The former interpretation arises from an extended Mundell-Fleming-Dornbusch (MFD) model in which sticky goods prices and rapidly clearing asset markets force adjustment onto the nominal exchange rate which, for a given configuration of relative prices, changes the real rate on an almost one-to-one basis: the nominal exchange rate drives the real exchange rate (Mussa (1986), for example, has articulated this view). The second interpretation (see, for example, Stockman (1988)) is extracted from equilibrium exchange rate models which posit the opposite causality: real disturbances - both supply-side and preference shocks - drive nominal exchange rates for unchanged relative prices within countries. The resolution of this issue is a key topic in

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This is an updated and extended version of MacDonald (1995a). For alternative literature surveys see Breuer (1994), Froot and Rogoff (1995) and Rogoff (1995). MacDonald and Swagel (1998) contains, inter alia, a survey of the literature on the relationship between real exchange rates and the business cycle. For a more detailed exposition of the topics covered in this paper see MacDonald (1999a). Paper prepared for the conference, Real Exchange Rates: Recent Theories and Evidence, Vienna, 3-4 April 1998. I am grateful to Peter Clark, Steven Husted and to conference participants for their helpful comments on the first draft of this paper.

the economics of real exchange rates. A number of alternative approaches have been adopted to get a handle on this issue.

The first involves an examination of the relationship between real interest differentials and real exchange rates. The MFD class of models suggests that this kind of relationship should be in the data and, in particular, there should be a clear business cycle component in real exchange rates. But is this in fact the case? It has become a widely accepted pardigm that real exchange rates and real interest rates are not related and therefore this is often cited as evidence in favour of the equilibrium approach to exchange rates (see, for example, Stockman (1988)). So one important theme which we attempt to address in this paper is the importance of the real interest rate effect; as we shall demonstrate, this seems to be highly dependent on the estimation method used.

The importance of the business cycle in real exchange rates has been investigated independently of the real interest differential by researchers who decompose real exchanges rates into permanent and transitory elements. Interpreting the latter component as that related to the business cycle gives another perspective on the sources of real exchange rate movements and we devote a section to this literature.

A third approach to the real-nominal debate involves an examination of the Balassa-Samuelson theorem. By decomposing real exchange rate volatility into movements in internal relative prices (the relative price of traded to non-traded goods) and movements in the relative external price (the relative price of traded goods), an indication of the relative importance of the sticky price effect may be gleaned.

A fourth way in which researchers have sought to distinguish between the real and nominal sources of real exchange rate movements has been to use structural vector autoregressive (VAR) models. Such modelling involves taking a multivariate VAR model of the real exchange rate and imposing a long-run structure, using the identification methods of Blanchard and Quah (1989). This kind of framework has been used to determine the source of real exchange rate fluctuations since the inception of floating exchange rates, and also to unravel the relative importance of real and nominal shocks.

A somewhat different strand in the real exchange rate literature, to that concerned with validating a particular theoretical structure, is that which models the systematic component of real exchange rates in terms of real fundamentals, such as productivity differentials, fiscal policy and terms of trade effects. Such modelling has proved particularly attractive of late in terms of trying to assess where actual exchange rates are in relation to equilibrium values. This is the so-called Behavioural Equilibrium Exchange Rate (BEER) approach to modelling equilibrium exchange rates.

The remainder of the paper proceeds as follows. In the next section we consider in some detail the validity of purchasing power parity. Since traditional PPP posits that real exchange rates should be strongly mean-reverting, much of our discussion focuses on the degree of mean reversion in real exchange rates. Since detection of such mean reversion can depend crucially on the span of the data set used, we devote section 3 to studies which expand the data span using either long historical runs of data or by utilising panel data sets. Panel data sets have also been used to address the relative importance of Balassa-Samuelson and sticky price effects in explaining real exchange rate volatility, and this literature is discussed in Section 4. The importance of transaction costs in explaining deviations from PPP is considered in Section 5, in terms of both geographical barriers and non-linear adjustment. The relationship between productivity differentials and real exchange rates is considered in Section 6 In Section 7 empirical research based on the relationship between real exchange rates and real interest rates is discussed. Studies which seek to decompose real exchange rates into transitory and permanent components are considered in Section 8 and the literature on structural VARs is overviewed in Section 9. Our conclusions are presented in Section 10.

2. Purchasing Power Parity: Traditional Versus Efficient Markets Hypothesis.

2.i The Nominal Benchmark.

A natural starting point for any discussion of real exchange rate modelling is the concept of purchasing power parity (PPP). The familiar expression for absolute PPP is:

$$s_t = p_t - p_t^*, \qquad (1)$$

where s_t denotes the home currency price of a unit of foreign exchange, $p_{t,}$ denotes a price level and an asterisk denotes a foreign magnitude (lower case letters denote logarithms). The restrictions necessary for this condition to hold continuously are well known (see, for example, MacDonald (1995a)). However, most researchers would go with a less restrictive version of PPP, which simply relies on a real exchange rate being mean-reverting. This may be interpreted as in the spirit of Cassel (1928), the formulator of modern PPP, who recognised that there are a number of factors, such as interest differentials, transportation costs and foreign exchange market intervention[2], preventing an exchange rate from always being at its PPP-defined value. In terms of the former, if the real exchange rate, $q_t = s_t - p_t + p_t^*$, is mean-reverting, a current disturbance to the nominal exchange rate / relative price configuration, due say to a liquidity effect (a la Dornbusch (1976)) will eventually be offset. That is:

$$q_t = rq_{t-1} + a + e_t, \quad 0 < r < 1. \tag{2}$$

In traditional, or Casselian, PPP it is arbitrage in tradeable goods which forces the PPP equality. A view diametrically opposed to this is efficient markets PPP (EMPPP) (see, for example, Roll (1979) and Darby (1980)) which relies on arbitrage in bond markets for its prediction that real exchange rates should follow a random walk process:

$$q_t = q_{t-1} + a + j_{t+k}. \tag{3}$$

These alternative interpretations of PPP have been tested in one of two ways: by focussing on the nominal exchange rate - relative price relationship or by examining the time series properties of real exchange rates. In terms of the former set of tests, recent work has concentrated on the application of cointegration methods to an equation such as (4):

$$s_t = b + a_0 p_t + a_1 p_t^* + j_t. \tag{4}$$

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[2] See Officer (1976) for a detailed discussion of the Casselian view of PPP.

If s_{t}, p_t, and p_t^* are integrated of order one - I(1) - then weak form PPP (MacDonald 1993) exists if the residual term from an estimated version of (4) is stationary - I(0). Strong-form PPP exists if in addition to weak form holding homogeneity is also satisfied: α_0=1 and α_1=-1. Symmetry implies α_0=-α_1. The distinction between weak- and strong-form PPP is important because the existence of transportation costs and different price weights across countries means that „there are no hypothesis regarding the specific values of α_0 and α_1 except that they are positive and negative.“(Patel 1990).

The basic message from cointegration-based tests of (4) is that the estimator used matters. Thus on the basis of the two-step Engle-Granger method, in which symmetry is generally imposed, Baillie and Selover (1987), Enders (1988), Mark (1990) and Patel (1990) and find no evidence of cointegration in the sense that the residual series recovered from the estimated equation is non-stationary. However, as is now well known this procedure suffers from a number of deficiencies such as having poor small sample properties and, in the presence of endogeneity and serial correlation, the asymptotic distribution of the estimates will depend on nuisance parameters (Banerjee *et al* (1986)). Since Johansen's (1988,1990) full information maximum likelihood method produces asymptotically optimal estimates (because it has a parametric correction for serial correlation and endogeneity) a number of researchers have applied this method in testing (4). Thus, Cheung and Lai (1993), Kugler and Lenz (1993), MacDonald (1993) and MacDonald and Marsh (1994) all report strong evidence of cointegration, although symmetry and homogeneity are often strongly rejected for US dollar bilaterals, but not so for DM-based bilaterals. MacDonald and Moore (1996) use the methods of Phillips-Hansen (1990) and Hansen (1992) as an alternative (to Johansen) way of addressing issues of simultaneity and temporal dependence in the residual of (4). They also find strong evidence of weak-form PPP for dollar bilaterals, while strong-form PPP holds for most DM-based bilaterals.

The superior performance of PPP when DM-based exchange rates are used is a recurring theme in this paper and was first noted by Frenkel (1981) in the context of a traditional regression based test of PPP. The effect may be attributed to a number of factors. The existence of the ERM has attenuated the volatility of DM bilaterals relative to US dollar bilaterals, thereby producing a higher signal-to-noise ratio; the geographical proximity of European countries facilitates greater goods arbitrage and therefore makes it more likely that PPP will occur; the openness of European countries, in terms of their trade making up a greater proportion of their collective national output than in the US.

The evidence in this section may be summarised as suggesting that on a single currency basis for the recent float, weak-form PPP holds for dollar bilateral pairings and strong-form PPP holds for many DM-based bilaterals. Although a finding in favour of weak-form PPP would now seem to be widely accepted in the literature, it is important to note that the implied mean reversion from the studies discussed in this section is often painfully slow.

2.ii. Testing Traditional PPP against EMPPP Using Real Exchange Rates.

In testing the null hypothesis of (3) against (2), the base-line test has involved a simple application of an augmented Dickey-Fuller statistic:

$$\Delta q_t = g_0 + g_1 t + g_2 q_{t-1} + \sum_{j=1}^{n-1} b_j \Delta q_{t-j} + n_t \ .$$

This kind of test has been implemented on a variety of real exchange rate data sets by numerous researchers (see *inter alia* Roll (1979), Darby (1980), MacDonald (1985), Enders (1988) and Mark (1990)). The typical coefficient of mean reversion in these papers is often around 0.97, which is statistically indistinguishable from unity and this would seem to be supportive of EMPPP and evidence against traditional PPP. However, as Campbell and Perron (1991), and others, have noted univariate unit root tests have relatively low power to reject the null when it is in fact false, especially when the autoregressive component in (2) is close to unity.

