Concepts to Calculate Equilibrium Exchange Rates: An Overview

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Abstract

In this paper we present a critical overview of different methods of constructing an equilibrium exchange rate. The recent literature on purchasing power parity (PPP) indicates that on its own PPP is not a good vehicle for defining an equilibrium exchange rate. Rather, we argue that the latter can only be recovered from a model in which the real determinants of exchange rates are explicitly modelled. The advantages and disadvantages of various such models are discussed. In particular, the internal-external balance approach to defining an equilibrium real exchange rate is disccused, and this method is compared to the so-called behavioural equilibrium approach. Finally, an approach which uses purely time series methods to construct an equilibrium exchange rate is also discussed.

Keywords: Equilibrium Exchange Rates; Purchasing Power Parity; Real Exchange Rate Models

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1 Introduction

The sharp fall in the external value of the euro since its inception in 1999 and the sustained appreciated value of sterling over the last few years has generated a renewed interest in the issue of equilibrium exchange rates. What explains these currency movements? Do they represent movements in the underyling equilibria, and therefore the currencies are correctly priced, or do they represent misalignments? Clearly to answer these kind of questions requires some measure of equilibrium. Such a measure is also desirable from the perspective of a country planning to join a monetary union, such as the central european countries currently engaged in the accession stages to full-blown European monetary union. Knowledge of equilibrium exchange rates is also desirable in the wider context of reform of the international monetary system (IMS). For example, current proposals for introducing a greater degree of fixity into the IMS - between the yen, dollar and euro - requires knowledge of the appropriate rate at which to lock currencies or the appropriate central rate of a target zone/ crawling peg arrangement.

Purchasing power parity (PPP) is often the measure economists first turn to when asked to

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think about the issue of equilibrium exchange rates and exchange rate misalignment. But how good is PPP as a measure of an equilibrium exchange rate? In this overview we argue that on its own PPP is not a particularly good metric by which to gauge if currencies are misaligned. However, there are a number of alternative measures of equilibrium which are suitable for assessment purposes and these are also reviewed here. Since the construction of an equilibrium exchange rate often relies on using recently developed econometric methods we present a brief overview of such methods where appropriate. We also focus exclusively on measures of exchange rate equilibrium which have been implemented in a practical sense for policy assessment purposes; we therefore do not discuss measures of an equilibrium exchange rate which could be obtained from an intertemporal modelling framework.

The outline of the remainder of this paper is as follows. In the next section we introduce a simple balance of payments model of the exchange rate and also address the issue of exchange rate misalignment. PPP and the monetary extension of PPP are discussed in Section 3, while measures of equilibrium which rely on combining PPP with uncovered interest parity are discussed in Section 4. Section 5 contains a discussion of so-called behavioural and permanent equilibrium exchange rates and Section 6 overviews measures of equilibrium which rely on a permanent and transitory decompositions of the real exchange rate. The internal-external balance approach to measuring equilibrium exchange rates is discussed in Section 7; in particular, the fundamental equilibrium exchange rate model, the IMF real exchange rate model and the natural real exchange rate model are all detailed. A concluding section summarises the advantages and disadvantages of the different approaches.

2 Balance of Payments Equilibrium Under Floating Rates and Exchange Rate Misalignment.

A useful starting point for our discussion is a simple balance of payments model. Absent foreign exchange market intervention, the standard balance of payments equilibrium condition under floating exchange rates is:

$$ca_t + ka_t = 0 \tag{1}$$

or

$$ca_t = -ka_t \tag{2}$$

where ca_t and ka_t denote, respectively, the current and capital accounts of the balance of payments. In one way or another this relationship is central to all of the models of equilibrium considered in this paper. Ignoring some minor components, the current account may be defined as:

$$ca_t = nx_t + i_t^{'} nfa_t \tag{3}$$

where nx_t denotes net exports (exports minus imports) and $i_t^{'} nfa_t$ represents net interest payments on net foreign assets (it is possible that exchange rate revaluation effects will have an influence through this term). Assume that net exports are determined by a standard relationship:

$$nx_t = \alpha_1(s_t + p_t^* - p_t) - \alpha_2 y_t + \ \alpha_3 y_t^*, \cdots \alpha_1, \alpha_2, \alpha_3 > 0, \tag{4}$$

where s_t is the log of the spot exchange rate (home currency price of a unit of foreign currency), p_t is the log of domestic price level, y_t is the log of domestic income, an asterisk denotes a foreign magnitude and the α's are elasticities. The first term after the equals sign is a measure of competitiveness and is assumed to be positively associated with net exports for the familiar competitiveness reason (we assume the Marshall-Lerner condition holds). A rise in domestic income is assumed to worsen net exports through its effect on imports, while a rise in foreign income improves the net export postition through its beneficial influence on domestic exports. The capital account is assumed to be a function of the net interest differential, as:

$$ka_t = \mu(i_t - i_t^* - \Delta s_{t+k}^e), \qquad \mu < \infty, \tag{5}$$

where i_t denotes an interest rate yield, and Δ is a first difference operator. If $\mu \to \infty$ then, of course, (5) reduces to the condition of uncovered interest rate parity (UIP).

Substituting (4) into (3) and the resulting expression, along with (5), into (1) we may obtain a 'textbook' balance of payments exchange rate equation:

$$s_t = p_t - p_t^* + (\alpha_2/\alpha_1)y_t - (\alpha_3/\alpha_1)y_t^* - \alpha_1^{-1}(i_t^{'} nfa_t) - \mu/\alpha_1(i_t - i_t^* - \Delta s_{t+k}^e) \tag{6}$$

Equation (6) may be thought of as a very general representation of an equilibrium exchange rate in that it satisfies balance of payments equilibrium under floating exchange rates. In this sense it could be thought of describing a so-called statistical equilibrium (one that captures, or recognises, the reasons why an exchange rate may not be in steady-state equilibrium) for the recent floating period. Of course, (6) does not represent a 'true' steady state equilibrium because it is not stock-flow consistent. As we shall see below, however, variants of the internal-external balance approach to the equilibrium exchange rate essentially use (6) to identify a 'medium-run' equilibirum exchange rate. Furthermore, since practically all of the extant equilbrium exchange rate models can be derived from (6), it provides a useful source of reference for the suceeding discussion. Let us assume for the time being, however, that (6) is a measure of the equilibrium exchange rate and illustrate how it may be used for assessment purposes. First, using the definition of the real exchange rate, q_t,:

$$q_t \equiv s_t - p_t + p_t^*. \tag{7}$$

we may renormalise (6) with the real exchange rate as the dependent variable. Furthermore, define Z_{1t} as a set of fundamentals which are expected to have persistent effects on the long-run real exchange rate and Z_{2t} as a set of fundamentals which have persistent effects in the medium-run. In terms of (6), Z_{1t} would contain the relative output terms and net foreign assets, while Z_{2t} would contain interest rate yields. Given this, the actual real exchange rate may be thought of as being determined in the following way:

$$q_t = \beta_1^{'} Z_{1t} + \beta_2^{'} Z_{2t} + \tau^{'} T_t + \epsilon_t, \tag{8}$$

where $\beta_1^{'}$, $\beta_2^{'}$ and $\tau^{'}$ are vectors of reduced form coefficients, T is a set of transitory, short-run, variables and ϵ_t is a random error term. Following Clark and MacDonald (1999) it is useful to distinguish between the actual value of the real exchange rate and the current equilbrium exchange rate, $q_t^{'}$. The latter is one in which the transitory and random terms are zero:

$$q_t^{'} = \beta_1^{'} Z_{1t} + \beta_2^{'} Z_{2t}, \tag{9}$$

and therefore the current misalignment, *cm*, is given as:

$$cm = q_t - q_t^{'} = q_t - \beta_1^{'} Z_{1t} - \beta_2^{'} Z_{2t} = \tau^{'} T_t + \epsilon_t. \tag{10}$$

So *cm* is simply the sum of the transitory and random errors. As the current values of the economic fundamentals can deviate from the sustainable, or desirable, levels, Clark and MacDonald (1999) also define the total misalignment, *tm*, as the difference between the actual and real rate given by the sustainable or long-run values of the economic fundamentals, denoted as $\bar{Z}_{1t}$and $\bar{Z}_{2t}$

$$tm_t = q_t - \beta_t^{'} \bar{Z}_{1t} - \beta_2^{'} \bar{Z}_{2t} . \tag{11a}$$

The calibration of the fundamentals at their desired levels may either be achieved by the user placing some judgement on what values the actual variables should have been during the sample period or, perhaps, using some sort of statistical filter, such as the Hodrick-Prescott filter. By adding and subtracting $q_t^{'}$ from the right hand side of (11a) the total misalignment can be decomposed into two components:

$$tm_t = (q_t - q_t^{'}) + [\beta_1^{'}(Z_{1t} - \bar{Z}_{1t}) + \beta_2^{'}(Z_{2t} - \bar{Z}_{2t})]. \tag{12}$$

Since $q_t - q_t^{'} = \tau^{'} T_t + \epsilon_t$, the total misalignment given in equation (12) can be rewritten as:

$$tm_t = \tau^{'} T_t + \epsilon_t + [\beta_1^{'}(Z_{1t} - \bar{Z}_{1t}) + \beta_2^{'}(Z_{2t} - \bar{Z}_{2t})]. \tag{13}$$

Therefore expression (13) says that the total misalignment at any point in time can be decomposed into the effect of the transitory factors, the random disturbances, and the extent to which the economic fundamentals are away from their sustainable values.

3 Purchasing Power Parity - PPP

The condition of PPP may be recovered from (6) by assuming $\alpha_1 \rightarrow \infty$, and given plausible values of the other parameters, that capital is immobile internationally; that is $\mu \rightarrow 0$.

$$s_t = p_t - p_t^* \tag{14}$$

This immediately illustrates the restrictiveness of PPP as a measure of an equilbrium exchange rate, since it ignores any real determinants of the real exchange rate, such as relative activity levels and net foreign asset positions, and also it ignores the influence of capital flows on the exchange rate (which may be important in defining a statistical equilibrium as in the UIP/PPP approach). Of course, since traditional PPP relies on arbitrage forcing the law of one price for the goods prices entering the overall price measure, it also requires an absence of impediments to international trade. Despite the restrictiveness of PPP, it is often the first model of equilibrium economists use to assess if a currency is misaligned (for example, the Economist magazine regularly publishes exchange rate misalignments based on PPP calculations - its Big Mac index). Some well-known examples of using PPP for assessment purposes are the return of the UK to the gold standard in 1925 and the calculation of the central rate for sterling's entry into the exchange rate mechanism of the European monetary system in 1991. But how useful is PPP as an assessment device? Recently a huge literature on testing PPP has emerged and we try to briefly summarise it here (see MacDonald (1995a) for a more complete overview).

