Concepts of equilibrium exchange rates

Rebecca L. Driver

and

Peter F. Westaway

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Bank of England, Threadneedle Street, London, EC2R 8AH, United Kingdom.

E-Mail: rebecca.driver@bankofengland.co.uk; peter.westaway@bankofengland.co.uk

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Contents

Abstract

This paper tackles the subject of what is meant by an equilibrium exchange rate. This is by no means an easy concept to pin down. We suggest that the equilibrium exchange rate will depend on the time horizon of interest. We discuss why purchasing power parity, the most common theoretical definition of an equilibrium real exchange rate, may be flawed. Finally we discuss the different strengths and weaknesses of alternative empirical measures of equilibrium exchange rates and try and provide a guide to the bewildering array of associated acronyms that has sprung up.

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Summary

1 Introduction

This paper sets out to examine the concept of equilibrium exchange rates. Empirical estimates of equilibrium exchange rates are frequently cited in policy-related discussions of the international conjuncture, not only by academics (see Williamson (1993) Wren-Lewis *et al* (1991)) but also by policy institutions. Such estimates are found to be useful for various closely related reasons:

- It is useful to know where current exchange rates stand relative to longer term measures of equilibrium, as these may provide some information on likely future movements in exchange rates. For example, it has been widely claimed that the considerable depreciation in the international value of the Euro following its launch caused it to become substantially undervalued relative to its equilibrium value. If this is true, it may be important to know by how much.
- In the context of fixed exchange rate arrangements, in particular monetary unions, it is important to know whether a particular entry rate will be costly to sustain or whether subsequent adjustment of relative inflation rates will be necessary to justify any nominal exchange rate peg. This requires information on the bilateral distribution of any given exchange rate misalignment.
- When interpreting the macroeconomic conjuncture, it is useful to know whether an observed change in the value of exchange rate is justified by perceived shocks to the macroeconomic environment. This information is important because the source of the shock is likely to have different implications for the outlook, especially so in open economies such as the UK where terms of trade effects can have important implications for inflation outcomes.

One of the purposes of this paper is to examine more carefully why concepts of equilibrium might be informative. To do this, the paper begins in section 2 by drawing a distinction between short, medium and long run concepts of equilibrium. All these types of equilibrium will be present in the system at any point in time and that there is no reason why they should be the same. We emphasise that what is important when it comes to choosing between them (and the models that have been used to represent them) is their relevance to the question in hand.

In section 3 we consider some of the practical issues that face researchers working on this topic, including which measures of the exchange rate are likely to be appropriate for different questions, different modelling strategies and some criteria which can be used to distinguish

between rival models.

In section 4 we describe some of the different methods researchers have used to attempt to capture different measures of equilibrium empirically. This work has spawned a bemusing array of acronyms to describe different measures of equilibrium. In describing these we provide a taxonomy of the different approaches, attempting to explain the differences and similarities between them. We start by discussing arbitrage based theories of the exchange rate including uncovered interest parity and purchasing power parity as well as the Balassa-Samuelson model. We then discuss various measures which have been used to try and understand short run movements in exchange rates. The next class of model we discuss are the underlying balance models, which represent a medium run notion of equilibrium whereby the economy is in internal and external balance. We also discuss different long run measures of equilibrium. Finally we consider models which aim to shed light on the impact of different shocks, but which do not explicitly allow for an equilibrium level of the exchange rate to be calculated.

Section 5 concludes by emphasising that equilibrium exchange rate measures can provide useful tools in helping to interpret the macroeconomic outlook. But we draw attention to the dangers of drawing over simplistic policy conclusions from the existence of some measure of misalignment.

2 What do we mean by equilibrium?

When thinking about the meaning of equilibrium it quickly becomes apparent that it is a difficult concept to pin down. This is clearly illustrated by the discussion in Milgate (1998) which charts the development of the concept of equilibrium within economics. The debate over what constitutes equilibrium has ranged over issues as diverse as its existence, uniqueness, optimality, determination, evolution over time and indeed whether it is even valid to talk about disequilibrium. All of these points are important, as is the question of whether the concept of equilibrium can be separated from the models which are used to measure it. Clearly in theory this is desirable, but in practice it may be much harder. As most models tend to have an equilibrium associated with them, then one question is how do you distinguish between these different equilibria? The work of von Neumann and Morgenstern (1944) would suggest that the solution to all models must enjoy equal analytical status. What is important therefore is their significance, which is determined by whether they are “similar to reality in

those respects which are essential in the investigation in hand" [von Neumann and Morgenstern (1944) p32].[1]

Equilibrium therefore means different things to different people and this is no less true in the context of exchange rates than it is for any other field in economics. This section therefore aims to discuss how different concepts of equilibrium can be useful for understanding the exchange rate literature. In particular we emphasise how the time scale under consideration will affect the concept of equilibrium, as it will influence the questions of interest and hence the significance of a given equilibrium.[2] We do not claim to have provided a new theory of equilibrium. Instead we are trying to apply some of the existing insights in the context of exchange rates.