Alternative tests for a unit root have therefore been adopted in a bid to overturn this result. The variance ratio test, popularised by Cochrane (1988), is potentially a more powerful way of assessing the unit root characteristics of the data, since it captures the long autocorrelations which are likely not picked up in standard ADF tests, and which will be important for driving mean reversion. Huizinga (1987) calculates the variance ratio test for 10 (industrial) currencies and 120 months of adjustment, and finds that the average V_k implies a permanent real exchange rate component of around 60 per cent, with the remaining 40 per cent being transitory; however, on the basis of standard errors, constructed using the $T^{1/2}$ formula, none of the estimated variance ratios are significantly below one. Glen (1992) and MacDonald (1995) demonstrate that on using Lo and MacKinlay (1988) standard errors, which are robust to serially correlated and heterogeneous errors, that significant rejections of a unitary variance ratio may be obtained, but that the extent of any mean reversion is still painfully slow. For example, on the basis of WPI constructed real exchange rates MacDonald finds that the Swiss franc, pound sterling and Japanese yen all have variance ratios which are approximately 0.5 after 12 years (and these values are significantly less than unity). So on a single currency basis for the recent float the evidence noted here suggests that adjustment to PPP is painfully slow.

3. The Power of Unit Root Tests and the Span of the Data.

One natural response to the finding of slow mean reversion observed in real exchange rate behaviour for the recent float is to increase the span of the data in order to give exchange rates a greater chance of returning to their mean value. In so doing, it is not sufficient, as Shiller and Perron (1985) have indicated, merely to increase the observational frequency, but rather to increase the span of the data using low frequency or annual data (that is, using, say, 20 years of monthly data from the recent float instead of 20 years of annual average data is unlikely to increase the lower frequency information necessary to overturn the null of no cointegration or the null of a unit root).

For example, assume the estimated value of r is 0.85, and its estimated asymptotic standard error is $[(1-r^2)/X]^{1/2}$, where X equals the total number of observations. Using 23 years of annual data the standard error would be approximately 0.11, with an implied t-ratio which is insufficient to reject the null of a unit root (i.e. the t-ratio for the hypothesis $r=1$ is 1.34). However, with 100 annual observations the standard error falls to 0.05, implying a t-ratio for the hypothesis $r=1$ of 6.8. Defining $X=N.T$, where T denotes the and N denotes the number of cross sectional units, then this example makes clear that by expanding the span in a time series dimension increases the likelihood of rejecting the null of a unit root. The span may also be increased by holding T constant and increasing N. We now consider each of these alternatives.

3.i Increasing the Span by Increasing T.

In terms of the former method, a number of researchers have examined the mean-reverting properties of real exchange rates (see Edison (1987), Frankel (1986),(1988), Abuaf and Jorion (1990), Grilli and Kaminski (1991) and Lothian and Taylor (1995)) using approximately 100 years of annual data and find evidence of significant mean reversion with an average half life across these studies being around 4 years. Diebold, Husted and Rush (1991), also use long time spans of annual data, ranging from 74 to 123 years, to analyse the real exchange rates of 6 countries. In contrast to other long time span studies, the authors use long memory models to capture fractional integration processes. They find considerable evidence that PPP holds as a long-run concept and report a typical half-life of 3 years.

As an alternative to examining the time series properties of real exchange rates, some long-run studies have examined the nominal exchange rate - relative price relationship and find that homogeneity restrictions hold, although the implied half-life is longer than that recovered from real exchange rate autoregressions. For example, Edison (1987) uses annual data on the UK pound-US dollar exchange rate over the period 1890-1978 and reports the following error correction model:

$$\Delta s_t = \underset{(0.08)}{0.135} + \underset{(0.17)}{0.756}[\Delta(p - p^*)_t] - \underset{(0.04)}{0.086}(s - p - p^*)_{t-1}, \qquad (5)$$

where standard errors are in parenthesis. The coefficient on the change in relative prices is insignificantly different from unity and the coefficient on the error correction term indicates that approximately 9 per cent of the PPP gap is closed each year, implying a half-life of 7 years.

Although studies which extend the span by increasing T are interesting, they are not without their own specific problems in that the basket used to construct the price indices is likely to be very different at the beginning and end of the sample, and this may be viewed as the temporal analogue to the spatial problem that arises in comparing price indices at a particular point in time. Also, such studies suffer from spanning both fixed and flexible rate regimes. For these reasons attention has turned from expanding T to extending N, the cross sectional dimension.

3.ii. Increasing the Span by Increasing N.

In particular, researchers have turned to analysing the behaviour of real exchange rates for the recent floating period using panel data sets. A standard panel framework is:

$$s_{it} = a_i + b'(p_{it} - p_{it}^*) + \{\Sigma_i\ g_i D_i\} + \{\Sigma_t\ d_t D_t\} + u_{it}, \qquad (6)$$

where the i subscript indicates that the data has a cross sectional dimension (running from 1 to N), D_i and D_t denote, respectively, country-specific and time-specific fixed effect dummy variables (although not noted here it is straightforward to incorporate random effects into (6)). In a standard panel setting a number of modelling strategies are available for the disturbance term: it may be assumed to be random, heteroscedastic, autoregressive (with either a common autoregressive terms across individual panel members or different autoregressive terms across members), it may be spatially correlated or some combination of these assumptions may be used. The earliest application of panel methods to testing PPP was Hakkio (1986) who used a monthly data set; the first paper to combine panel methods with annual data in a PPP test was MacDonald (1988b). These papers used conventional panel methods, such as the Kmenta estimator. The more recent panel exchange rate literature has involved testing for the stationarity of the residual series in (6) or reparameterising the equation into an expression for the real exchange rate and testing the panel unit root properties of real exchange rates. In term of the latter, a rapidly growing literature has been inspired by the work of Levin and Lin (1992,1994) who demonstrated that there are „dramatic improvements in statistical power" from implementing a unit root test in a panel context, rather than performing separate tests on the individual series.

The Levin and Lin approach involves testing the null hypothesis that each individual series is I(1) against the alternative that all of the series as a panel are stationary. Their approach allows for a range of individual-specific effects and also for cross sectional dependence by the subtraction of cross sectional time dummies. Frankel and Rose (1995), Wu (1995), Oh (1995) and MacDonald (1995b) have all implemented variants of the Levin and Lin panel unit root test on 'overall' price measures (such as WPI and CPI) and find evidence of mean reversion which is very similar to that reported in long time spans of annual data, namely half-lives of four years. Another feature of these studies, which is quite similar to the long time span studies, is the finding of price homogeneity when PPP is tested in a panel context using nominal exchange rates and relative prices. Oh (1996) and Wei and Parsley (1995) have examined the unit root properties of panel data for the Summers-Heston data set and tradable sectors, respectively, and report similar results to those based on aggregate data.

Bayoumi and MacDonald (1998) examine the panel unit root properties of inter- and intra-national exchange rates. The former are defined for a panel of CPI and WPI based real exchange rates for 20 countries, over the period 1973 to 1993, while the intra-national data sets are constructed from Canadian regional and US federal data for the same period and the same number of real rates. The argument in the paper is that if indeed the predominant source of international real exchange rate movements is monetary, observed mean reversion should be more rapid in international data than in intra-national data because monetary shocks are transitory relative to real shocks This is in fact borne out by the panel data sets: for the international data set there is clear evidence of stationarity on the basis of the Levin and Lin test, while for the intra-national panel sets real rates are non-stationary and only very slowly mean-reverting.

Liu and Maddalla (1996) and Pappell (1997) both highlight the importance of residual correlation in panel unit root tests, a feature absent from the first set of critical values tabulated by Levin and Lin (1992) (used by Frankel and Rose (1995), Wu (1995), Oh (1995)) although not in the Levin and Lin (1994) paper (used by MacDonald (1995)). Pappell (1997) finds that for a number of different panels the null of a unit root cannot be rejected when monthly data is used, although it can be using quarterly data. O'Connell (1997) also takes the Levin and Lin test to task by noting that the power of the test relies on each new bilateral relationship being added to the panel adding new information. Although each relationship added may indeed contain some new information it is unlikely that this will be one-to-one given that the currencies are bilateral rates, are often defined with respect to the US dollar, and therefore will contain a common element. Correcting for this common cross correlation using a GLS estimator (although assuming that the errors are iid over time), O'Connell (1997) finds that the significant evidence of mean reversion reported in earlier studies disappears.

The observation, referred to in section 2.i, that PPP works better for DM-based bilaterals than US dollar bilaterals is confirmed in a panel context by Jorion and Sweeney (1996) and Pappell (1997), who both report strong rejections of the unit root null (CPI) based real exchange rates when the DM is used as the numeraire currency. This result is confirmed by Wei and Parsley (1995) and Canzoneri, Cumby and Diba (1996) using tradable prices. Pappell and Theodoridis (1997) attempt to discrimante amongst the potential reasons for the better performance of DM rates by taking the candidates refereed to earlier - measures of volatility, openness and distance. Using a panel data base constructed for 21 industrialised countries over the period 1973 to 1996, they find that it is both volatility and distance which are the significant determinants of this result; openness to trade proves to be insignificant. Lothian (1997) has given another reason why US dollar bilaterals are likely to work less well in a panel context and that is because they are dominated by the dramatic appreciation and depreciation of the dollar in the 1980's (therefore the informational content of adding in extra currencies is less for a dollar-based system than a mark-based system).[3] Pappell and Theodoris have confirmed this result and, in particular, show that the evidence in favour of PPP for the dollar strengthens the more post-1985 data is included in the sample.

In a bid to gain further insight into the robustness of the panel unit root findings discussed above, Engle, Hendrickson and Rogers (1998) analyse a panel data base constructed from prices in 8 cities, located in 4 countries and in 2 continents. They use this panel set to address some of the perceived deficiencies in other panel tests. For example, their panel estimator allows for heteroscedastic and contemporaneously correlated disturbances, differing adjustment speeds of real rates and the model structure used means that their results are not dependent on which currency is picked as the base currency (which, as we have seen, is an issue in some tests). In implementing this general panel structure, they are unable to reject the null of a unit root for the period September 1978 to September 1994. However, and as they recognise, it is unclear if their failure to reject the null is due to the fact that their panel is much smaller than that used in other studies and also is defined for prices in cities, rather than country wide price measures which are used in most other studies (also, they do not allow the disturbance terms to have different serial correlation properties, which, as we have seen, may be important).