A useful starting point is the definition of the real exchange rate given by equation (7). A proponent of strict PPP would argue that the real exchange rate should always equal zero, although the use of price indices to calculate q_t, or the existence of constant transaction costs, means that it may only hold up to a constant term. However, most researchers would go with a less restrictive version of PPP, which simply relies on real exchange rates 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 the context of equation (15):

$$q_t = \rho q_{t-1} + \alpha + \epsilon_t, \tag{15}$$

the estimated value of ρ is expected to lie in an interval between zero and unity. Furthermore, there is an expectation that ρ should be closer to zero than one; that is, a shock to the real

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

exchange rate should not be too persistent. Since Cassel is generally thought to have believed that the half-life of a shock to PPP is about one year this implies a ρ value of around 0.7. A number of different ways of estimating the mean reversion speed have been proposed in the literature. For example, using univariate unit root methods and data for the recent floating period a number of researchers find that ρ is insignificantly different from unity (see MacDonald (1995a)).[3] The point estimate of ρ is usually estimated to be around 0.98, suggesting a half-life of around 20 years. Studies which consider long time span data sets (see, for example, Edison (1987), Frankel (1986,1988), Abuaf and Jorion (1990), Grilli and Kaminski (1991) and Diebold, Husted and Rush (1991)), and use approximately 100 years of annual data, find evidence of significant mean reversion. However, in these studies the point estimate of ρ is usually around 0.85, implying a half-life of 4 years, a number which is apparently still too slow to be consistent with a traditional form of PPP (Rogoff (1997)). Similarly, studies which exploit panel data sets defined for the recent floating period, (see, for example, Bayoumi and MacDonald (1999), Frankel and Rose (1995), Wu (1996), Oh (1995) and MacDonald (1995b)) also find evidence of significant mean-reversion, although again the implied half-life is still around 4 years.

The persistent nature of real exchange rates has been labeled the 'PPP puzzle' by Rogoff (1997). One explanation for this puzzle lies in recognising the importance of transaction costs in producing sustained deviations form PPP. For example, a number of theoretical papers (see: Dumas (1992) and Sercu, Uppal and Van Hulle (1995)) have demonstrated that

[3] Studies which use the variance ratio statisic to test for mean reversion in real exchange rates essentially come to a similar conclusion (see, for example, Huizinga (1987), Glen (1992) and MacDonald (1995a))

if markets are spatially separate, 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 deviations from PPP 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)). A number of papers (see, inter alia, Obstfeld and Taylor (1997), Michael, Nobay and Peel (1997), O'Connell (1996), O'Connell and Wei (1997) and Bec, Ben-Salem and MacDonald (1999)) have implemented this idea using band threshold autoregressive models. For example, Obstfeld and Taylor use a band threshold autoregressive model to estimate mean reversion speeds for real exchange rates, defined using both CPI and disaggegate price series (the latter facilitates testing the LOOP). For the CPI-based real exchange rates they report adjustment speeds outside the transaction band of one year, while for the disagregate prices they report adjustment speeds as low as 2 months.[4]

An alternative interpretation of the causes of persistence in real exchange rates is to explicitly

[4] However, it is worth noting that Obstfeld and Rogoff remove a deterministic trend from their real exchange rates before estimating their non-linear models. This presumably affects their estimated adjustement speeds.

recognise that there are real determinants of real exchange rates. Although this is discussed in some detail below, we have a first pass at this topic here by introducing what is perhaps the best known real determinant of the real exchange rate, namely the Balassa-Samuelson effect. We ask the question: how important is the Balassa-Samuelson effect in explaining the volatility and persistence in real exchange rates relative to the sticky price effect? These kinds of tests may be illustrated in the following way. First, assume that the general prices entering our definition of the real exchange rate can be decomposed into traded and non-traded components as:

$$p_t = \alpha_t p_t^T + (1 - \alpha_t) p_t^{NT}, \tag{16}$$

$$p_t^* = \alpha_t^* p_t^{T*} + (1 - \alpha_t^*) p_t^{NT*}, \tag{17}$$

where p_t^T denotes the price of traded goods, p_t^{NT} denotes the price of non-traded goods and the α_t's denote the share of traded goods in the overall price level. Using the definition of the real exchange rate, defined with respect to overall prices, given previously as (7), and defining a similar relationship for the price of traded goods as:

$$q_t^T = s_t - p_t^T + p_t^{T*} \tag{18}$$

By substituting (16),(17) and (18) in (7) the following expression may be obtained:

$$q_t = q_t^T + [(1 - \alpha_t)(p_t^T - p_t^{NT}) - (1 - \alpha_t^*)(p_t^{T*} - p_t^{NT*})], \tag{19}$$

$$q_t = q_t^T + q_t^{T,NT}, \tag{20}$$

$$q_t^{T,NT} = [(1-\alpha_t)(p_t^T - p_t^{NT}) - (1-\alpha_t^*)(p_t^{T*} - p_t^{NT*})]. \tag{21}$$

This expression is useful because it allows us to think of the volatility, or trend, in the overall real exchange rate as being driven by the volatility or trend in either q_t^T or $q_t^{T,NT}$,or both. The $q_t^{T,NT}$ term is the Balassa-Samuelson productivity bias effect and indicates that if the home country's relative price of non-traded to traded goods is rising over time then its overall exchange rate will appreciate relative to the real exchange rate defined for traded goods prices.[5] Indeed, under a strict interpretation of the Balassa-Samuelson hypothesis q_t^T should equal zero (or, less restrictively, a constant).[6] Alternatively, if it is sticky prices which drive the real exchange rate then q_t^T will be the main driving force of q_t. Two sets of tests have been devised to examine the relative importance of the sticky price effect relative to the Balassa-Samuelson effect in the overall real exchange rate. The first computes measures of conditional volatility of q_t^T and $q_t^{T,NT}$ and then compares them. If it is the Balassa-Samuelson effect which drives the volatility in the real exchange rate then $V(\ q_t^{T,NT}\ )$ should be greater than $V(\ q_t^T\ )$ where V denotes some measure of conditional volatility. Conversely, if the sticky price effect is the dominant component of q_t then this will show up in q_t^T rather

[5] The Balassa-Samuelson hypothesis requires the assumption of 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.

[6] Rogoff (1992) and Obstfeld (1995) have modified the original Balassa-Samuelson model to be consistent with forward looking, optimising, agents.

than $q_t^{T,NT}$ (since s does not enter the latter term), and this would be picked up by the inequality running in the opposite direction. An alternative way of discriminating between the two effects is in terms of the trends in the series and their cointegratedness. If sticky prices explain the time series behaviour of CPI-based real exchanges - which as we have seen are approximately I(1) - q_t^T and q_t should be cointegrated, since $q_t^{T,NT}$ should be a stationary, or an I(0), process. If Balassa-Samuelson is, however, correct q_t and $q_t^{T,NT}$ should be cointegrated and q_t^T should be I(0).

Engel (1993) compares the conditional variances of relative prices within and across countries using disaggregated indices of the CPIs of the G7 countries, over the period April 1973 to Sept 1990. Out of a potential 2400 variance comparisons, Engel finds that in 2250 instances the variance of the relative price within the country is smaller than the variance of the relative price across countries; that is, $V(q_t^T) > V(q_t^{T,NT})$. Rogers and Jenkins (1995) essentially confirm Engel's analysis using finer disaggregations of the prices entering the CPIs of 11 OECD countries. Additionally, however, they also examine the relative importance of trends in q_t^T and $q_t^{T,NT}$ in explaining the systematic element of q_t. They find little evidence that q_t^T is an $I(0)$ process even when a fine level of dissagregation is used. Furthermore, they produce very little evidence that q_t and $q_t^{T,NT}$ are cointegrated. Taken together, the empirical evidence on the relative importance of the two left hand side elements in (21) would seem to favour sticky price models such as those of Dornbusch (1976) and Giovanini (1988). One alternative interpretation is to attribute it to the pricing to market policies of companies. However, both Rogers and Jenkins (1995) and Wei and Parsley (1995) show that adjustment speeds for disaggregate relative prices are similar to the adjustment speeds estimated for aggregate CPI real exchange rates, which seems inconsistent with the pricing to market hypothesis.

However, these findings do not, of course, mean that the Balassa-Samuelson effect is unimportant or insignificant, it is just that the q_t^T element is the dominant force driving the real exchange rate.[7] Although, as we have noted, this may be due to a sticky price effect, the degree of persistence seems to be too slow to be consistent with this interpretation (see Rogoff (1997), for example). Recognising that goods entering international trade are imperfect substitutes opens up the possibility of real factors explaining the volatility and systematic trends in q_t^T. Before discussing what these real determinants are, we first of all consider a measure of equilibrium which is closely associated with PPP, namely the monetary model of the exchange rate.

3.1 The Monetary Extension of PPP

Although the monetary model is usually motivated as an asset market model, it is in fact simply an extension of PPP which fleshes out the determination of prices in each country by imposing continuous money market clearing. In particular, assume that the demand for money in the home and foreign country is given by a (log-linearised) Cagan money demand function and that the supply of money is continuously equal to the demand at some exogneous level, m_t :

[7] Indeed, a number of papers have shown that an appropriately constructed measure of the Balassa-Samuelson effect is a significant determinant of the real exchange rate; see, for example, Chinn (1999), Chinn and Johnston (1996) and MacDonald and Ricci (2000).

$$m_t - p_t = \alpha_0 y_t - \alpha_1 i_t, \qquad \alpha_0, \alpha_1 > 0 \tag{22}$$

$$m_t^* - p_t^* = \alpha_0 y_t^* - \alpha_1 i_t^*, \qquad \alpha_0, \alpha_1 > 0 \tag{23}$$

On rearranging (22) and (23) for the home and foreign country price levels, respectively, and substituting these into (14) we obtain the so-called flex-price monetary reduced form:

$$s = (m_t - m_t^*) - \alpha_0(y_t - y_t^*) + \alpha_1(i_t - i_t^*) \tag{24}$$

which simply states that the nominal exchange rate is driven by relative excess money supplies. Note that the only way real variables can influence the (nominal) exchange rate in this model is through the effect they have on the demand for money (i.e. a rise in domestic income, *ceteris paribus*, raises the real demand for money which, for an exogneously determined supply of money can only be satisfied by a fall in the price and an exchange rate appreciation). Although this version of the monetary model relies on flexible prices for its derivation, Frankel (1979) has proposed a hybrid equation which nests both the sticky and flex-price approaches. Equation (24) and its variants have recently been intensively scrutinised using cointegration methods and dynamic modelling and this research has leant some support to the model, both in terms of supporting it as a long-run construct and also in terms of its out-of-sample forecasting properties (see, for example, MacDonald and Taylor (1993,1994)). However, equation (24) and its variants have not been widely exploited for assessment purposes. Notable exceptions are La Cour and MacDonald (2000), who use a variant of the monetary model to construct a BEER (see below) for the ECU-USD and Chinn (1998) and Husted and MacDonald (2000) who use variants of the monetary model to assess if East Asian currencies were misaligned at the time of the 1997 crises.