Pedroni (1997) has proposed panel cointegration methods as an alternative to panel unit root tests. The construction of such a test is complicated because regressors are not normally required to be exogenous, and hence off-diagonal terms are introduced into the residual aysmptotic covariance matrix. Although these drop out of the asymoptotic distributions in the single equation case, they are unlikely to do so in the context of a non-stationary panel because of idiosynchratic effects across individual members of the panel. A second difficulty is that generated residuals will depend on the distributional properties of the estimated coefficients and this is likely to be severe in the panel context because of the averaging that takes place. Pedroni proposes statistics which allow for heterogeneous fixed effects, deterministic trends, and both common and idiosynchratic disturbances to the underlying variables (and these, in turn, can have very general forms of temporal dependence). Applying his methods to a panel of nominal

[3] See Jorion and Sweeney (1996) and Pappell (1997) for a further discussion.

exchange rates and relative prices for the recent float, he finds evidence supportive of weak-form PPP. Husted and MacDonald (1997) have a first pass at panel cointegration tests of the monetary model, for a sample period encompassing the recent float. Using the estimators of Hansen (1990) and Levin and Lin (1994) they find evidence in favour of cointegration. One particularly interesting feature of their work is that for DM-based bilaterals they find half-lifes of one year. In a further paper, Husted and MacDonald (1998) apply the Pedroni cointegration estimator to a monetary approach panel and confirm their earlier results.

Despite recent criticisms of panel unit root tests, we believe the evidence in this section indicates that when the span of the data sample is extended - either in a cross sectional or time series dimension - the power of unit root tests increases significantly (as does the size of the tests). The stylised result is for half of a disturbance to PPP to be reversed after around four years. Although such adjustment is reassuring for a believer in PPP it is nevertheless probably still too long to be consistent with a traditional form of PPP (such as that proposed by Cassel and others) where the gravitational pull back to equilibrium is thought to have been much faster than around 8 years. In succeeding sections we will address the issue of slow mean reversion in some detail. However, before doing that we first try to gain a perspective on what it is that actually causes a change in the real exchange rate in the first place.

4. Sticky Prices Versus the Traded-Non Traded Bias: A First Pass at Balassa-Samuelson.

The previous section suggests that real exchange rates have been mean-reverting for the recent floating period. How, though, may the typical speed of adjustment be explained? In order to address this issue it will prove useful in this section to examine the sources of systematic real exchange rate movements in terms of the Balassa-Samueslon theorem (Balassa (1964), Samuelson (1964)) This may be illustrated by assuming that the general prices entering our definition of the real exchange rate can be decomposed into traded and non-traded components as:

$$p_t = a_t p_t^T + (1 - a_t) p_t^{NT}, \tag{7}$$

$$p_t^* = a_t^* p_t^{T*} + (1 - a_t^*) p_t^{NT*}, \tag{7'}$$

where p_t^T denotes the price of traded goods, p_t^{NT} denotes the price of non-traded goods and the a's denote the share of traded goods in the economy. Using the definition of the real exchange rate, defined with respect to overall prices, given previously

$$q_t \equiv s_t - p_t + p_t^* . \qquad (8)$$

A similar relationship may be defined for the price of traded goods as:

$$q_t^T \equiv s_t - p_t^T + p_t^{T*} , \qquad (9)$$

By substituting (7), (7') and (9) in (8) an expression for the real exchange rate, which captures the Balassa-Samuelson effect is given as:

$$q_t = q_t^T + (a_t - 1)(p_t^T - p_t^{NT}).+(1 - a_t^*)(p_t^{T*} - p_t^{NT*}) . \qquad (10)$$

Balassa-Samuelson assumes that the law of one price holds continuously and therefore the first term on the right hand side of (10) should be zero (or perhaps, less restrictively, equal to a constant): trends in the real exchange rate arise because of movements in the relative prices of goods within countries. In particular, countries which have relatively high productivity will have an appreciated real exchange[4] rate; countries which have systematically positive productivity differentials over time will have appreciating real exchange rates (demand side effects can also introduce similar biases over time). Rogoff (1992) and Obstfeld (1995) modified the original Balassa-Samuelson to be consistent with forward looking, optimising agents.

An indication of the relative importance of the two components in (10) may gleaned from Engel's (1993) calculation of the conditional variances of relative prices within - $V(p_{ij})$ - and across - $V(p_{ii})$ - countries, where relative prices are assumed to follow a twelfth-order autoregressions (in both levels and differences). Four indexes (energy, food, services and shelter), which are disaggregated components of the CPI and therefore capture different degrees of tradeability, are utilised for the G7, over the period April 1973 to Sept 1990. Engel demonstrates that out of a potential 2400 variance comparisons, 2250 have the variance of the relative price within the country smaller than the variance across countries for the same type of good; that is, $V(p_i\text{-}p_j) < V(p_i\text{-}s\text{-}p_i^*)$. This result would seem to favour sticky price models such as those of Dornbusch (1976) and Giovanini (1988)

[4] It is necessary to assume constant returns to scale in production, that factors are mobile between the traded and non-traded sectors, the terms of trade are fixed and capital markets are integrated internationally.

Rogers and Jenkins (1995) push Engel's analysis further both by considering finer disaggregations of the prices entering the CPIs of 11 OECD countries (in contrast to Engel their price series are mutually exclusive and collectively combine to give the total CPI) and also by using cointegration methods to assess the relative importance of the two terms in (10). Their sample period is 1973:4 to 1991:12. and they show that, on average, 81% of the variance of the real CPI exchange rate is explained by changes in the relative price of traded goods, rather than the relative price of non-traded goods. This confirms Engel's results. They then go on to explore the stationarity and cointegration of various combinations of exchange rates and relative prices.

In particular, if sticky prices explain the time series behaviour of CPI-based real exchange rates, then q_t and q_t^T should be cointegrated, since the second component on the RHS of (10) should be stationary. However, if the Balassa-Samuelson model is correct, q_t and the relative price of traded to non-traded prices should be cointegrated and q_t^T should be stationary. Using food prices as the most tradable price they find little evidence of stationarity of q_t^T, which would seem to be evidence against the Balassa-Samuelson hypothesis. Further, although there are a small number of instances where q_t and q_t^T are cointegrated, they do not regard this as sufficiently convincing to support Balassa-Samuelson. As the authors recognise, however, the food index used as their measure of traded goods prices is not composed entirely of tradable items and this may introduce a bias into the calculations. To tackle this issue Rogers and Jenkins also analyse a highly disaggregate data set of relative prices defined the US- Canada. They find, that although some relative prices are stationary (8 out of 54) the majority (46) appear non-stationary. Interestingly, the real rates that are non-stationary relate to highly non-tradable items like haircuts and highly tradable items like frozen vegetables. Rogers and Jenkins conclude by arguing that although a small proportion of real exchange rate variability is explicable in terms of a Balassa-Samuelson effect, the overwhelming majority comes from price stickyness and hysteretic effects.

The evidence in this section supports the view that in the presence of sticky prices, nominal exchange rate movements are the key source of real exchange rate volatility. We return to the sources of real exchange rate volatility in section 9, and also to the systematic determinants of real exchange rates in Section 7. First, though, having established an important reason why real exchange rate movements get started we now attempt to gain a perspective on the slowness of mean reversion in real exchange rates.

5. Does Geography Matter?: A Linear and Non-Linear Perspective.

A number of researchers (see, *inter alia,* Heckscher (1916), Beninga and Protopapadakis (1988), Dumas (1992) and Sercu, Uppal and Van Hulle (1995)) have argued that the existence of transaction costs, due largely to the costs of transportation, are a key explanation for the relatively slow adjustment speeds in PPP calculations and, in particular, as an explanation for the failure of the law of one price to hold. For example, in the presence of transaction costs, the price of good *i* in location *j*, p_j^i may not be equalised with its price in location k, p_k^i. If there are transportation costs, c^i , the relative price could fluctuate in a range:

$$1 / c_i \le p_j^i / p_k^i \le c_i \qquad (11)$$

Further, if the transportation costs depend positively on distance, the range of variation in the relative price will also depend on that distance. In this section we explore the effects of transactions costs in two ways: first, by examining how important transportation costs are relative to other factors and, particularly, nominal exchange rate volatility; second we examine the implications of transaction costs for nonlinear exchange rate behaviour.

5.i Transactions Costs Versus Nominal Exchange Rate Volatility

Wei and Parsley's (1995) panel study attempts to decompose the sources of the real exchange rate exchange rate volatility, noted in the previous section, into that relating to transportation costs, and other related impediments to trade, and a single macoreconomic factor, namely nominal exchange rate volatility. More specifically, they focus on the first difference of the real exchange rate:

$$q_{ij,k,t} = \ln[P_{i,t} / (P_{j,t} S_{ij,t})] - \ln[P_{i,t-1} / (P_{i,t-1} / (P_{j,t-1} S_{ij,t-1})], \qquad (12)$$

where *ij* denotes the country pairing and *k* denotes the sector. They use annual data, 1973-1986, covering 14 countries and 12 tradable sectors (chosen on the basis of an export-to-production ratio greater than 10). They define the standard deviation of $q_{ij,k,t}$ as $V_{ij,k}$. and use as explanatory variables for transaction costs the distance between trading centres, a dummy for a common border (which should reduce variablity, to the extent that it reduces transaction costs), a dummy if two countries are seperated by sea (which should increase variability because it increases transactions costs), dummies to represent free trade areas (EEC and EFTA), which should be significantly negative. And a language dummy to represent cultural differences (i.e. common language should directly facilitate transactions). Finally *VS*, exchange rate volatility, is included to represent a sticky price or macro effect. A representative result is:

$$V_{ij} = \underset{(0.002)}{0.0064} LogDis\tan ce - \underset{(0.005)}{0.0058} Border + \underset{(0.005)}{0.0260} Sea \qquad (13)$$

$$+ \underset{(0.0668)}{0.2315} VS - \underset{(0.0068)}{0.0048} EEC + \underset{(0.0069)}{0.0361} EFTA + \underset{(0.0035)}{0.021} LANG$$

This reveals that the distance between the major cities in the sample is statistically significant and, in particular, indicates that a one per cent increase in distance is associated with a rise in the variability of price differences of approximately 0.01. The *Border* variable is wrongly signed, although insignificant, while the *Sea* variable is correctly signed and significant. Nominal exchange rate volatility, *VS*, has a significantly positive effect and, in terms of absolute magnitude, has the biggest impact. Having controlled for transport and exchange rate volatility, free trade areas do not seem to significantly reduce deviations from PPP relative to other OECD countries, since the *EEC* and *EFTA* dummies are both insignificant. *Lang* dummy takes on value of 1 if common language (i.e. UK and US, Belgium and France) is positive, which is the wrong sign, although insignificant. So the upshot of the work of Wei and Parsley is that transportation costs and exchange rate volatility are the key explanations for PPP deviations. The importance of volatility seems consistent with the findings of Bayoumi and MacDonald (1998)

Engel and Rogers (1995) seek further clarification of the transportation cost issue by using a consumer price data, disaggregated into 14 categories of goods, for nine Canadian cities and 14 cities in the United States. The basic hypothesis they test is that the price of similar goods between cities should be positively related to the distance between those cities if transportation costs are important. On holding distance constant, volatility should be higher between two cities seperated by a national border (because of the influence of exchange rate volatility). For each good i there are 228 city pairs and for each city pair they construct standard deviations as their measure of volatility. Cross border pairs do exhibit much higher volatility than within country pairings (although the volatilitty of US pairings is generally higher than that for Canadian pairings). Their regressions seek to explain the relative price volatility using the following type of equation:

$$V(p_j^i / p_k^i) = b_1^i r_{j,k} + b_2^i B_{j,k} + \sum_{m=1}^{n} g_m^j D_m + u_{j,k} \qquad (14)$$

where $r_{j,k}$ is the log of the distance between locations, $B_{j,k}$ is a dummy variable 'Border' for whether locations j and k are in different countries and this is expected to be positive and the *Ds* are city dummies. Using both single equation methods, for each of the 14 categories of price, and also panel methods they find strong evidence that both distance and the border are highly significant explanatory variables for real exchange rate volatility and each has the correct sign. It turns out that the border term is the relatively more important in that to generate as much volatility by distance as generated by the border term, the cities would have to be 75,000 miles apart. Engel and Rogers work therefore confirms the findings of Wei and Parsely that it is the seperation by nation that is the key determinant of real exchange rate volatility.

5.ii Transactions Costs and Non-Linear Adjustment.

Transportation costs have been used in another way to rationalise deviations from PPP. In particular, Dumas (1992) has demonstrated that for markets which are spatially seperated, and feature proportional transactions costs, deviations from PPP should follow a non-linear mean-reverting process, with the speed of mean reversion depending on the magnitude of the deviation from PPP. The upshot of this is that within the transaction band, as defined in (11) say, deviations are long-lived and take a considerable time to mean revert: the real exchange rate is observationally equivalent to a random walk. However, large deviations, those that occur outside the band, will be rapidly extinguished and for them the observed mean reversion should be very rapid. The existence of other factors, such as the uncertainty of the permanence of the shock and the so-called sunk costs of the activity of arbitrage may widen the bands over-and above that associated with simple trade restrictions (see Dixit (1989) and Krugman (1989)). Essentially the kind of non-linear estimators that researchers have applied to exchange rate data may be thought of as separating observations which represent large deviations from PPP from smaller observations and estimating separately the extent of mean reversion for the two classes of observation.

Obstfeld and Taylor's (1997) attempt to capture the kind of non-linear behaviour imparted by transaction costs involves using the so-called Band Threshold Autoregressive (B-TAR) model. If we reparametrise the AR1 model (2) as:

$$\Delta q_t = l q_{t-1} + e_t \qquad (2')$$

where the series is assumed demeaned (and also detrended in the work of Obstfeld and Taylor, because the do not explicitly model the long-run systematic trend in real exchange rates). Then the B-TAR is:

$$\Delta q_t = \begin{cases} l^{out}(x_{t-1} - c) + e_t^{out} & \text{if } q_{t-1} > c; \\ l^{in} q_{t-1} + e_t^{in} & \text{if } c \geq q_{t-1} \geq -c; \\ l^{out}(q_{t-1} + c) + e_t^{out} & \text{if } -c > q_{t-1}; \end{cases} \qquad (15)$$

where e_t^{out} is $N(o, s_t^{out})^2$, e_t^{in} is $N(o, s_t^{out})^2$, $l^{in} = 0$, and l^{out} is the convergence speed outside the transaction points. So with a B-TAR, the equilibrium value for a real exchange rate can be anywhere in the band [-c,+c] and not necessarily to a zero point (the real rate is demeaned). The methods of Tsay (1989) are used to identify the best-fit TAR model and, in particular, one which properly partitions the data into observations inside and outside the thresholds. Using the data set of Engel and Rogers (1995), discussed above, Obstfeld and Taylor find that for inter-country CPI-Based real exchange rates, the adjustment speed is between 20 and 40 months, when a simple AR1 model is used, but only 12 months for the TAR model. When dissagregate price series are used to test the law of one price the B-TAR model produces evidence of mean reversion which is well below 12 months, and indeed as low as 2 months in some cases. Obstfeld and Taylor also show that measures of economic distance - distance itself, exchange rate volatility and trade restrictions - are all positively related to the threshhold value and these variables also have a consistent inverse relationship with convergence speed.

Michael, Nobay and Peel (1997) apply the exponentially autoregressive (EAR) model of Haggan and Ozaki (1981) (see also Granger and Teravirta (1993)) to a monthly inter-war data base and a data base consisting of two centuries of annual real exchange rate data (period . For each of the exchange rates considered, they are able to reject linearity in favour of an EAR process. An interesting further feature of the work of Michael *et al* is that the estimated EAR parameters are consistent with Dumas's hypothesis; in particular, real exchange rates behave like random walks for small deviations from PPP, but are strongly mean-reverting for large (positive or negative) deviations.

In contrast to both Obstfeld and Taylor and Michael *et al,* O'Connell (1996) tests a TAR model for the post Bretton Woods period and finds that there is no difference between large and small deviations from PPP - both are equally persistent. The difference between O'Connell's result and those reported above may relate to the fact he does not use a search algorithm to locate the thresholds (they are simply imposed) or to the fact that he uses aggregate price data (although this was also used in the above studies). In a bid to determine if these points are indeed responsible for the O'Connell's finding, O'Connell and Wei (1997) use a BTAR model and disaggregate US price data set to test the law of one price. As in Obstfeld and Taylor, they confirm the point that large deviations from the law of one price are band reverting whilst small deviations are not.

The work over-viewed in this section indicates that transaction costs are a significant determinant of real exchange rate volatility, although nominal exchange rate volatility dominates. Of more significance, however, is the import of transportation costs for the mean-reverting behaviour of real exchange rates. To the extent that such costs are responsible for introducing non-linearities into exchange rate data it would seem that this can explain almost all of the relatively slow mean-reversion that we noted at the end of section 3. However, this is not to rule out other interpretations of the non-linearity/ slow adjustment speeds and these are considered below.

6. Productivity Differentials and the Real Exchange Rate - A Second Pass at Balassa-Samuelson.

Other studies in the Balassa-Samuelson tradition focus directly on the relationship between a variety of measures of productivity and the real exchange rate A number of these examine the short-run interaction between real exchange rates and relative productivity (see, for example, Hsieh (1982), Marston (1990), Micossi and Miles-Ferrretti (1994) DeGregario and Wolf (1994)). Although these models do tend to capture significant Balassa-Samuelson links, their specification is perhaps questionable. For example, they all rely on difference specifications (for bilateral and multilateral rates) and, as Chinn (1996) points out in his critical review of this literature, such tests are all likely to be misspecified (irrespective of whether the underlying time series process of the series are I(1) or trend stationary) because Balassa-Samuelson is about the relationship between the level of productivity and the level of the real exchange rate. (i.e. if the series are I(1) then the theory implies that the series must be cointegrated and therefore a regression which relies solely on differences will be misspecified from a statistical perspective).

Balassa-Samuelson studies which use cointegration methods to detect a relationship between the level of the real exchange rate and the level of productivity are Faruqee (1995), Strauss (1995), MacDonald (1995) Strauss (1996), Chinn (1996), Chinn and Johnston (1996) and Canzoneri et al (1996). Some of these studies, relying on a more general theoretical structure than Balassa-Samuelson (such as the models of Mussa (1984) and Frenkel and Mussa (1985)) include other variables such as government fiscal balances. Faruqee (1995), for example, uses the methods of Johansen to test for cointegration between the real effective values of the dollar and yen (over the period 1950-1990) and a Balassa-Samuelson effect (measured as the ratio of CPI to WPI in the home relative to foreign country), a net foreign asset position and terms of trade effect. Clear evidence of cointegration is found for both currencies and for the dollar a set of exclusion tests indicate that neither net foreign assets nor Balassa-Samuelson alone can explain permanent movements in the exchange rate (although TOT can be excluded); for the yen none of the variables can be excluded. Strauss (1996) examines six bilateral DM rates (Belgian franc, Canadian dollar, Finnish Marka, French franc, Pound sterling and the US dollar) for the period and, using sectoral labour productivity as his measure of Balassa-Samuelson, finds strong evidence of cointegration with the Johansen cointegration method. In a further paper, Strauss (1995) uses total factor productivity for German mark bilaterals and finds evidence of cointegration in 8 countries out of 14.

Chinn (1996) uses a variety of cointegration estimators - Johansen, Phillips-Loretan, and Pedroni - to assess the relationship between real exchange rates and Balassa-Samuelson (as measured by total factor productivity), and a government spending variable to proxy the demand side, although he also tests for the inclusion of a number of other variables such as a preference variable, the terms of trade and the price of oil. Chinn uses an 'effective' data base (effective exchange rates and effective explanatory variables, constructed using the weights implicit in the effective rates), for 14 countries over the period 1970-1991. Using single equation time series methods he finds the statistical links between real exchange rates and the explanatory variables to be weak, although when panel estimation methods are used a correctly signed and statistically significant productivity effect is found (other variables are not significant). One interesting aspect of the panel result is that the implied estimate of mean reversion is between 2.5 and 3 years, which is faster than that found in panel estimates of real exchange rate when the only explanatory variable is the lagged real exchange rate. Chinn and Johnson (1996) adopt a similar approach/ data set to Chinn, the difference being they focus on bilateral real (CPI) exchange rates. Their findings are also similar to Chinn, in that they find greater evidence of cointegration in a panel setting than on a single equation basis; their estimate of mean reversion is, though, slightly slower since the reported coefficient is around 4 to 5 years.