Chinn (1998), for example, estimates variants of the monetary model, augmented by the inclusion of a relative productivity term, for the US dollar bilaterals of the Indonesian rupiah, Korean won, Malaysian ringgit, Phillippine peso, Singapore dollar, Taiwanese dollar and the Thai baht for the period 1974 quarter 1 to 1997 quarter 4. The Phillips-Loretan NLS estimator is used and, in general, results favourable to the monetary model are reported in the sense that coefficient values are usually plausable and the adjustment speeds are relatively rapid. Backing out measures of equilibrium from these estimates, Chinn finds that the Indonesian rupiah, Malaysian ringgit, Singapore and Taiwanese dollar and Thai baht are overvalued. However, only the two dollar currencies appear substantially overvalued and the two currencies which exhibited the sharpest falls during the crises - the Indonesian rupiah and Malaysian ringitt - were only slightly overvalued. One interpretation that Chinn places on these results is that they represent an indictment against the monetary model as a tool for exchange rate assessment.

Husted and MacDonald (1999) also apply the monetary model to assess if certain Asian exchange rates were overvalued at the time of the 1997 crash. The currencies examined are: the Japanese yen bilaterals of the Australian dollar, Indian rupiah, Indonesian rupiah, Korean won, Malaysian ringgit, New Zealand dollar, Phillippine peso, Singapore dollar, Taiwanese dollar and the Thai baht for the period 1974 to 1996 (monthly data) and panel cointegration methods are used. Clear evidence of cointegration is reported for the panel of currencies and, furthermore, estimated coefficients are close to their hypothesised priors and this evidence is interpreted as supportive of the monetary model. Using these estimates to construct the current misalignments of the currencies, Husted and MacDonald find that only two currencies, the Malaysian ringgit and Indonesian rupaih were substantially misaligned at the end of 1996 (and indeed the model implies the rupiah was undervalued). These results are interpreted as suggesting that the currency falls experienced by these currencies respresented shifts in long-run mean values unrelated to underlying fundamentals.

Chinn (2000) estimates a monetary approach equation, extended to include a Balassa-Samuelson effect, for the synthetic euro, over the period August 1991 to December 1999. Using the cointegration methods of Johansen a statistically significant cointegration vector is reported and this appears to conform to a monetary approach relationship. The model is then re-estimated, over the period August 1991 to December 1998, and used to construct out-of-sample dynamic simulations and these produce an implied undervaluation of the euro in December 1999 of approximately 12 per cent.

4 PPP and UIP: Capital Enhanced Measures of the Equilibrium Exchange Rate - CHEERS.

One approach to explaining the persistence in real exchange rates, and also in obtaining well-defined measures of the equilibrium exchange rate, involves combining UIP and PPP. This approach has been popularised by Juselius (1991,1995), Johansen and Juselius (1992), MacDonald and Marsh (1997,1999) and Juselius and MacDonald (2000a,b). We refer to this approach as a capital enhanced equilibrium exchange rate, or CHEER. The approach captures the basic Casselian view of PPP, discussed above, that an exchange rate may be away from its PPP determined rate because of non-zero interest differentials. In terms of expression (6), therefore, the approach focuses on the interaction between the real exchange rate and the capital account items; it ignores the relative output terms and net foreign assets (and indeed any other real determinants). Unlike the strict Casselian approach outlined above, however, this approach does not regard non-zero interest differentials as having only a transitory impact on the real exchange rate. The essential proposition of this approach is that there is long term persistence in both the real exchange rate and the interest differential. We consider the CHEERs approach firstly from a statistical perspective and then from an economic perspective.

If we assume that $\mu \rightarrow \infty$ in (5), and therefore capital is perfectly mobile, we may recover the uncovered interest parity (UIP) condition as:

$$(i_t - i_t^*) = \Delta s_{t+k}^e \tag{25}$$

Since interest differentials are usually empirically found to be I(1) processes, some combination of an appropriate interest differential and the real exchange rate may cointegrate down to a stationary process. More specifically, if the expected exchange rate in (25) is determined by the relative prices in (14) we may summarise this in the following relationship:

$$(i - i^*) = \omega_2(p - p^*) - s \ , \tag{26}$$

or, less restrictively, as:

$$[\omega_1(i - i^*) - \omega_2(p - p^*) + s] \sim I(0). \tag{27}$$

The intutition for this expression is as follows. For a period such as the recent float we know that there have been large current account imbalances (this is especially clear when the US dollar is the bilateral numeraire) and these have been driven in large measure by national savings imbalances, such as fiscal imbalances. The fact that real exchange rates have been so persistent, and therefore any adjustment of the current account to relative prices is painfully slow (see Juselius and MacDonald (2000a,b)) means that the current account imbalances have to be financed through the capital account of the balance of payments. The CHEERs approach, therefore, involves exploiting the following vector:

$$x' = [s, p, p^*, i, i^*]. \tag{28}$$

The CHEERs approach has been extended by Juselius and MacDonald (2000a,b) to include both short and long interest rates and MacDonald and Marsh (1999) and Juselius and MacDonald (2000b) have suggested pushing this relationship further and, in particular, recognising that since currency markets are closely linked they should be modelled jointly. Taking the tripolar relationship between Germany, the US and Japan as an example this means modelling the following vector:

$$x' = [s^{ger}, s^{jap}, p^{ger}, p^{jap}, p^{us}, i^{ger}, i^{jap}, i^{us}]. \tag{29a}$$

The advantages of the CHEERs modelling approach are, at least, two-fold. First, well-founded measures of equilibrium may be recovered from either (28) or (29a), in the sense that the composite term is stationary and often degree one homogeneity restrictions can be imposed on the relative price terms and the coefficients on the interest differential are consistent with a capital account interpretation.[8] Furthermore, the speed of mean-reversion of the adjustment term is often much faster than the univariate PPP-based adjustment referred to above and the out-of-sample exchange rate forecasts can be constructed which dominate a random walk at horizons as short as two months ahead (see, for example MacDonald and Marsh (1997)). As a measure of the equilibrium exchange rate it is clearly a 'medium-run' concept in the sense that it does not impose stock-flow consistency. This may be seen as a disadvantage of the approach for assessment purposes. However, it may, nevertheless, provide a useful measure of equilibrium in circumstances where data on net foreign asset positions are not available.

5 Behavioural Equilibrium Exchange Rates - BEERs

The BEER approach explicity recognises the real determinants of real exchange rates and indeed it takes as its staring point the proposition that real factors are a key explanation for the slow reversion to PPP observed in the data. Referring back to (6) the BEER approach essentially advocates that both current and capital account items of the balance of payments are likely to be important determinants of the evolution of the real exchange rate. As in the

[8] Thus the estimated CHEER gives a different measure of equilibrium to that which would be obtained by simply using the UIP condition (a positive relationship would be expected in the latter approach).

CHEER approach, its starting point is the UIP condition, expressed here in real terms and adjusted to include a risk premium:

$$\Delta q^e_{t+k} = -(r_t - r^*_t) + \lambda_t, \tag{30}$$

where λ_t denotes a risk premium. Since the BEER approach is normally applied to real effective exchange rates, the real exchange rate is now expressed as the foreign currency price of a unit of home currency. Expression (30) may be rearranged as an expression for the real exchange rate as:

$$q_t = q^e_{t+k} + (r_t - r^*_t) - \lambda_t \tag{31}$$

and if q^e_{t+k} is interpreted as the 'long-run' or systematic component of the real exchange rate, $\bar{q}_t$,we may re-write this as:

$$q_t = \bar{q}_t + (r_t - r^*_t) - \lambda_t \tag{32}$$

Based on the stock-flow consistent model of Frankel and Mussa (1986), Clark and MacDonald (1999) assume[9] :

$$\bar{q}_t = f(nfa_t, tot_t, tnt_t) \tag{33}$$

where of terms not previously defined, tot_t is the terms of trade and tnt is the relative price of traded to non-traded goods and is a measure of the Balassa-Samuelson effect. Although

[9] See also Faruqee (1995) and MacDonald (1997).

the BEER may be constructed using a variety of estimators, it is useful to briefly discuss the method used by Clark and MacDonald since this can be used to produce a related representation of the BEER, labeled the permanent equlibrium exchange rate (PEER). The latter has characteristics which may, for example, be of use to a policy maker interested in using a BEER-based approach for assessment purposes.

The particular estimator used by Clark and MacDonald (1999) is the vector error correction mechanism (VECM) estimator of Johansen (1995). For example, consider the $(nx1)$ vector of variables, $x_t^{'}$

$$x_t^{'} = [(r_t - r_t^*), nfa_t, tot_t, tnt_t, \lambda_t] \tag{34}$$

and assume that it has a vector autoregressive representation of the form:

$$x_t = \eta + \sum_{i=1}^{p} \Pi_i x_{t-i} + \epsilon_t, \tag{35}$$

where η is a (nx1) vector of deterministic terms, and ϵ_t is a (nx1) vector of white noise disturbances, with mean zero and covariance matrix. Expression (35) may be reparameterised into the (VECM) as:

$$\Delta x_t = \eta + \sum_{i=1}^{p-1} \Phi_i \Delta x_{t-i} + \Pi x_{t-1} + \epsilon_t, \tag{36}$$

where Φ_i is an (nxn) coefficient matrix (equal to $-\sum_{j=i+1}^{p} \Pi_j$), Π is an (nxn) matrix (equal to $\sum_{i=1}^{p} \Pi_i - I$) whose rank determines the number of cointegrating vectors. If Π is of either full rank, n, or zero rank there will be no cointegration amongst the elements in the long-run relationship (in these instances it will be appropriate to estimate the model in, respectively, levels or first differences). If, however, Π is of reduced rank, r (where r<n), then there will exist (nxr) matrices α and β such that $\Pi = \alpha\beta'$ where β is the matrix whose columns are the linearly independent cointegrating vectors and the α matrix is interpreted as the adjustment matrix, indicating the speed with which the system responds to last period's deviation from the equilibrium level of the exchange rate. Hence the existence of the VECM model, relative to say a VAR in first differences, depends upon the existence of cointegration.

Clark and MacDonald (1999) use (37) to estimate BEERs for the real effective exchange rates of the United States dollar, Japanese yen and German mark, for the period 1960-1996 (annual data). The long-run component of the equilibrium real exchange rate, $\bar{q}_t$, is assumed to be a function of net foreign assets, a Balassa-Samuelson effect and a terms of trade effect. Using the VECM methodology discussed above, evidence of two significant cointegrating relationships are reported for each country and in each case the first vector is interpreted as the longer run systematic component of the real exchange rate, while the second is interpreted as the real interest differential. A typical set of results for the US dollar are reported here as equations (37) and (38):

$$q_t = \underset{(0.014)}{4.595} + \underset{(0.04)}{0.084}\, tot_t + \underset{(0.33)}{2.701} tnt + \underset{(0.10)}{1.237} nfa_t - \underset{(0.01)}{0.0004}\, \lambda_t, \tag{37}$$

$$r_t - r_t^* = \underset{(0.003)}{-0.014}\ . \tag{38}$$

All of the coefficients in (37) are correctly signed and all, apart from the coefficient on the risk premium, are statistically significant. The US dollar real exchange adjusts significantly to both disequilibrium errors (with an alpha coefficient of -0.374 on the first error correction term and -0.434 on the second). In Figure 1a we report the BEER estimated from (37) and (38). In terms of our discussion in section 2, Figure 1a shows the current equilibrium rate $q_t^{'}$. Perhaps the most striking feature of the figure is the extent to which the dollar was overvalued in the period 1980-86. It is worth noting that this finding is common to other BEER estimates (see, for example, Faruqee (1995), Kramer (1996), MacDonald (1997) and Stein (1994)). As discussed above, the US BEER plotted in Figure 1a reflects a *behavioural* equilibrium. However, since it is possible for the fundamentals to be away from their equilibrium values it is also possible to calibrate the BEER with some normative structure placed on the fundamentals. For example, in figure 1b a BEER calculation in the spirit of the FEER approach is performed. In particular, the NFA position of the US is set at a 'sustainable level' (equal to its 1980 level) and the total misalignment calculated. This shows that the sharp depreciation of the dollar over the post-1980 period was an equilibriating response to the deterioration in the net foreign asset position of the United States.