Canzoneri, Cumby and Diba (1996) use panel cointegration methods to examine the Balassa-Samuelson effect. Using a panel consisting of 13 OECD countries, over the period 1970 to 1991, and the US dollar as the numeraire they find strong evidence of cointegration between the relative price of non-tradeables (the second component on the RHS of (10)) and the ratio of average products of labour (their measure of productivity), thereby validating an important component of the Balassa-Samuelson hypothesis. Indeed, they are unable to reject the hypothesis that the slope coefficient in the cointegrating relationship is unity. However, their panel tests of the proposition that exchange rates and the relative price of traded goods prices are cointegrated finds some support in the data although the slope of the coefficient in the cointegrating relationship appears not to be unity. However, in testing the stationarity of the difference between exchange rates and relative prices they are unable to reject the null of a unit root. Using the DM as the numeraire currency they confirm that the relative price of non-tradables and the ratio of average products of labour are cointegrated (with a unitary coefficient). In contrast to the US dollar results, nominal exchange rates and relative prices appear to be cointegrated with a cointegrating coefficient which is close to unity.

Using an annual data base, spanning the period 1871-1994, Mark (1996) analyses the importance of economic fundamentals in explaining systematic movements in the real value of the pound sterling-US dollar exchange rate. A variety of fundamentals are experimented with - relative real interest rates, relative money supplies and relative productivity levels - but the only significant relationship occurs with the relative productivity measure (defined as per capita income). One interesting feature of this result is that it appears to be exchange rate regime specific (the significance and magnitude of this coefficient is most significant for the Bretton Woods period) which would seem to be evidence against the equilibrium approach of Stockman (1988).

The evidence in this section is supportive of the existence of a Balassa-Samuelson effect, although it would seem that the effect is not very strong. However, given that the studies overviewed here focus exclusively on the real exchange rates of industrialised countries, this is perhaps not surprising. Are there other factors introducing systematic variability into real exchange rates? The next section attempts to answer this question.

7. Real Interest Rate Parity

In moving from PPP-based relationships to explicit modelling of the real exchange rate, a number of researchers have used the real interest rate parity condition as their benchmark real exchange rate relationship:

$$q_t = E_t(q_{t+k}) - (r_t - r_t^*), \qquad (16)$$

Expression (16) describes the current equilibrium exchange rate as being determined by two components: the expectation of the real exchange rate in period t+k and the negative of the real interest differential with maturity t+k. It is common practice to assume that the unobservable expectation of the exchange rate, $E_t(q_{t+k})$, is the 'long-run' equilibrium exchange rate, which we define as $\bar{q}_t$:[5]

$$q_t = \bar{q}_t - (r_t - r_t^*). \qquad (17)$$

One strand of the literature based on (17) assumes is the sticky price representation of the monetary model. If one is prepared to make the further assumption that *ex ante* PPP holds then $\bar{q}_t$ may be interpreted as the flexible price real exchange rate (which, as was implied by our earlier discussion, must simply equal a constant, or zero in the absence of transaction/ transportation costs) and so (17) defines the deviation of the exchange rate from its long-run equilibrium in terms of a real interest differential. Papers that follow this interpretation are Baxter (1994) and Clarida and Galli (1995).

Regression-based estimates of the relationship between the real exchange rate and the real interest differential may conveniently be split into two strands: that which assumes the equilibrium real rate is equal to a constant, and therefore does not explicitly model the underlying determinants of $\bar{q}_t$, and a group of papers which explicitly focus on trying to model such determinants.

7.i. A Constant Equlibrium Exchange Rate

Papers which assume the equilibrium real rate is constant focus on the following regression equation:

$$q_t = b_0 + b_1 r_t + b_2 r_t^* + j_t, \qquad (18)$$

which may be derived from (17) by assuming $\bar{q}_t = b_0$. In an estimated version of (18) it is expected that b_1<0 and b_2>0. Some researchers put some structure on these coefficients. For example, when (14) is derived as a representation of the sticky price monetary model of Dornbusch (see Edison and Melick (1995)), the assumption of regressive exchange rate expectations implies that the coefficients should be above plus 1 and minus 1, and inversely related to the underlying maturity. However, the relationship between real exchange rates and real interest rates can be derived without imposing regressive expectations and, since (18) is a

[5] This assumption has been invoked by, for example, Meese and Rogoff (1988).

reduced form, and given possibly substantial measurement error, the only requirement on the coefficients in (18) is that they be negative and positive, respectively.

A variety of researchers have used Engle-Granger cointegration methods (see, for example, Meese and Rogoff (1988), Edison and Pauls (1993), Throop (1994) and Coughlin and Koedijk (1990)[6]), and have failed to uncover a statistically significant link between real exchange rates and real interest differentials[7] However, paralleling the work with PPP and unit root testing in real exchange rates, these results seem to be estimation-specific. When the Johansen method is used to tie down the real exchange rate real interest rate relationship, clear evidence of cointegration is found.

For example Edison and Melick (1992,1995), MacDonald (1997) and MacDonald and Swagel (1998) used Johansen multivariate cointegration methods and found evidence of a unique cointegrating vector between a variety of real exchange rates and real interest rates; Edison and Melick find that this result only holds with long rates, while MacDonald and Swagel find it holds for both short and long rates. Relatedly, Johansen and Juselius (1992), Hunter (1992) and MacDonald and Marsh (1997) find that when PPP is tested jointly with UIP, again using Johansen methods, strong evidence of cointegration is found (up to two significant vectors) which is evidence supportive of a relationship between real exchange rates and real interest rates.

Baxter (1994) forcefully argues that the failure of many empirical studies of the real interest rate / real exchange rate relationship to capture a significant relationship has to do with the use of a first difference operator to induce stationarity in the vector of variables. As we noted earlier, although the use of the difference operator ensures that I(1) variables are transformed into stationary counterparts, it also removes all of the low frequency information from the data, some of which may be useful for tying down a desirable relationship Moreover, from a theoretical perspective transforming the data using a first difference operator presupposes that the effect of real interest rates on the real exchange rate is permanent; however, to the extent

[6] Coughlin and Koedjik (1990) find some evidence for cointegration for one of the currencies in their data set, namley the German mark-US dollar.
[7] Throop (1994), using an error correction relationship for the real exchange rate / real interest rate relationship reports some evidence for cointegration on the basis of the estimated t-ratio on the error correction term; however, this is not significant on the basis of a small sample correction.

that (17) represents a reduced form representation of the sticky price monetary model the relationship between the two variables would only be expected to be transitory.

In order to better understand the RERI model Baxter (1994) proposes an alternative specification to (18), namely one which relates the transitory component of the real exchange rate to the real interest differential (she assumes real interest rates are stationary). In regression equation form this is given as:

$$q_t^T = a + b_k ({}_k r - {}_k r_t^*) + u_{kt} \qquad (19)$$

Such a relationship can be derived by assuming the real rate comprises permanent (q_t^P) and transitory (q_t^T) and that the permanent component follows a random process. Using, alternatively, univariate and multivariate Beveridge-Nelson decompositions to derive q_t^T , and *ex post* and *ex ante* measures of the real interest differential, Baxter estimates (19) for a number of bilateral country pairings. The majority of her estimates of b turn out to be significantly negative, the only exception being those for the UK. Further, the majority of point estimates reported by Baxter are above unity, which (her version of) the model predicts, and it is noteworthy that this is the only paper on the RERI which establishes this result. MacDonald and Swagel (1998) used band pass filters to extract the business cycle component from both real exchange rates and real interest rates for bilateral and real effective exchange rates. They find very strong evidence of the real interest rate real exchange rate relationship in the sense that coefficients are correctly signed and significant.

7. ii Non-constant Equlibrium - Productivity, Terms of Trade.

A number of researchers (Meese and Rogoff (1988), Edison and Pauls (1993), Coughlin and Koedjik (1990), MacDonald (1997), Clark and MacDonald (1998)) do not assume ex ante PPP and propose that $\bar{q}_t$ may systematically change over time in response to *inter alia* productivity effects, fiscal imbalances, net foreign asset, accumulation and terms of trade effects. The theoretical justification for the inclusion of these kinds of variables is given by the models of Mussa (1984) and Frenkel and Mussa (1986). However, despite allowing a broader range of variables to affect the real exchange rate, Meese and Rogoff (1988), Edison and Pauls (1993) and Coughlin and Koedjik (1990) fail to find any evidence of cointegration; all of these studies utilise the Engle-Granger two step estimator. For example, Kees and Koedjik (1990) sequentially regress the real exchange rate on the various candidates noted above and find no evidence of a cointegrating relationship for 6 bilateral real exchange rates In contrast, using multivariate cointegration methods, Meese and Rogoff (1988) also find no evidence of cointegration and, additionally, confirm that their celebrated dictum that nominal exchange rate models cannot outperform a random walk, also holds for real rates.

In contrast to the above, Throop (1992), MacDonald (1997) and Clark and MacDonald (1998) find clear evidence of cointegration in these types of relationships. For example, Throop (1992) uses both a two-step estimator and a dynamic error correction model, over the period 1982 quarter 1 to 1990, quarter 3, to reveal significant evidence of cointegration in systems containing the effective US dollar, and the US bilaterals of the yen, the mark and the pound sterling. Interestingly, the US effective is shown to dominate a random walk, in an out-of sample forecasting contest, at horizons of 1 to 8 quarters; however, the evidence for bilaterals is more mixed - in one-half of the horizons it is able to beat a random walk. In MacDonald (1997) clear evidence of a significant cointegrating relationship is reported for the effective rates of the mark, yen and dollar, and these are shown to produce dynamic real exchange rate models capable of outperforming a random walk at horizons as short as 2 quarters. Clark and MacDonald (1998) has as its goal the interpretation of multiple cointegrating vectors and the construction of a BEER estimate of the equilibrium exchange rate (see below). They report two significant cointegrating vectors, for the effective systems of the US dollar, the German mark and the Japanese yen. An example, for the effective US dollar over the period 1960 to 1996, here indicates the kind of relationships that may be recovered from this kind of system:

$$q_t = \underset{(0.04)}{0.084}\, ltot + \underset{(0.33)}{2.701} bs + \underset{(0.10)}{1.237}\, nfa - \underset{(0.01)}{0.004}\ l + \underset{(0.014)}{4.595}, \qquad (19)$$

$$r_t - r_t^* = -\underset{(0.003)}{0.014}, \qquad (20)$$

where *ltot* is the log of the terms of trade, *bs* is a Balassa-Samuelson effect (measured as the ratio of CPI to WPI in the home country relative to the foreign country), *nfa* is net foreign assets, λ is a risk premium and standard errors are in parenthesis. All of the coefficients are correctly signed and all, apart from that on the relative debt term (the proxy for the risk premium), are statistically significant. The $\chi(4)$ test of whether the chosen restricted vectors span the cointegrating space has an estimated value of 5.49 and a marginal significance level of 0.24; the restrictions are easily satisfied at standard levels of significance.