Clostermann and Friedmann (1998) estimate (34), without the terms of trade and risk premium terms, for the German mark real effective exchange rate over the period 1975 first quarter to 1996 fourth quarter. Using a dynamic error correction model they find that the key determinants of this exchange rate (in terms of statistical significance) are the Balassa-Samuelson effect and the real interest differential; the net foreign asset term is statistically insignificant in both the short- and long-run components of the regression.

Wadhwani (1999) constructs estimates of the equilibrium UK pound-German mark exchange rate using a variant of the BEER, which he christens an intermediate term model-based equilibrium exchange rate (ITMEER). This is an explicitly medium-run concept in that there is no constraint that flows need be zero. In contrast, however, to other implementations of the BEER, Wadhwani argues that relative unemployment rates are a crucially important determinant of the exchange rate, in addition to the kind of terms entering (34). Two justifications are given for the inclusion of relative unemployment terms. First, if a country has a relatively high unemployment rate investors will infer that its true current account position is worse than the observed current account. This is because when unemployment eventually falls the external balance will worsen and require an exchange rate depreciation over-and-above that implied by the currrent external balance position. Therefore, unemployment acts as a proxy for the expected current account. Secondly, the relative unemployment term may also act as a proxy for a supply side effect: a country with a relatively low unemployment rate may be more attractive to external investors and therefore attract more FDI flows. A further novel aspect of Wadhwani's approach is that he also advocates modelling the risk premium as a latent variable, driven by a variety of asset yield returns.

Wadhwani finds that his estimated reduced form has significant explanatory power, explaining around two thirds of sterling's appreciation over the period 1996 to 1998 and 7.1% of this is attributable to the relative unemployment term. Interestingly, in constructing a current misalignment of the sterling-DM rate, based on actual data values in September 1999, Wadhwani finds that the actual sterling-DM rate is very close to its equilibrium value (i.e.

around 3DM compared to 2.60DM with PPP). Wadhwani also considers various counterfactuals and estimates the implied total misalignments. For example, a scenario in which the German unemployment rate falls relative to the UK produces an equilibrium exchange rate of around 2.8DM.

Clostermann and Schnatz (2000) construct a real synthetic euro for the period 1975 to 1998 and estimate a BEER type equation using the methods of Johansen (1995). The conditioning variables are the relative price of traded to non-traded goods, a real interest differential, the real price of oil and relative fiscal policy term. A unique statistically significant long-run relationship is found and this is used to build a single equation dynamic error correction relationship which is shown to outperform a random walk model at 4 quarters ahead. This model is then used to calculate the medium run equilibrium euro-dollar exchange rate as US$1.126 (although using a 95% confidence interval around this point estimate suggests a range of 0.99 to 1.256).

6 Permanent and Transitory Decompositions of Real Exchange Rates - PEERS

A somewhat different way of measuring equilibrium exchange rates is to use a time series estimator to decompose a real exchange rate into permanent and transitory components:

$$q_t = q_t^P + q_t^T. \tag{39}$$

where q_t^P is the permanent component of the real exchange rate and q_t^T is the transitory component of the real exchange rate. The permanent component is then taken to be the measure of equilibrium - the permanent equilibrium exchange rate, or PEER.

6.1 Beveridge-Nelson Decompositions

A number of researchers have used the univariate and multivariate Beveridge-Nelson decompositions to decompose real exchange rates into permanent and temporary components. For example, Huizinga (1987) uses univariate BN decompositions to extract the permanent components of his chosen currencies. On average, he finds that around 90% of real exchange rate movements are permament. Plotting the permanent component against the actual real rate Huizinga interprets (current) currency misalignments for a variety of exchange rates. For example he argues that the pound-dollar was 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. Huizinga argues that the post-1985 depreciation of the dollar to have been just right in terms of returning the dollar 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.

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 univariate results, on average around 0.8 per cent of the variance of the real exchange rate is permanent and 0.2 per cent is transitory. However, for Germany and Japan the picture is quite different: when the multivariate decompositions are used 0.7 and 0.6 per cent, respectively, of the variance of the real exchange rate change is due to transitory components. Clarida and Gali attribute the larger transitory component with the multivariate decomposition 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. Furthermore, they demonstrate that multivariate decompositions can generate a very different picture of misalignment compared to the univariate decomposition. This is illustrated in Figure 2, for the Real $/ DM combination where we clearly see periods when the two measures give conflicting signals. This should therefore be taken as a cautionary message against using univariate methods and, indeed, against a purely atheortical approach. If an exchange rate model indicates that certain fundamentals are potentially important they should be tested and, if significant, used for assessment purposes - that essentially is the objective of the behavioural equilibrium exchange rate approach discussed in the previous section.

6.2 Structured Vector Autoregressions Estimates

Clarida and Gali (1994) have proposed a relatively sophisticated way of decomposing real exchange rates into permanent and temporary components. In particular, they propose decomposing real exchange rates into supply, demand and nominal components and then assessing which of these shocks are the most important in explaining the variability of real exchange rates. In particular, Clarida and Gali consider the following vector:

$$\Delta x_t^{'} = [\Delta y_t, \Delta q_t, \pi_t] \tag{40}$$

where y_t, denotes relative output (home-foreign) and π_t denotes relative inflation. Using a trivariate VAR modeling approach, and the identification methods of Blanchard and Quah on the long-run matrix C(1), Clarida and Gali are able to identify three shocks from this vector: a supply shock, a demand shock and a nominal shock. The particular identifying restrictions used are based on a modified version of the Mundell-Fleming-Dornbusch (MFD) model: money, or nominal, 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 (that is they have a permanent effect in the long-run).

Using this approach Clarida-Gali decompose the US dollar bilateral rates of the Canadian dollar, German mark, Japanese yen and UK pound for the recent floating period into the constituent components. For example, in figure 3 reproduced from CG the actual real exchange rate, with the cumulative effect of all three shocks netted out, $newsslogq$, is plotted against a series which shows the evolution of the real exchange rate if only one shock had prevailed. For example, the top panel shows that nearly all of the real depreciation of the dollar against the DM in the late 1970s is attributable to nominal shocks, while the real appreciation in the first half of the 1980s is attributable to demand shocks. One key aspect of the Clarida-Gali study (which has not gone uncriticised - see Stockman (1987)) is the finding that supply side shocks explain only a very small proportion of real exchange rate movements (this result holds for all of the currencies studied by Clarida-Gali). The methods of Clarida and Gali have been applied to other exchange rates and time periods, sometimes using different definitions of the shocks (see Astley and Garrat (1996), Chadha and Prasad (1997), Rogers (1995), Weber (1998) and MacDonald and Swagel (2000)).

MacDonald and Swagel (2000) apply the Clarida Gali method to the real effective exchange rates of the German mark, Japanese yen, UK pound and US dollar (and also the bilateral US dollar exchange rates of the German mark, pound sterling and Japanese yen). They interpret the cyclical, or business cycle, component as the sum of the demand and nominal shocks and netting this out from the actual real exchange rate, produce an alternative measure of the permanent (i.e. supply side) component of the real exchange rate. These permanent components are plotted against the actual effective rates in figure 4. For the DM, for example, supply side movements explain the movement in the effective rate up to 1984 and then cyclical factors account for the subsequent weakness and then appreciation and depreciation through 1989. Supply side factors explain the appreciation of the mark from 1991 to 1994 while the appreciation from 1994 to 1995 is explained by a relatively strong cyclical position.

6.3 Cointegration-based PEER estimates

Clark and MacDonald (2000) propose pushing their BEER analysis further by constructing a permanent equilibrium exchange rate (PEER). In contrast to the PEER estimates discussed above, this approach explicitly takes account of potential cointegrating relationships amongst the relevant variables. The construction of the PEER relies on the moving average representation of (36). Johansen (1995) has demonstrated that this has the following form:

$$x_t = C \sum_{i=1}^{t} \epsilon_i + C\eta t + C(L)(\epsilon_t + \eta), \tag{41}$$

where

$$C = \beta_{\perp}(\alpha_{\perp}^{'}(I - \sum_{1}^{k-1} \Gamma_i)\beta_{\perp})^{-1}\alpha_{\perp}^{'}, \tag{42}$$

and where $\alpha_{\perp}$ and $\beta_{\perp}$ denote the orthogonal complements to α and β, respectively, and $\alpha_{\perp}$ determines the vectors defining the space of the common stochastic trends while $\beta_{\perp}$ gives the loadings associated with $\alpha_{\perp}$. If the vector x is of reduced rank, r, then Granger and Gonzalo (1995) have demonstrated that the elements of x can also be explained in terms of a smaller number of $(n - r)$ of $I(1)$ variables called common factors, f_t, plus some I(0) components, the transitory elements:

$$x_t = A_1 f_t + \tilde{x}_t \tag{43}$$

It is this decomposition which Clark and MacDonald use to construct the PEER. The identification of the common factors may be achieved in the following way. If it is assumed that the common factors, f_t, are linear combinations of the variables x_t:

$$f_t = B_1 x_t, \tag{44}$$

and if $A_1 f_t$ and $\tilde{x}_t$form a permanent-transitory decomposition of x_t then from the VECM representation (7) the only linear combination of x_t such that $\tilde{x}_t$ has no long-run impact on x_t are:

$$f_t = \alpha'_{\perp} x_t, \tag{45}$$

where $\alpha'_{\perp}\alpha = 0$. As Granger and Gonzalo point out, these are the linear combinations of Δx_t which have the 'common feature' of not containing the levels of the error correction term in them. This identification of the common factors enables Granger and Gonzalo to obtain the following permanent-transitory decomposition of x_t:

$$x_t = A_1 \alpha'_{\perp} x_t + A_2 \beta' x_t, \tag{46}$$

where, of terms not previously defined, $A_1 = \beta_{\perp}(\alpha'_{\perp}\beta_{\perp})^{-1}$ and $A_2 = \alpha(\beta'\alpha)^{-1}$.