Gagnon (1996) examines the $\bar{q}_t$ component using a panel equivalent to the Phillips-Loretan estimator (leads and lags in the regression). In particular, using an annual data set for 20 bilateral DM rates, over the period 1960 to 1995, he examines the effect of Balassa-Samuelson, NFA, and share of government consumption in total output. Two alternative measures of Balassa-Samuelson are used - real per capita income and the ratio of CPI to WPI in the home relative to the foreign country - and only the relative price measure proves to be statistically significant. The government consumption ratio also does not exhibit any explanatory power. The only variable found to have a robust and significant relationship with the exchange rate, in both the short and long-run, is the NFA term; an increase in NFA equal to the sum of exports and imports produces a real exchange rate appreciation of 24 per cent in the short run and approximately 10 per cent in the long-run. Adjustment speeds in his different specifications range from -0.23 to -0.5, with the average being -0.4.

Kawai and Ohare (1998) examine monthly bilateral real exchange rates (defined using both CPI and WPI measures) for the G7 countries 1973-1996 They also use the Johansen cointgeration method to demonstrate considerable evidence of cointegration amongst real exchange rates and the kinds of explanatory variables discussed above. For example, relative labour productivity is statistically significant and correctly signed in over one half of the country pairs for which they define cointegration (productivity measure as industrial productivity per labour employed in the industrialised or manufacturing sector).

7. iii. Behavioural Equilibrium Exchange Rates (BEERS) versus Fundamental Equilibrium Exchange Rates (FEERS)

Recently it has become fashionable to use (17) and its variants to address the issue of exchange rate assessment; that is, how far or how close an exchange rate is from its equilibrium value. This approach, labeled a BEER by Clark and MacDonald (1998), is seen to have advantages over the FEER-based approach of Williamson (1985) and Wren-Lewis (1992). Amongst the disadvantages of the FEER approach are its relative intractability, its use of normative assumptions and it is unclear whether the underlying exchange rate relationship is in any sense well-founded in a statistical sense.

The BEER approach may be used to construct data determined measures of equilibrium exchange rates such as that derived from equations (19) and (20). Clark and MacDonald refer to the gap between the actual and the data determined equilibrium as the current misalignment, a term which recognises that in defining an equilibrium the underlying fundamentals may not be calibrated at their equilibrium values. However, it is not difficult to devise an alternative measure of equilibrium - where such fundamentals are calibrated at desired levels and this is defined by Clark and MacDonald as the total misalignment. The BEER approach is seen to have advantages over the FEER in that it is highly tractable, can be assessed in terms of how good a representation of the data generating process it is, and is amenable to the construction of simple counterfactual experiments.

The BEER approach may be illustrated by referring to Figure 2, where the BEER calculated from the sum of the two cointegrating vectors (19) and (20), is reported. The fitted values are interpreted as 'equilibrium' values in the sense that they reflect the full adjustment of the real exchange rate to the set of identified fundamental economic variables, and the estimated level of the exchange rate is therefore consistent in a well-defined sense with economic fundamentals. Hence unexplained movements in the actual exchange rates are a measure of exchange rate misalignment because they reflect exchange rate behaviour that cannot be accounted for by fundamentals, but rather by unobserved transitory and random factors. Perhaps the most striking feature of figure 2 is the extent to which the dollar was overvalued in the period 1980-86, a feature that Clark and MacDonald attribute to a speculative bubble or extrapolative expectations.

Of course, since the BEER is an explicitly behavioural concept, it does not necessarily follow that the fundamentals underpinning the BEER reported in Figure 2 are themselves equilibrium values. In contrast, in the FEER approach economic fundamentals are calibrated at values which correspond to internal and external balance. However, the BEER approach can also be implemented in a similar manner by calibrating the variables in the cointegrating vectors at particular values. For example, in Figure 3 a time path for the US BEER is derived by assuming that the large deterioration in the US fiscal deficit and net foreign asset position did not take place post-1980. It demonstrates that the post-1985 dollar depreciation would not have been as large as that which occurred. The gap between the actual real rate and the BEER in Figure 3 reflects a *total* misalignment, where the difference between the actual and fitted values incorporates the effects of departures of the economic fundamentals from their long-run, sustainable, or desired levels. The BEER approach to exchange rate assessment has recently become increasingly popular amongst practitioners.

Although we noted at the end of Section 4 that nominal exchange rate variability combined with sticky prices seemed to be the predominant source of real exchange rate variability this does not necessarily rule out the importance of real factors in driving real exchange rates. We believe that the evidence in this section convincingly illustrates the importance of the real determinants of real exchange rates, such as fiscal imbalances and terms of trade effects, of real exchange rates. Further, not only do these kinds of variables explain the systematic movement of real exchange rates they also produce much faster mean reversion than simply conditioning a real exchange rate on a lagged real exchange rate. For example, the dynamic exchange rate equation reported by Clark and MacDonald for their US dollar system indicates that approximately 40 per cent of the gap between the actual and equilibrium rate is closed within a year and so all of the adjustment is completed in approximately 3 years. This is, of course, a dramatically different result from studies which simply condition the real exchange rate on the lagged real exchange rate (i.e. the unit root studies, reported in Section 3, which by extending the span of the data find that full adjustment takes around 8 years to complete). Finally, the kinds of real exchange rate models discussed in this section also seem to be helpful from an assessment perspective.

8. Permanent Versus Transitory Components in Real Exchange Rates

One of the key ways in which researchers have attempted to assess the relative merits of the equilibrium exchange rate models of Lucas (1982) and Stockman (1988) has been to refer to the relative importance of permanent and transitory components in real exchange rates. Since the equilibirum model stresses that causality runs from the real to the nominal rate, evidence that real rates are non-stationary would seem to be evidence in favour of this class of model. We have already discussed the literature on testing for unit roots above, and this may be viewed as offering an 'all or nothing' test, in the sense that the null hypothesis is simply that the series contains a unit root. A related literature seeks to decompose real rates into permanent and transitory components and assess the relative importance of these two elements. For example, define the real rate as:

$$q_t = q_t^P + q_t^T, \tag{21}$$

where q_t^P is the permanent component and q_t^T is the transitory counterpart. A standard approach to constructing this decomposition involves using a Beveridge-Nelson decomposition (either bivariate or multivariate). For example, Huizinga (1987) uses univariate BN decompositions to construct the long- run components of his chosen currencies. Plotting the permanent component against the actual real rate he draws inferences about the extent of over or undervaluation of particular currencies. For example, using this method he estimates the dollar to have been overvalued for the two-year period 1976 to 1978, undervalued for the four-year period from late 1978 to late 1982 and overvalued for the three year period from early 1983 to early 1986. He estimates the post-1985 depreciation of the dollar to have been just right in terms of returning it to its current long-run value against the pound

Cumby and Huizinga (1990) use a multivariate B-N decomposition (MBN) based on a bivariate VAR of the real exchange rate and the inflation differential and present a set of plots of the permanent component of the real exchange rate against the actual real rate for the $-DM, $-Yen, $-Sterling and $-C$. In general, the permanent components of these real rates are shown to exhibit substantial time-variability, but to be more stable than the actual real exchange rate. Their key message is that there are often large and sustained deviations of real exchange rates from their permanent values and such deviations are interpreted as being driven by the business cycle component.

Clarida and Gali (1994) present both univariate and multivariate (the latter are generated from a trivariate VAR consisting of the change in the real exchange rate, the change in output and the inflation rate) Beveridge-Nelson (BN) decompositions of the real exchange rates of Germany, Japan, Britain and Canada. On the basis of the average univariate results, it would seem that around 0.8 per cent of the variance of the real exchange rate is permanent and only 0.2 per cent is transitory. Interpreting the latter as the business cycle related component implies that only a very small percentage of individual country real exchange rate movements are business cycle driven. However, for Germany and Japan the picture changes quite dramatically when the multivariate decompositions are used: now for Germany and Japan 0.7 and 0.6 per cent, respectively, of the variance of the real exchange rate change is due to transitory, or business cycle, components. Clarida and Gali attribute this difference to the fact that in the $-

DM and $-Yen systems inflation has significant explanatory power, in a Granger causality sense, over-and-above past values of lagged real exchange rate changes and lagged output changes.

Baxter (1994) also reports univariate and multivariate BN decompositions for a number of currencies, and on the basis of the univariate tests she finds that the permanent component of the real exchange rate always exceeds the transitory component and it is greatest in the case of the pound-dollar (this is consistent with the Clarida and Gali analysis which also finds the pound sterling has the largest permanent component). However, her multivariate decompositions - consisting of the real exchange rate and inflation differential - reveal that the transitory component dominates in three of the currency pairings. The finding that the transitory component is much greater in the multivariate decompositions is in accord with Clarida and Gali. Baxter (1994) also presents correlations of the permanent and transitory components across countries. For the univariate models all of the permanent components are strongly correlated across countries (having correlation coefficients in excess of 0.5), but the transitory components show no such clear-cut pattern; some are positively correlated (German mark - Swiss franc and French franc - Swiss franc), but most are zero or negative. The multivariate correlations, however, reveal much stronger evidence of positive correlations across countries; interestingly, the only currency pairings to produce negative correlations are those involving sterling. So on the basis of the multivariate results there is much more evidence of an international business cycle.