Clark and MacDonald (2000) have used the Granger and Gonzalo decompostion to push the interpretation of a BEER further. In particular, they estimate BEERs and PEERs for the real effective exchange rates of the US dollar, the Canadian dollar and UK pound for the period 1960-1997. The model is simpler than that used in Clark and MacDonald (1999) since both the terms of trade and the risk premium are dropped from the analysis. For all three currencies evidence of one statistically significant cointegration vector is reported and this is therefore consistent with three common trends. For both the US and Canadian dollars a close association is found between the BEER and the PEER. For these currencies therefore the value added in using the PEER approach lies in its ability to detect the source of the common trends. The orthogonal decomposition of alpha and beta suggests that they are driven predominantly by the net foreign asset and Balassa-Samuleson terms. For the UK pound, however, the implied time path of the BEER and PEER are very different, as is seen in Figure 5. Note that the UK BEER is more volatile than the actual real exchange rate, particularly in the first half of the sample period, whereas the PEER is smoother than the BEER. An analysis of the permanent and transitory components of the other variables reveals that the source of the difference is that the actual real interest differential contains a substantial transitory element in the case of the UK (the correlation between the actual and transitory real interest rates for the UK is 0.8, while for the US it is only 0.06) and the PEER measure, by definition, filters this out of the data leaving only the permanent component. Clark and MacDonald (2000) therefore argue that supplementing the BEER approach with a PEER decomposition may be useful for assessment purposes, especially if the driving fundamentals contain important transitory elements.

Alberola *et al* (1999), estimate BEER type relationships (the cointegrating vector comprises the real exchange rate, net foreign assets and a Balassa-Samuelson term) for a variety of industrial country real effective exchange rates, using the Engle-Granger two-step method.

PEERs are then constructed to gauge the extent of currency misalgnments. For example, they estimate that the euro is undervalued by 4.5%, the dollar overvalued by 7.5% and the pound sterling is overvalued by 15.7% at the end of 1998. Bilateral estimates are then constructed and these show that the euro was undevalued against the dollar at end of 1998 by 7.5 per cent, and this had widened to an undervaluation of around 20 per cent by the end of 1999. Similarly, the dollar proved to be strongly overvalued against the yen, by 13.64%, and to a lesser extent against the Canadian dollar by 4.63%.

Hoffman and MacDonald (2000) present PEER estimates which are subject to both a cointegration constraint and to the additional constraints implied by a structural VAR. In particular, they consider a vector comprising a real income differential, the real effective exchange rate and the real interest differential (this choice being motivated by an extended Mundell-Fleming-Dornbusch model). Six country systems are considered (the US, Japan, Germany, France, Italy, the UK and Canada) and the estimation period is 1978, quarter 2 to 1997, quarter 4. In contrast to the studies considered in the last sub-section, permanent and transitory components are identified solely from the cointegration information in the data. Real and nominal shocks are then disentangled using the identification methods of Blanchard and Quah. In sum, Hoffman and MacDonald find that the majority of real exchange rate variation is explained by real shocks, although nominal shocks have an important role to play as well.

Using the Granger-Gonzalo decomposition Hoffman and MacDonald generate a permanent and transitory decomposition and they find that the bulk of exchange rate movements are permanent. For the US effective rate, practically all of the appreciation of the US dollar in the 1980s would seem to be permanent, and this contrasts with the findings of Clark and MacDonald (2000). Japan has the largest misalignment of the countries studied (being around 10 per cent of the permanent component) and all misalignments tend to be very persistent, with autocorrelations ranging between .6 (for Canada) to 0.96 (for Italy). Hoffman and MacDonald also explore the sources of the shocks and find that, on average, between one quarter and one third of the misalignment forecast error variance is due to nominal permanent shocks. The role of real shocks, however, tends to be more varied across countries. For example, in the cases of the US and France it accounts for almost two-thirds of misalignment variance, but plays little role for Germany and Canada.

7 The Internal-External Balance (IEB) Approach.

The internal-external balance (IEB) approach has perhaps been the most popular way of estimating an equilibrium exchange rate where deviations from PPP are explicitly recognised. In that sense it has some similarities with the BEER approach. However, the key difference is that it places more structure, in a normative sense, on the determination of the exchange rate. In particular, and in general terms, the equilibrium real exchange rate is defined as that rate which satisfies both internal and external balance. Internal balance is normally taken to be a level of output consistent with full employment and low inflation - the NAIRU - and the net savings generated at this output level have to be equal to the current balance, which need not necessarily equal zero in this approach. The general flavour of the IEB approach may be captured by the following equation:

$$S(W) - I(X) = CA(\hat{q}, Y) = -KA(Z), \tag{47}$$

where S denotes national savings, I denotes investment spending and W, X, Y and Z are a vectors of variables, to be discussed below, and $\hat{q}$ is the real exchange rate consistent with internal balance. All of the approaches discussed in this section use a variant of this relationship.

7.1 Fundamental Equilibrium Exchange Rates - FEERS

In the internal-external balance approach of Williamson (1983,1994) the equilibrium exchange rate is labeled a fundamental equilibrium exchange rate (FEER). This is an explicitly medium-run concept, in the sense that the FEER does not need to be consistent with stock-flow equilibrium (the medium-run is usually taken to be a period of about 5 years in the future), and in that sense is in the spirit of the balance of payments model presented in Section 2. The FEER approach has been refined and developed by Wren-Lewis (1992). The definition of internal balance used in this approach is as given above - high employment and low inflation. External balance is characterised as the sustainable desired net flow of resources between countries when they are in internal balance. This is usually arrived at judgementally, essentially by taking a position on the net savings term in (47) which, in turn, will be determined by factors such as consumption smoothing and demographic changes. The use of the latter assumption, especially, has meant that the FEER is often interpreted as a normative approach and the calculated FEER is likely to be sensitive to the choice of the sustainable capital account. It also means that the misalignment implied by the FEER is a total misalignment.

There are essentially two approaches to estimating a FEER. The first involves taking an estimated macroeconometric model, imposing internal and external balance, and solving for the real exchange rate which is the FEER. However, by far the most popular method of generating a FEER involves focussing on a current account equation such as (3) and setting it equal to a sustainable capital account (see Wren-Lewis (1992)). For example, consider again the current account relationship implied by our model in section 2 and set this equal to a sustainable capital account term:

$$\alpha_1(s_t + p_t^* - p_t) - \alpha_2 \bar{y}_t + \alpha_3 \bar{y}_t^* + \bar{i}_t^{'} a_t = \bar{cap}_t^{st} \tag{48}$$

where an overbar denotes that a variable has been calibrated at a desired, or sustainable, level and cap_t^{st} is the measure of the capital account.[10] It is important to note that Williamson's definition of the latter excludes speculative capital flows and focuses on structural capital flows, hence the superscript *st* on *cap*. As Wren-Lewis (1992) emphasises, this implies that the real interest rate has settled at its long-run equilibrium value in the medium-run. Clearly this is a strong assumption, since it places a constraint on monetary policy in the medium-run. Furthermore, Wren-Lewis (1992) notes that the FEER is a 'method of calculation of a real exchange rate which is consistent with medium term macroeconomic equilibrium.' That is to say the FEER approach does not embody a theory of exchange rate determination. Nonetheless, there is the implicit assumption that the actual real effective exchange rate will converge over time to the FEER. Hence embedded in this approach is a medium-run current account theory of exchange rate determination. That is, it is assumed that a divergence of the actual real rate from the FEER will set in motion forces that will eventually elliminate this divergence, but as the approach characterises only the equilibrium position, the nature of the adjustment forces is left unspecified.

[10] Barrell and Wren-Lewis (1989) demonstrate that in calculating the FEER it is very important to allow for revaluation effects through the $\bar{i}_t^{'} a_t$ term, especially if the Marshall-Lerner condition just holds.

In addition to the difficulty in measuring a sustainable capital account, the calculation of trade elasticities has often meant that an extra layer of judgement has to be imposed before the FEER can be calculated. This is because the estimated trade elasticity (or elasticities) (the α_1 in (48)) often turn out to be effectively zero (see Goldstein and Khan (1985)). Furthermore, what has been described by Driver (2000) as the 'achilles heel' of the FEER approach, is the hystersis introduced into the FEER due to interest payments on the net foreign asset term. Bayoumi et al (1994) consider this effect in some detail. To illustrate, assume that in the initial period the current exchange is at the FEER level and internal and external balance obtains. The actual real exchange rate then depreciates in the next period, thereby improving the current balance and improving the net foreign asset position. The latter, in turn, implies that in future periods the real exchange rate which is consistent with medium-run capital accumulation will no longer be the FEER; in particular, the FEER needs to appreciate to squeeze out the effects of the net asset accumulation. This hysterisis effect is a necessary consequence of viewing the exchange rate as a medium run concept. Taking a stock measure of equilibrium would of course rule out this kind of effect

Driver and Wren-Lewis (1999) assess the sensitivity of FEER calculations of the US dollar, Japanese yen and German mark to different formulations and assumptions. They find that two key factors impart a considerable amount of uncertainty into FEER type calculations. For example, changes in the assumed value of the sustainable capital account (as a proportion of GDP) of 1% can produce changes in the value of the FEER of around 5%. Since such changes in the capital account could easily be due to measurement error, this suggests caution in interpreting point estimates of the FEER. For example, in using a FEER to define the equilibrium rate with which to lock two currencies together, some sort of confidence interval should be applied to the point estimate (this uncertainty is one of the reasons why Williamson argues that crawling peg arrangements should feature wide exchange rate bands). Driver and Wren-Lewis also show that it is often difficult to produce well-defined estimates of the trade equations, and therefore the underlying trade elasticities, which are so central to the FEER. Inevitably this means that the FEER estimate will be sensitive to the chosen elasticity. Wren-Lewis, Westaway, Soteri and Barell (1991) estimated a FEER for the UK pound and demonstrated that the central parity rate at which the UK entered the ERM was overvalued. This finding contrasted sharply to an estimate based on PPP which showed the pound correctly valued on entry. Driver and Wren Lewis (1998) present estimates of the FEER for the G7 in the year 2000. They find, inter alia, that the FEER estimates for 2000 differ in important respects from the rates prevailing in early 1998 (at the time the study was written). In particular, they find that the US dollar was substantially overvalued, the yen grossly undervalued, while the pounds value was about correct against the dollar, although overvalued against European currencies.

7.2 The IMF Variant of the Internal-External Balance Approach

One of the key objectives of the recent IMF implementation of the IEB approach (see, for example, Isard and Faruqee (1998) and Faruqee, Isard and Masson (1999)) is to produce a more satisifactory measure of the desired capital account term. One important element in this approach is the recognition that the equilibrium current account can be viewed as the difference between desired saving and investment, $\bar{S}$ - $\bar{I}$, which, in turn, is equal to the sustainable capital account in (48). The equilibrium real exchange rate is then calculated as the real effective exchange rate that will generate a current account equal to $\bar{S}$ - $\bar{I}$. More specifically, the IMF works with the following variant of (47):

$$S(def, gap, dep, (y - y^*)) - I(gap, dep, (y - y^*)) = CA(q, gap, gapf) \tag{49}$$

where, of variables not previously defined, *def* is the government deficit, *gap* is the difference between actual and potential output and *gapf* is the difference between foreign and actual and potential output and *dep* is the dependency ratio. The IMFs IEB approach defines two measures of equilibrium. A medium-run current account equilibrium (a flow equilibrium rather than a stock equilibrium) is defined as a position where domestic and foreign output gaps are eliminated and the current exchange rate is expected to remain into the indefinite future. A longer run equilibrium is one in which the underlying current account position is compared with a stable ratio of NFA to GDP, where the latter is designed to measure stock equilibrium.

The mechanics of calculating the medium-run equilibrium exchange rate are as follows. First, dynamic savings and investment equations are estimated along with a dynamic current account equation. These equations are then solved for the long-run equilibrium and output gaps are set equal to zero and the fiscal deficit is cyclically adjusted. The resulting savings-investment gap is then compared with the estimated current account position and if there is a discrepancy the exchange rate is assumed to move to equilibriate the two relationships.

The latter exchange rate is interpreted as the medium-run equilibrium. For example, if the savings-investment relationship produces a surplus of 1 per cent of GDP, while the current account relationship suggests a defecit of -1 per cent of GDP, the exchange rate would have to depreciate in order to bring about an improvement of the current account of 2 per cent of GDP. One of the appealing components of this approach is that the required exchange rate changes required across countries are ensured to be internally consistent on a multilateral basis by an appropriate normalisation.

7.3 The Natural Real Exchange Rate - The NATREX

In the natural real exchange rate (NATREX) approach of Stein (1994,1999), Stein and Allen (1995) and Stein and Sauernheimer (1995) the starting point is again equation (47). As in the FEER approach, Stein excludes speculative capital flows from his measure of the capital account, and the sustainable capital account term is assumed equal to social saving less planned investment. The key determinant of social savings is the rate of time preference, tp, while the key determinant of investment is Tobin's 'q'. The latter in turn is determined by productivity, ω, and the real exchange rate:

$$S(tp, nfa) - I(\omega, q, k) = CA(q, k, nfa) \tag{50}$$

Aditionally, savings are assumed to be a function of net foreign assets and investment a function of the capital stock, k. The inclusion of stocks in the flow relationships enables an equilibrium to be derived which is stock-flow consistent. Stein (1999) proposes two forms of NATREX equilibrium. In 'long-run' equilibrium the following criteria have to be satisfied.

First, net foreign assets are constant and, in a non-growing economy, the current account is equal to zero. Second, the capital stock is constant and the rate of capacity utilisation is at its stationary mean. Real interest rate parity prevails, in the sense that real interest rates are equalised (since the real exchange rate is also in equilibrium, the expected change in the real exchange rate is zero). Finally, there are no changes in reserves or speculative capital movements. The difference between the medium and long-run NATREX relates to the evolution of net foreign assets and the capital stock. For example, in the medium-run the current account can be non-zero to the extent that ex ante savings minus ex ante investment is non-zero. Such imbalances get integrated into the stocks and these ultimately drive the system to a long-run equilibrium where intertemporal budget constraints are satisfied. In both the long- and medium-run equilibria, internal balance is assumed to hold.

Using a VECM model, Stein (1999) empirically implements the NATREX in a single equation context for the real US dollar effective exchange rate against the G7 for the post Bretton Woods period. Time preference is measured as the ratio of social (sum of public and private) consumption to GDP and the productivity of capital is measured as a four quarter moving average of the growth of real GDP. These are the two key explanatory variables that Stein uses to model the long-run real exchange rate. The long-run estimates (using the Johansen method) are:

$$q = -\underset{(88.93)}{404.97}\, tp_t + \underset{(202.87)}{1207.98}\, tp_t^* + \underset{(1.06)}{2.044}\, pr_t - \underset{(0.50)}{2.211}\, pr_t^*. \tag{51}$$

All of the variables are seen to be correctly signed in terms of the NATREX - an increase in US (G7) time preference depreciates (appreciates) the US dollar, while an increase in US (G7) productivity appreciates (depreciates) the US dollar. The implied equilibrium here is clearly a current equilibrium since none of the fundamentals are calibrated at desired levels. Furthemore, none of the stock levels, which are so crucial in defining the longer run NATREX, appear in (51). Stein also presents estimates of a medium-run equilibrium exchange rate in which an interest differential and the deviation of capacity utilisation from its mean are included in addition to the above variables.

8 Panel Dols Estimates of Some Simple Measures of the Equilibrium Exchange Rate.

For illustrative purposes, we present in this section some estimates of equilibrium exchange rates, based on BEER type approaches, for the DM-USD, UK pound-US dollar and DM-UK pound at the end of the first quarter 2000. In particular, we estimate equilibrium exchange rates using PPP, PPP plus Balassa Samuelson and CHEERS. A panel DOLS estimator of the following form is utilised (as advocated by Kao (1999) and Mark and Sul (1999)):

$$y_{it} = \alpha_i + \beta x_{it} + \sum_{j=-p}^{+p} \theta_{ij} \Delta x_{it+j} + \xi_{it}. \tag{52}$$

In sum, this estimator includes leads and lags of the right hand side variables in order to address issues of simultaneous equation bias and serial correlation. The inclusion of leads and lags thereby cleans the residual term. The estimation period is 1976 quarter 1 to 1999 quarter 2 and all data are collected from the IMFs IFS CD-ROM disc of March 2000. The equilibrium values for March 2000 are calculated using the estimated coefficients and updated

Tabelle 1: Panel DOLS Estimates and Implied Equilibrium Values.

	dm	*cab*	*yen*	$p-p^*$	*bal*	$i-i^*$	$DM-$ USD	CABLE	DM $-UK$
PPP	0.547	−0.417	4.868	1.616 (15.01)	–	–	1.74 (2.04)	0.74 (0.63)	2.34 (3.22)
PPP+ BAL	0.561	-0.394	4.845	1.568 (15.85)	−0.634 (4.29)	–	1.80 (2.04)	0.74 (0.63)	2.42 (3.22)
CHEERS	0.460	-0.353	4.718	1.478 (15.11)	–	−19.91 (7.34)	1.69 (2.04)	0.76 (0.63)	2.22 (3.22)

data from the Economist March 24, 2000.

Table 1 should be read in the following way. The mnemonics in the first column indicate the model, the columns labeled dm, cab and yen contain the fixed effects for the German mark, Pound sterling and Japanese yen, the next three columns contain the point estimates for the coefficients on the variables in the column heading (standard errors in parenthesis). Table 1b contains the implied equilibrium values from the three models with actual values prevailing on March 24 2000 in brackets. All of the models point in the same direction: the DM - US dollar rate is undervalued by around 17 per cent, the pound sterling is overvalued by 17% and the implied DM-UK cross rate suggests an undervaluation of the DM of around 30 per cent. These point estimates are not intended to be the final word on the misalignments of these currencies since a more fully fleshed out BEER type model may give a different, and perhaps more precise, point estimate (although Aberola et al produce a similar estimate of undervaluation of the DM-US dollar using a fully specified BEER model). However, we believe these estimates are, at least, suggestive of the direction of misalignment for these currencies at the time of writing.

9 Conclusions.

In this paper we have overviewed different ways of constructing an equilibrium exchange rate. We argued that purchasing power parity and atheoretical constructs are unlikely to be well-suited for this purpose. However, we have also argued that there are a variety of approaches which do provide well-defined measures of equilibrium. A strictly medium-run measure of the equilibrium exchange rate is provided by the capital enhanced extension of PPP. This approach has been demonstrated to produce mean-reversion speeds which are much faster than that produced by PPP on its own. The approach may also be extended in a straightforward fashion to incorporate other financial effects such as the yield gap and, say, stock market revaluations. More structured approaches to defining the medium-run equilibrium exchange rate are provided by the different variants of the internal-external balance approach. In this approach the key characteristic of the medium-run is that any current account imbalance must be sustainable. This approach also provides a measure of the long-run exchange rate which is usually defined as a position where net foreign assets are constant. One key feature of the internal-external balance approach is that it usually contains a substantial normative element, in terms of what is meant by sustainability and internal balance. The behavioural equilibrium approach seeks to provide a measure of the equilibrium exchange rate which is stock-flow consistent and which is independent of assumptions about sustainability. However, the approach can be used to provide a measure of equilibrium which does calibrate fundamentals at sustainable levels, although this is quite a seperate exercise. We have also argued that further insight into the nature of a behavioural equilibrium exchange rate may be gauged from a decomposition of the real exchange rate into its permament and transitory components.

10 References

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Figure 1A

US BEER

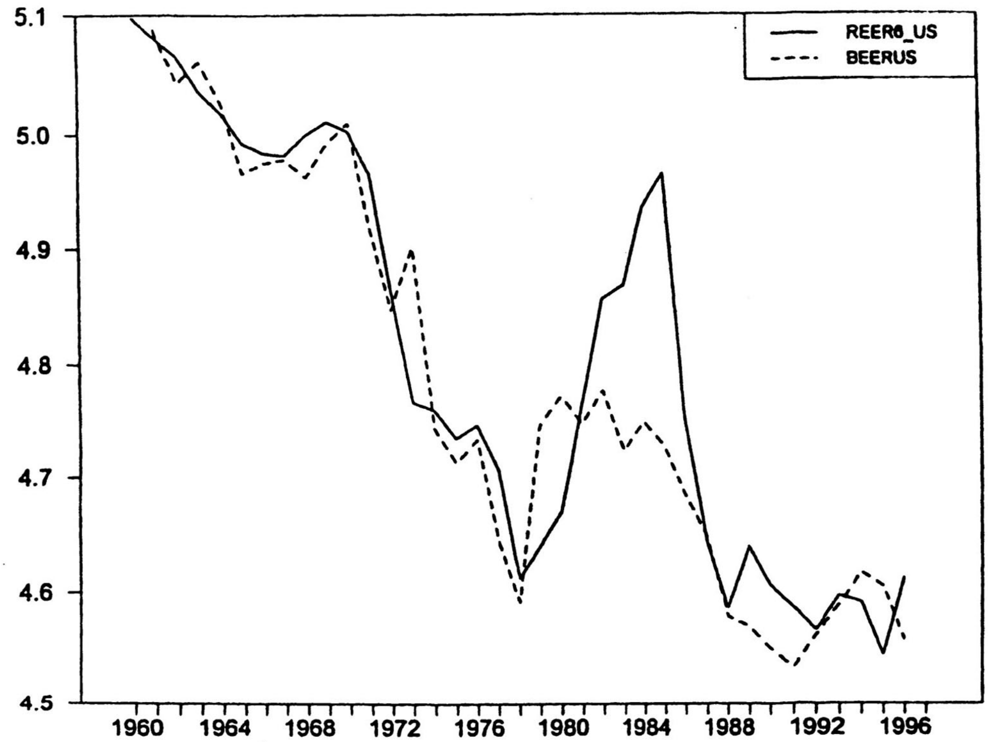
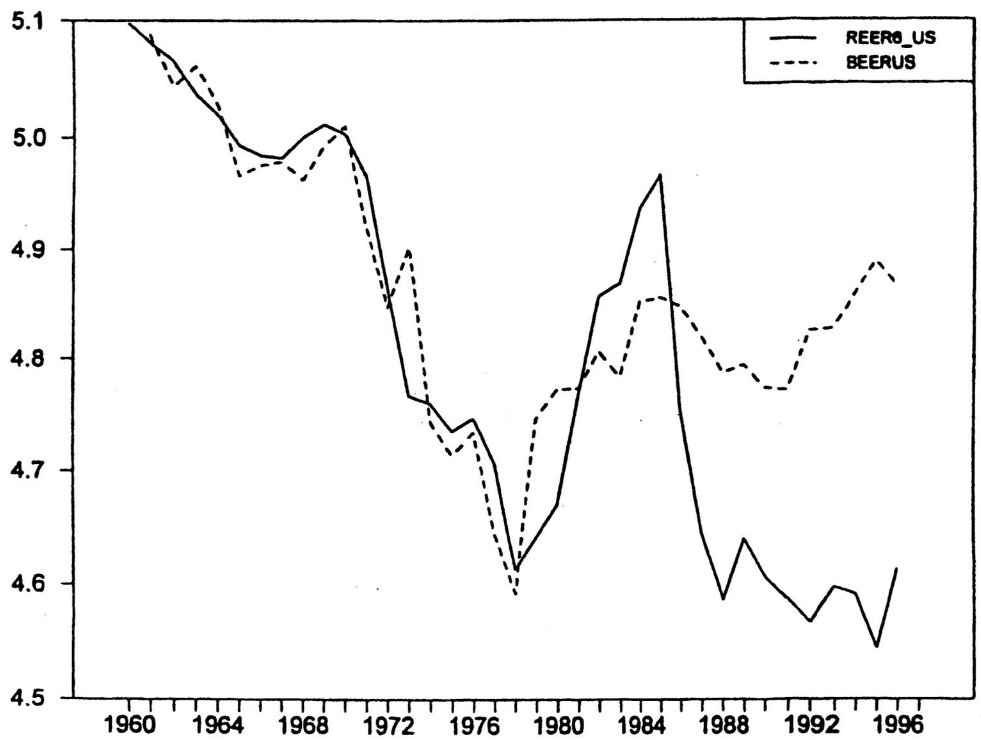