Campbell and Clarida (1987) apply an unobserved components model to the real exchange rate - real interest rate model (18) and extract the permanent and transitory components. They demonstrate that the majority of movements in the real exchange rate (at least 79 per cent) are driven by movements in the permanent component of the real rate and the remainder due to the transitory element. MacDonald and Swagel (1998), decompose their cointegration-based estimates of (18) into permanent and transitory components using the methods of Gonzalo and Granger (1995) and find that the permanent component is around 0.8 per cent, with the remainder being the transitory element.

Univariate decompositions of real exchange rates into permanent and transitory components indicate the dominance of permanent elements, although multivariate representations give a far more even split between the two components. Since the univariate results exclude information which may be an important determinant of real exchange rates, we believe that the multivariate results give a more accurate picture of the importance of the business cycle in driving real exchange rate movements.

9. Structural VAR Modelling.

As noted in the introduction, one of the key issues in the economics of real exchange rates is the extent to which movements in real rates are driven by underlying real factors, such as preferences and technology, or nominal factors such as asset market disturbances. Most of the evidence that is cited in support of one camp or the other on this issue relates to the relative importance of permanent and transitory components of real exchange rates. For example, Stockman (1988) appeals to some of the univariate evidence on real exchange rates to support his contention that it is real factors which drive real rates, whereas Mussa (1988) cites the kind of evidence reported in Section 4. However, this kind of evidence is, at best, merely suggestive of the relative importance of real and nominal shocks in driving real exchange rates. Starting with Clarida and Gali (1994) [CG] researchers have sought to explicitly model the relative importance of real and nominal shocks using a 'structural VAR' approach; that is, a VAR with the kind of long-run identification restrictions of Blanchard and Quah (1989) imposed.

CG estimate trivariate VAR models consisting of the change in relative output levels, the change in the real exchange rate and a relative inflation rate. In particular, letting $\Delta x_t \equiv [\Delta y_t, \Delta q_t, p_t]'$ denote the 3x1 vector of the system's variables and $e_t \equiv [z_t, d_t, v_t]'$ denote the 3x1 vector of the system's three disturbances, where z_t represents the supply shock, d_t is the demand shock and v_t is the nominal shock. The data are assumed to generated from the following structural moving average model:

$$\Delta x_t = C_0 e_t + C_1 e_{t-1} + C_2 e_{t-2} + \dots, \qquad (22)$$

where C_0 is the 3 by 3 matrix that defines the contemporaneous structural relationship among the systems 3 variables. Imposing the identification methods of Blanchard and Quah, on the long-run matrix C(1), recovered from an estimated VAR of Dx_t, CG impose the following long-run restrictions: money shocks do not influence the real exchange rate or relative output in the long run; only supply shocks are expected to influence relative output levels in the long run; both supply and demand shocks are expected to influence the real exchange rate in the long-run.

These restrictions are based on the long-run behaviour of a modified version of the Mundell-Fleming-Dornbusch (MFD) model (modified to be stock-flow consistent and exhibit long-run neutrality of money).[8]

The expected sign patterns of the real shocks on output, the real exchange rate and the price level generated by the MFD model are as follows. A permanent demand shock should permanently appreciate the currency, increase the price level and output in the short run. A supply shock should produce a depreciation of the currency, a fall in prices and a rise in output. Finally, a nominal shock should also produce a nominal depreciation of the currency which, with sticky prices, will also generate a real depreciation; however, in contrast to the supply side shock this will not be permanent. The nominal shock also produces a rise in the price level and a, perhaps, transitory effect on output.

Given this kind of framework, CG seek to answer 2 questions: what have been the sources of real exchange rate fluctuations since the inception of floating exchange rates and how important are nominal shocks relative to real shocks? To answer these questions they use their estimated structural VAR models to estimate variance decompositions of the real exchange rate, impulse response functions of the set of VAR variables, to the underlying shocks and compute 'real time' historical decompositions of the real exchange rate. CG estimate this model for the dollar bilaterals of the German mark, Japanese yen, UK pound and Canadian dollar, over the period 1974q1 to 1992q1.

CGs impulse response analysis indicate that the responses of relative output, relative inflation and the real exchange rate to the underlying structural model are, in general, consistent with the underlying theoretical structure of the MFD model. For example, US-German impulse response indicates that in response to a one-standard deviation nominal shock, the real exchange rate initially depreciates by 3.8 per cent (the nominal overshoots by 4%), US output rises relative to German output by 0.5 percent and US inflation rises relative to German inflation by 0.3 percent rise in. The output and real exchange rate effects of a nominal shock take between 16 to 20 quarters to die out. In response to a one-standard deviation relative demand shock, the dollar initially appreciates in real terms by 4 per cent, relative output rises by 0.36 per cent and there is a 0.44 per cent rise in US inflation relative to foreign inflation. The effect on the

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[8] The particular version is a stochastic version of Obstfeld's representation of the Mundell-Fleming-Dornbusch

exchange rate is permanent and after 20 quarters the real rate appreciates by 6 per cent. A one-standard deviation relative supply shock produces a (wrongly signed) 1 per cent dollar appreciation in quarter 2 and this quickly goes to zero (after 20 quarters the appreciation is only .2 per cent). Other currency pairings produce similar results and, in particular, the perverse supply side effect appears for the other currencies as well which would seem to indicate an unsatisfactory aspect of their modelling.

Following MacDonald and Swagel (1998), if we interpret the business cycle related component as the sum of the demand and money shock then CG's variance decompositions demonstrate that for all four real exchange rates the business cycle component constitutes approximately 90 per cent of the variance of the exchange rates at quarter 40. Of this total, almost all is attributable to demand shocks in the case of the UK and Canada, while for Japan the split is 60% demand and 30 % monetary with the split being approximately equal for the German mark. The proportion of the forecast error variance due to the supply shock is statistically insignificant at all forecast horizons. The very small supply side specific component reported by CG has become something of stylised fact in the literature on the economics of real exchange rates.

Chadha and Prasad (1997) apply the Clarida-Gali approach to the Japanese yen-US dollar exchange rate over the period 1975 quarter 1 to 1996 quarter 1. Their impulse response analysis indicates a permanent real exchange rate depreciation in response to a supply shock (of around 8 per cent), while a demand shock produces a permanent appreciation (of around 8 per cent). The nominal shock produces an initial real depreciation which is eventually offset with the real rate settling down to zero by quarter 8. The fact that all shocks have a correctly signed effect on the Japanese yen exchange rate contrasts with the findings of CG and may be a reflection of the longer sample period used by Chadha and Prasad. Their variance decomposition analysis reveals a somewhat different split between the different shocks at quarter 40. In particular, the business cycle shocks total 78% (compared to 90% in CG), with the supply side shock accounting for the remainder. Interestingly, supply and demand shocks each contribute about one-fourth of the forecast error variance after quarter 8, with nominal rates explaining the remainder. In contrast to CG, Chadha and Prasad find that the proportion of the forecast error variance due to the

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model.

supply shock is statistically significant at all forecast horizons. Chadha and Prasad interpret their findings as suggesting that monetary and fiscal policy can have a substantial effect on the real exchange rate at business cycle frequencies, whereas the role of technology and productivity shocks is relatively small.

Ghosh (1991) also uses a Blanchard-Quah decomposition to identify a simple VAR model for Dollar-Yen and Dollar-mark for the period 1972-1987. He considers 5 shocks: home and foreign supply; home and foreign money and a relative demand shock (these are essentially the same shocks as in C-G, although they constrain the first two to enter in relative terms). In contrast to C-G, Ghosh allows all of these shock to affect the real exchange rate in the long-run (the restrictions appear in the other equations: only supply side shocks can affect output, although both supply and monetary shocks are allowed to affect inflation). The variance decompositions from his estimated VARs indicate that Keynesian factors predominate in the short-run, but supply side factors dominate the long-run behaviour. For example, at a four quarter horizon, 25% of the yen real rate is accounted for by monetary changes, and 57% by aggregate demand shocks, with the remainder being split between supply side shocks (8%) and exogenous oil shocks (5%). In contrast, at the ten year horizon Japanese supply side shocks account for 83% of the variance, combined monetary shocks the remaining 7% and relative demand 7%. So although monetary shocks are allowed to affect the long-run value of the yen they only have a very small effect. Ghosh's results for the DM are similar to the yen results.

Clarida and Gali's results for the real US bilateral rates of the German mark, Japanese yen and UK pound are confirmed by MacDonald and Swagel (1998) for a longer sample period (1973 to 1997); the sum of demand and nominal shocks - the business cycle related components - dominate, as in CG, explaining approximately 90 per cent of the variance of the mark and yen exchange rates after 40 quarters, with demand shocks being by far the most important component, especially for the UK. For the German mark, however, the business cycle component explains 70 per cent of the forecast error variance with the supply side shock explaining the remaining 30 per cent. Interestingly, all of the forecast error variances are statistically significant at all forecast horizons and this is also the case for horizons of quarter 12 and above for the yen (all of the supply shock forecast error variances for UK pound are insignificant). Furthermore, MacDonald and Swagel also confirm the perverse sign of a supply side shock on the real exchange rate and the statistically insignificant forecast error variances due to the supply side shock. Interestingly, however, when considering real effective exchange rates (of the US dollar, UK pound and Japanese yen) the supply side shocks become correctly signed with respect to the exchange rate and although the aggregate effect of the business cycle component is similar to the bilaterals at quarter 40 (explaining 85% of the variance, rather than 90%) the composition of the business cycle component is different. For example, for the UK bilateral 73% of the residual variance is due to the demand shock, 14% nominal while for effectives the relative proportions are 59% and 25%. For the Japanese yen the difference is more marked, since the demand component moves from a 47% share in the bilateral to 25% in the effective, with the nominal share moving from 40% per cent to 59%. The use of effective rates would therefore seem to be important in measuring the relative importance of demand shocks, but not the supply shocks which have a very similar influence to their role in the bilateral case.