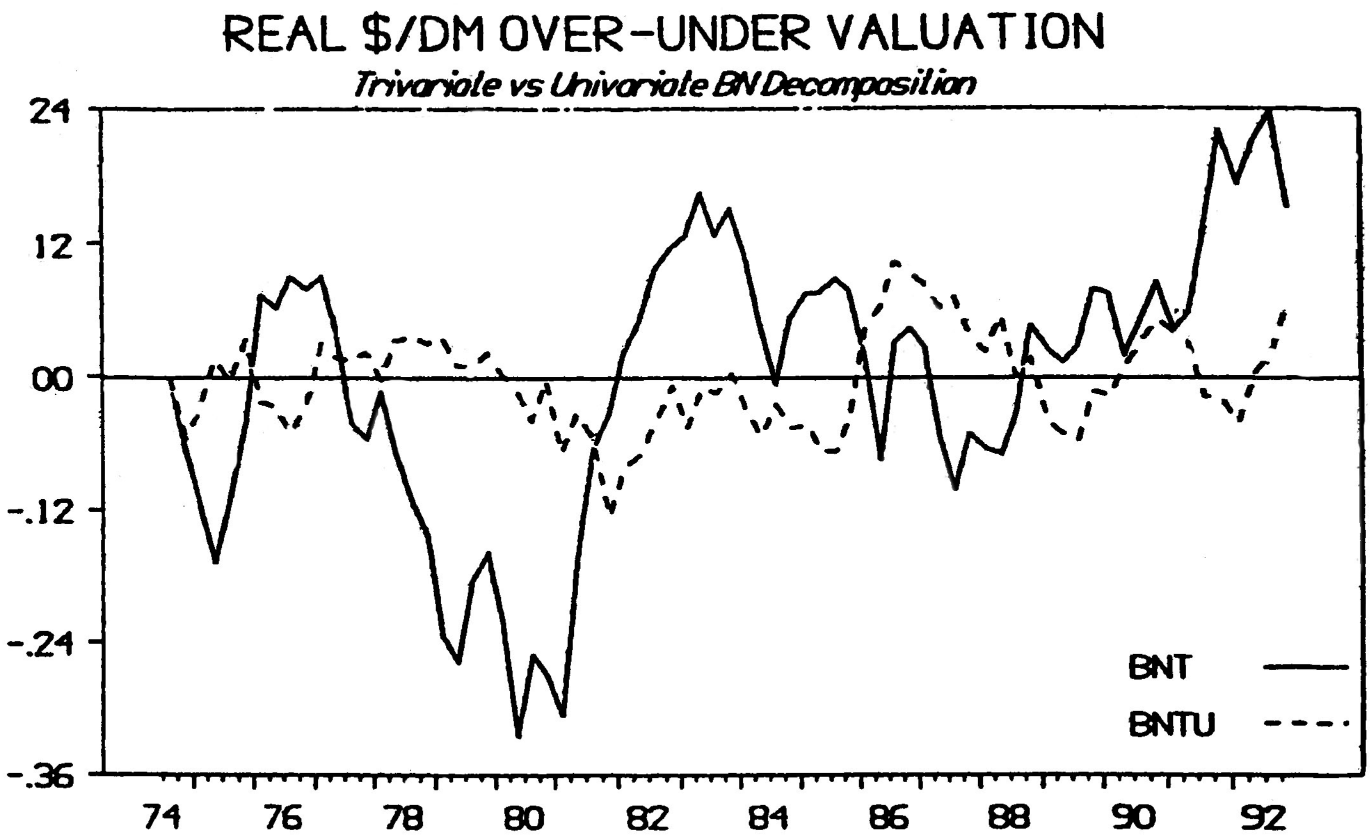
Figure 1B

US BEER, Counterfactual I, NFA at 1980 values (post 1980)



Source: Clark-MacDonald (2000)

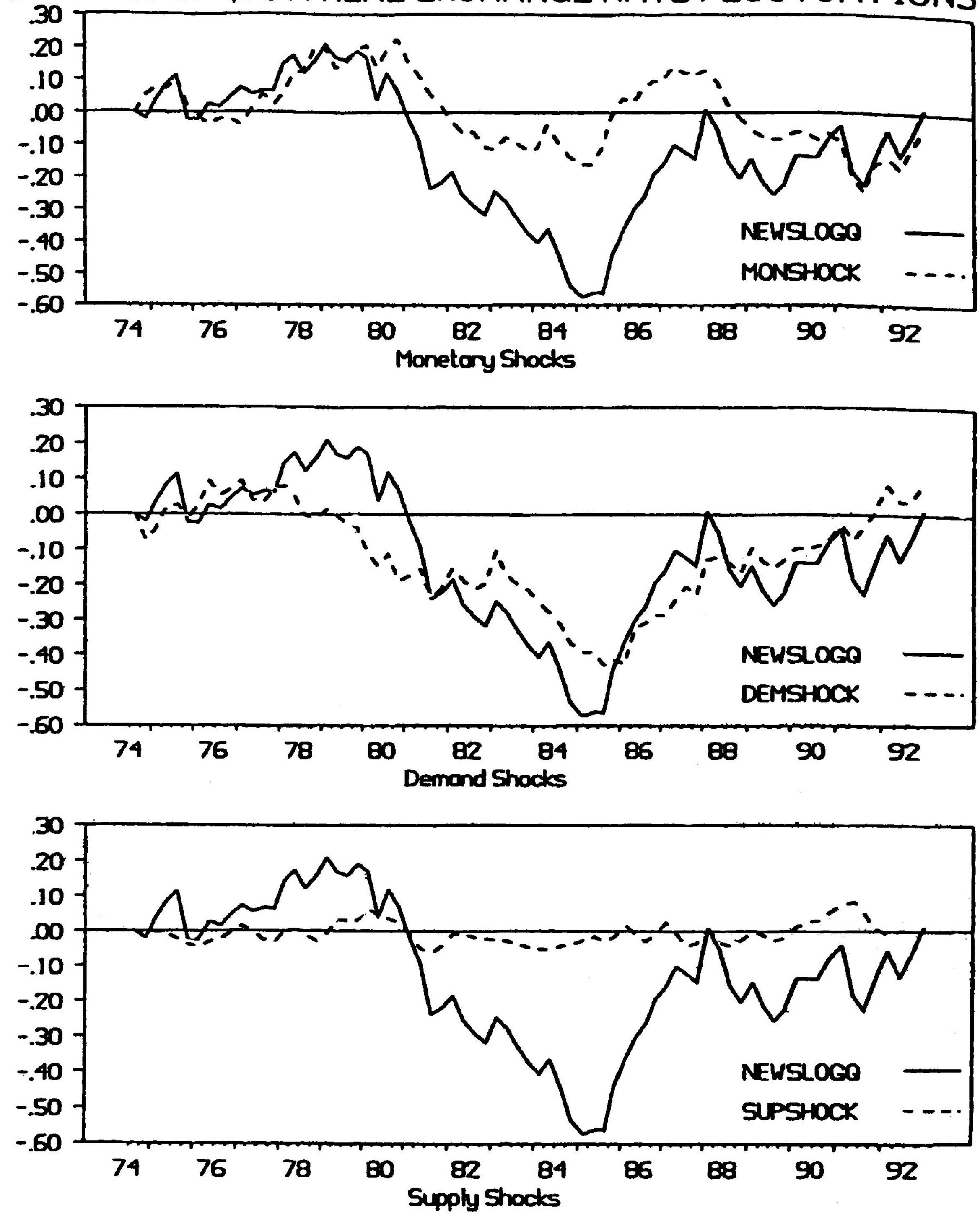
Figure 2



Source: Clarida-Gali (1994)