Two further studies seek to address the issue of the relative dominance of demand shocks by specifying a richer menu of shocks, particularly on the supply side. For example, Rogers (1995) expands the *x* vector in (22) to include the change in the ratio of government spending to output, and replaces inflation as the nominal variable with base money and the base money multiplier. The particular identification restrictions imposed allow him to construct fiscal and productivity shocks (both of which should produce a long-run appreciation on the real exchange rate), a demand shock (a long-run depreciation, due to having a model in which traded/ non-traded distinction is made) and a monetary shock (no long-run effect). This particular specification is implemented on an annual data set for the UK pound - US dollar exchange rate over the period 1859-1992. The impulse response analysis reveals that 50% of the variance of the real exchange rate is due to monetary shocks (with a roughly equal split between money multiplier shocks and the monetary base shock), productivity (supply) shocks account for approximately 35 per cent with the remainder coming from the demand side. So supply shocks put in a more respectable performance in this paper. In a bid to discern if this is dependent on the sample period or the richer shock specification, Rogers implements his VAR specification for the same data sample as that used in CG, and the CG specification for his longer sample. In terms of the latter exercise, he finds that the longer sample does not increase the role of the supply side shock, although it does increase the role of the monetary shock at the expense of the demand shock (interestingly, this is similar to the extended sample findings of MacDonald and Swagel). Implementing his model structure on the CG data set produces a similar result: the business cycle shocks dominate the total but the composition changes from the demand shocks being the dominant shocks to the nominal shocks contributing about one-half the total for all of the currencies considered by CG. So specification of shocks important

Weber (1998) also extends the CG model by specifying a richer menu of shocks. In particular, he splits supply shocks into labour supply and productivity components and segments monetary shocks into both money demand and money supply; additionally, he also includes a relative aggregate demand shock. In terms of the real exchange rate, the long-run restrictions are that the real exchange rate depreciates in response to both a relative productivity and relative labour supply shocks and the real exchange rate appreciates in response to a relative demand disturbance. The long-run restrictions are imposed using the Blanchard-Quah decomposition. The data set consists of the three real bilaterals: US dollar - German mark, US dollar-Japanese yen and German mark - Japanese yen and the period spanned is 1971 VIII to 1994XII. Weber's results essentially confirm the findings of CG - demand shocks are the dominant force driving real exchange rates, although for the two cross rates involving the Japanese yen supply side shocks (in the form of labour market shocks) do contribute a much larger fraction of the forecast error variance (around one third) compared to the original CG study; and this result confirms the findings of Chadha and Prasad (1997). However, Weber notes that the demand shocks are highly correlated with the real exchange rate and, indeed, for the US dollar-German mark this is on a one to one basis; most intriguingly he demonstrates that the relative demand shock does not have a significant impact on output, which presumably it should have if it is to serve any purpose in representing a demand shock. Weber concludes by arguing that the AD shock is simply a 'catch-all' term which reflects what is left of real exchange rate movements that cannot be forecast from the other variables in the system. It is therefore questionable to interpret such shocks as AD shocks when they contain such a large share of the residual variance.

The basic CG model suffers from other deficiencies in addition to those noted by Weber.[9] First, the basic identification procedure used forces all of the temporary shocks to have a monetary origin. Of course in practice, or in the data, this is unlikely to be the case. This means that a whole range of temporary supply shocks - oil price shocks, changes in fiscal policy - are subsumed as a monetary shock. The same kind of argument could be made for temporary

[9] Our discussion here is based on Stockman (1995).

demand shocks. Second, in setting up the identifying assumptions, it is assumed that the innovations to demand and supply are uncorrelated, which, for a variety of reasons, seems implausible (i.e. an increase in AD raises I, which raises the future capital stock and supply, as well as demand). Third, in the original CG study nominal shocks only have a miniscule effect on relative output and this raises the question of whether it is the way nominal shocks are specified, rather than the absence of important nominal effects that is to blame. Sarte (1994) has demonstrated that identification in structural VARs can be very sensitive to identifying restrictions particularly when residual series are used as instruments for the variables for which they are intended as instruments.[10]

The empirical work on structural VAR relationships may be summarised in the following way. The basic message from the original paper by Clarida and Gali is that supply side shocks explain a miniscule and insignificant proportion of the variance of key real exchange rates. Extending the sample from that in CG seems to have the effect of increasing the importance of nominal shocks at the expense of demand shocks, while leaving the role of supply side shocks unchanged, although supply side shock do seem to be important for the Japanese yen. The measurement of shocks also seems to be important, especially on the demand side: defining the monetary variable to be monetary rather than price has an important bearing on the relative split between demand and nominal. The use of effective rates rather than bilateral measures seems to make a difference, particularly with respect to achieving correctly signed impulse response functions.

10. Summary and Conclusions

What have we learned from our overview of the real exchange rate literature? First, considering single currency results for the recent floating experience we noted some clear evidence of weak-form PPP holding for US dollar bilaterals and strong- form PPP holding for some DM-based bilaterals. Further, we reported some evidence of statistically significant real

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[10] As in Rogers (1995) and Weber (1997), MacDonald (1999b) advocates a wider range of shocks (both demand and supply shocks) and also a completely different way of estimating the effects of the shocks. In particular, MacDonald points out that in systems which are relatively rich in terms of the numbers of shocks the cointegratedness of the system bust be recognised. The existence of significant cointegrating vectors is then used to impose a set of long-run restrictions. The impulse response functions and variance decompositions are then calculated using the generalised impulse response approach of Pesaran. This approach appears to give a more balanced approach.

exchange rate mean reversion for the recent float. However, in both the real and nominal studies the half-life adjustment back to equilibrium is painfully slow and cannot be consistent with traditional PPP. To increase the power of unit root and cointegration tests many researchers have advocated extending the span of the data on either an historical basis or by utilising panel methods. Such methods produce evidence which is favourable to the homegeneity of nominal exchange rates in relative prices, and of mean reversion processes for real rates which suggests a half-life to equilibrium of approximately four years. But what do these half-lives mean and are they not too long to be consistent with traditional PPP (see Rogoff (1995))? In trying to answer this question it is useful to think about the sources of real exchange rate movements.

A number of studies, discussed in Sections 4 and 5, indicate that the sticky price effect (that is, the combination of sticky prices and excess liquidity) is an important source of real exchange rate variability. For example, studies which decompose real exchange rates into the relative price of traded goods and the relative price of traded to non-traded goods, indicate that it is movements in the former term are largely responsible for real exchange rate volatility, although the Balassa-Samuelson effect does have a small role. This kind of evidence would seem to favour a sticky price interpretation of the sources of real exchange rate movements, although such modelling is not informative about the role of other kinds of real shocks (a la Stockman (1988)) which may move the real rate independently of the internal relative price structure. We discuss these other real factors below. To the extent that sticky price effects are an important source of an initial real exchange rate movement, what is it that makes real rates so persistent?

In an early contribution to the literature, Hecksher (1916) emphasised the importance of transaction costs in generating bands within which it proves unprofitable to arbitrage away deviations from PPP/ the law of one price. A number of recent studies, therefore, have sought to explore the effects transactions costs on real exchange rate behaviour. One set of studies focuses on geographical sources of transaction costs - particularly distance - while another set focuses on the potential non-linear behaviour of real exchange rates induced by transaction costs. In the former category of study, the main finding is that transaction costs are an important and significant factor in explaining real exchange rate behaviour, although the volatility of the nominal exchange rate is by far the most important variable, thereby confirming the sticky price story noted above. In the non-linear studies the central point is that impediments to international trade can produce a zone of inaction in which it is not profitable for deviations from PPP to be arbitraged away, but when deviations are large and, in particular, lie outside the zone, adustment back to equilibrium is very rapid. For example, half-life adjustment speeds are on average 6 months with aggregate data and only one month with law of one price data. The non-linear literature is still at an early stage but it would seem to offer considerable promise in explaining the stylised fact of relatively slow mean reversion. Are there other ways of reconciling such slow reversion with a sticky price effect?

Another interpretation involves the existence of hysteretic effects, which arise as a result of menu costs. For example, in Delgado's (1991) model optimizing rational individuals do not change prices on a one-to-one basis as the exchange rate moves because of menu costs. Indeed, menu costs of 0.1 per cent of production costs imply that the nominal exchange rate would have to move by up to 7 per cent for price to change; as menu costs increase so to does the exchange rate change necessary to induce price changes. So for relatively small nominal exchange rate movements real rates moves in tandem, while for relatively large movements there will eventually be some adjustment but this is not on a one-to-one basis. In contrast, the model of Baldwin and Krugman (1989) imparts hysteresis into exchange rates through the entry and exit decisions of firms. For example a firm's decision to enter or exit a market in response to past exchange rate movements will not be reversed when an exchange rate returns to its initial level because of the existence of sunk costs. The pricing to market or industrial organisation models of Dornbusch (1987) and Marston (1990) give essentially the same result and are another potential rationalisation of slow mean reversion.

Further support for a sticky price interpretation of real exchange rate movements are the studies which find, on the basis of parametric and non-parametric tests, a significant relationship between real exchange rates and real interest rates. Additionally, studies which decompose real rates into permanent and transitory elements generally find that the transitory, or business cycle dependent component, is an important component of the real exchange rate, particularly when multivariate methods are used.

Although it is possible to rationalise much of the slow mean reversion of real rates with a sticky price interpretation, this is not to exclude the influence of systematic real factors on the real exchange rate. Indeed, a number of studies discussed in this paper have shown that factors like productivity differentials, fiscal balances, terms of trade effects and net foreign asset positions are important determinants of real exchange rates. Indeed, on a single country basis for effective exchange rates the average half-life is approximately one year and half when the real rate is conditioned on real fundamentals.

A more direct way of obtaining a feel for the relative importance of real over nominal shocks has involved estimating structural VARs, which facilitate a decomposition of real exchange movements into supply, demand and nominal shocks. The kind of stylised fact to emerge from these models is that the business cycle related element (the sum of demand and nominal shocks) dominates the movement of the real exchange rate and in the original study of Clarida and Gali the dominant component is the demand shock, although other studies find that the nominal shocks are more important when a richer nominal decomposition is used. This kind of work offers considerable scope for future research, especially if the supply side of these kind of models can be better specified and a more appealing method of identification is used.

In sum, real exchange rates are mean reverting and the speed of mean reversion may be thought of as a function of real factors, transaction bands, pricing to market and hysteretic effects. Real exchange rates contain important business cycle related components, although the failure to define important supply side effects may be more a reflection of the kind of methods used than their lack of importance. It seems we do know a great deal about the behaviour of real exchange rates, although there is plenty of scope for refining and elaborating the current body of knowledge.

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