Figure 3

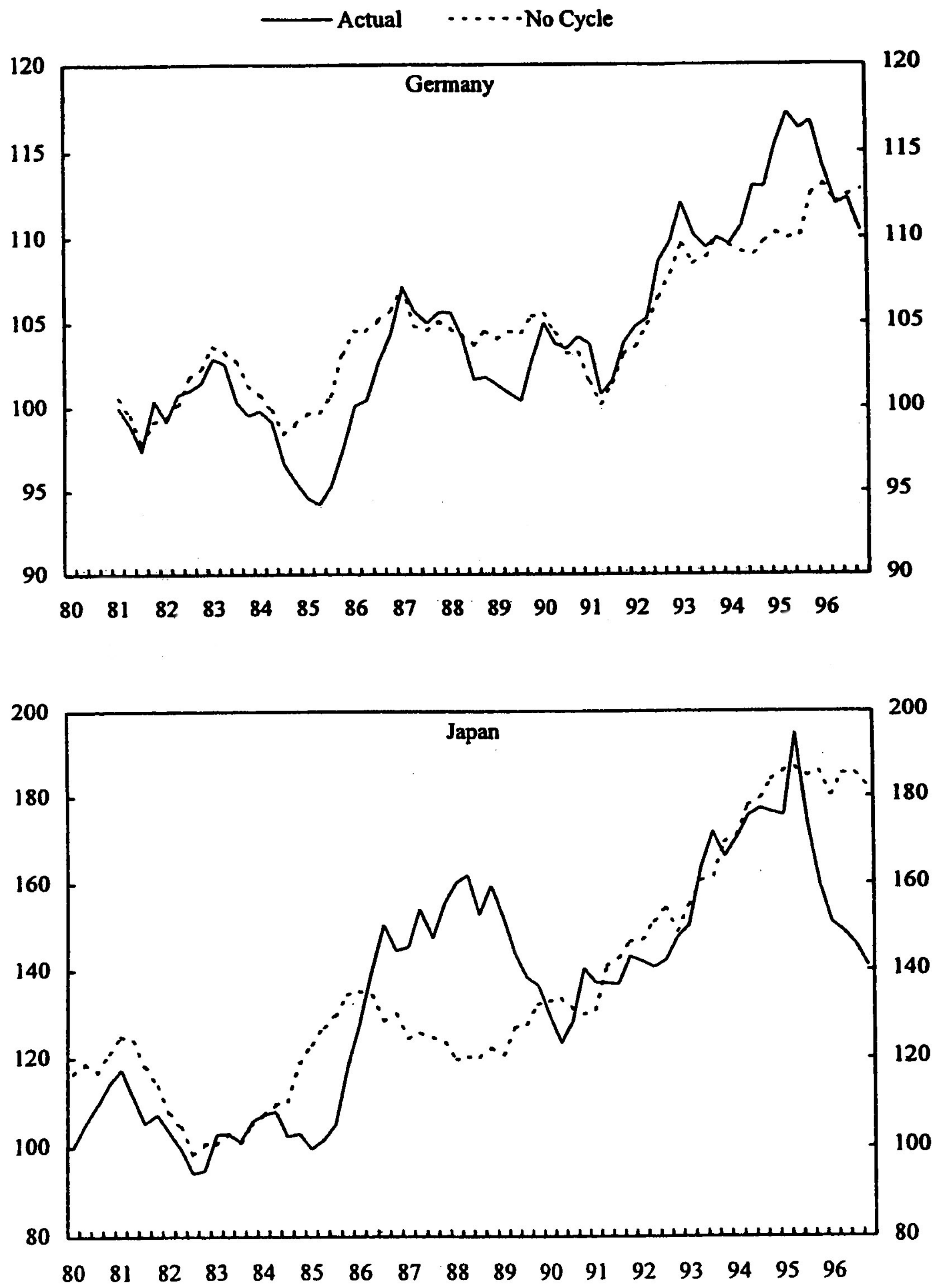
SOURCES OF $/DM REAL EXCHANGE RATE FLUCTUATIONS



Source: Clarida-Gali (1994)

Figure 4

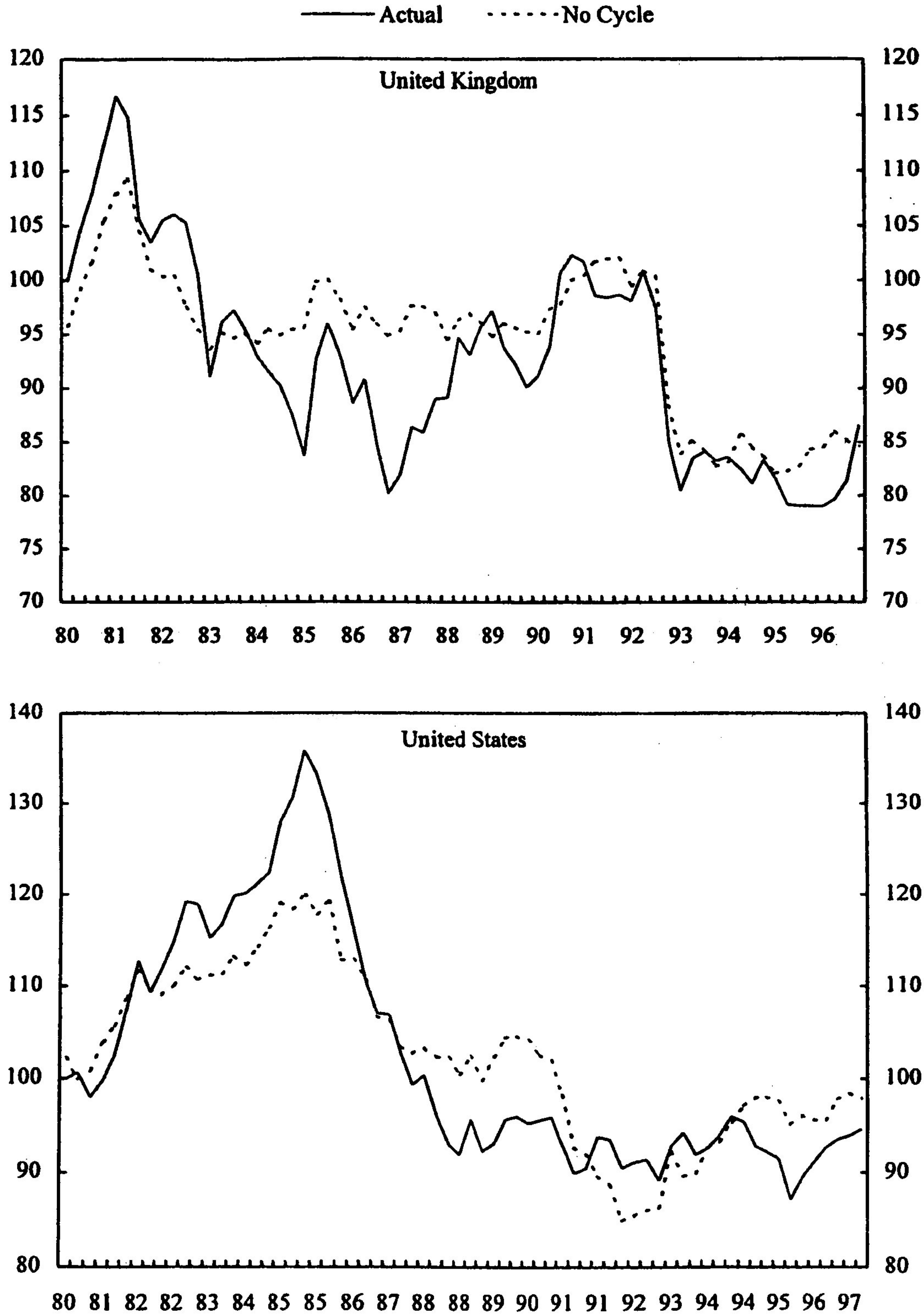
Real Effective Exchange Rate



Source: MacDonald-Swagel (2000)

Figure 4

Real Effective Exchange Rate



Source: MacDonald-Swagel (2000)

Figure 5A

UK BEER

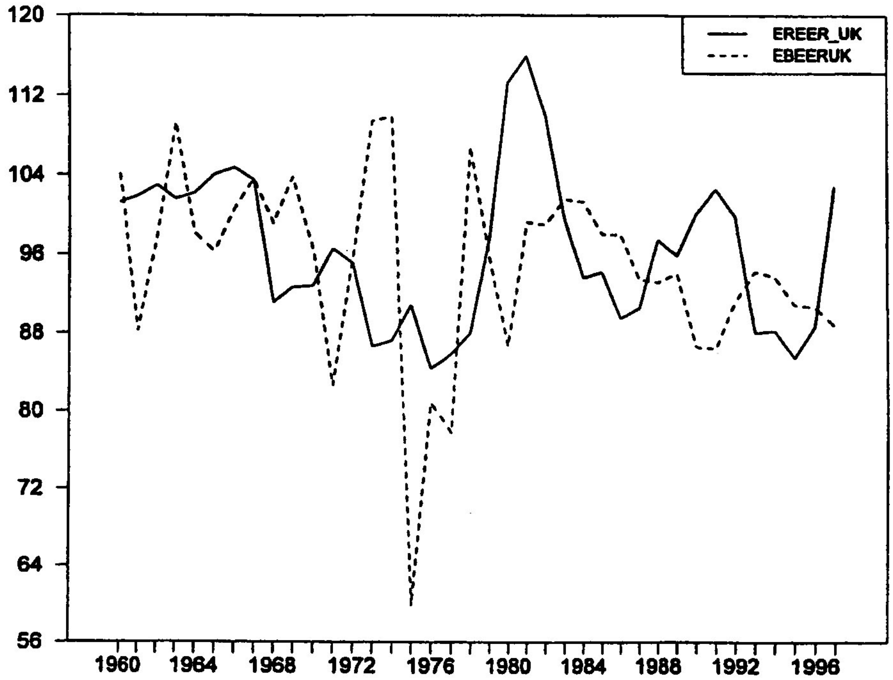
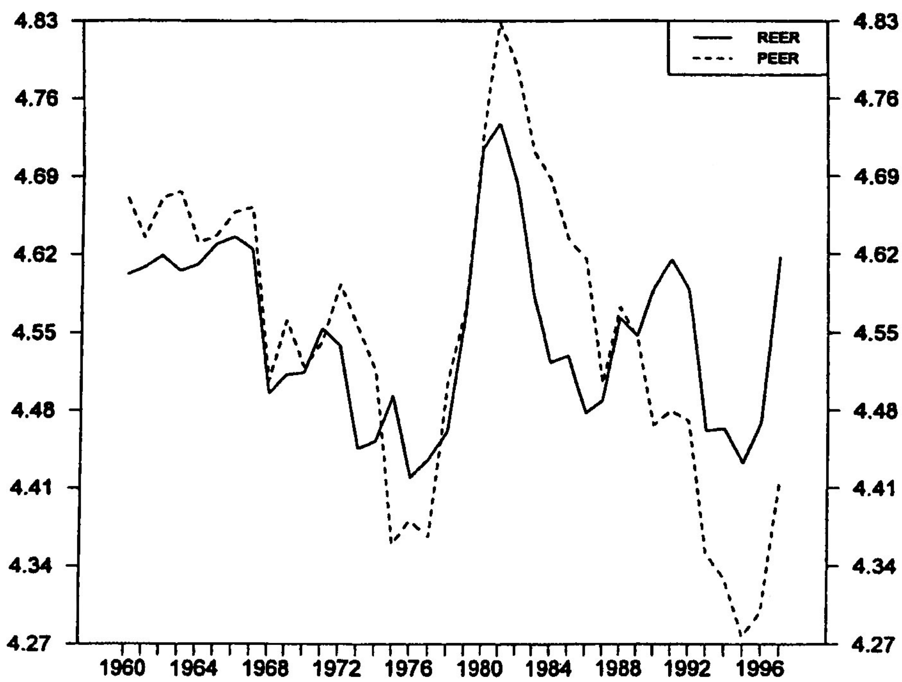


Figure 5B

United Kingdom # Permanent and Actual



Source: Clark-MacDonald (2000)

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