2.1 What do we mean by an equilibrium exchange rate?

So far the discussion has been deliberately vague on the time horizon over which the equilibrium exchange rate might be achieved. At one level one might argue that since the exchange rate is determined continuously in foreign exchange markets by the supply and demand for currencies, the exchange rate will always be at its equilibrium value. This is clearly linked to what Williamson (1983) distinguishes as the market equilibrium exchange rate, which is the one which balances demand and supply of the currency in the absence of official intervention. However, in attempting to interpret movements in the real exchange rate it is necessary to go beyond this truism.

We find it informative to define three different types of equilibrium exchange rate which differ according to the time horizon to which they apply. We distinguish between:

- A short term equilibrium concept which is defined as the exchange rate which would pertains when its fundamental determinants are at their current settings after abstracting from the influence of random effects (for example from the effect of asset market bubbles). This is closely related to what Williamson (1983) calls the current equilibrium exchange rate which he argues will pertain if the market has full knowledge of the facts and reacts rationally. Of all the equilibrium concepts, this is perhaps the most difficult to define rigorously in economic terms but, as will be explained later, it clearly defines a particular empirical estimation approach.

[1] See the summary of this debate in Milgate (1998).
[2] This can be linked to the work of Marshall (1890), who distinguished between three periods: 'market', 'short' and 'long'. See the discussion in Milgate (1998).

- A medium-term equilibrium which is defined when the economy is at internal and external balance. There are therefore two parts to this equilibrium. The first is *internal balance*, which occurs when demand is at its supply potential and the economy is running at normal capacity. By construction, this equilibrium can be defined as the point reached when nominal inertia has washed out of system so any output gap is zero and unemployment is at its NAIRU. However, internal balance alone is not sufficient for this to be a valid equilibrium. Instead the rest of the world also needs to be at internal balance, which from the domestic point of view is equivalent to *external balance* being achieved. If all economies are at internal balance then by definition the fundamental determinants of the exchange rate (e.g. fiscal policy, productivity growth) are at their medium term setting. For example, once cyclical influences have been eliminated then fiscal policy can be thought of as structural.[3] However, this does not mean that all current accounts will be equal to zero, as there is no reason why in the medium term savings has to equal investment in every economy. As such, for medium term equilibrium, the current account of the balance of payments will be at a "sustainable" level in the sense that it will be consistent with eventual convergence to the stock-flow equilibrium. This is often what is used to mean *external balance*.[4] Importantly, since the real exchange rate is still converging towards its long run stock-flow equilibrium, domestic real interest rates will still be in the process of converging to world levels. This type of equilibrium will therefore be important in models with real rigidities, where the adjustment to steady state asset stocks takes time to achieve. The assumption that at this time horizon any nominal inertia will have been washed out of the system also implies that the medium term equilibrium can be thought of as a flexible price equilibrium. Finally it is worth noting that typically this horizon is taken to imply that the real exchange rate will be independent of monetary policy.[5]

- A long term equilibrium which is defined as the point when stock-flow equilibrium is achieved for all agents in the economy. This may take many years or decades to achieve. The medium-term equilibrium concept is conditioned on prevailing levels of national wealth (once cyclical effects and bubble effects have washed out). The long term equilibrium pertains when net wealth is in full stock-flow equilibrium, so that changes to asset stocks (as a percentage of GDP) are zero. The distinction between medium and long

[3] Importantly, simply because fiscal flows are structural does not say anything about whether they are either normal, or optimal.
[4] Arguably, this characterisation of external balance may be slightly confusing since the only true position of balance is that associated with the full stock-flow equilibrium.
[5] This would not be true if hysteresis effects are important. In addition, although the economy may naturally return to equilibrium, the period over which it does so may not be short enough from a welfare point of view, and so an activist policy may assist in restoring balance.

term equilibria therefore rests on at what point the influence of any real inertia has been eliminated.

2.2 Assessing exchange rate equilibrium

Having defined these different equilibrium exchange rate concepts, it is useful to show how they can be modelled using a relationship for the exchange rate which is specified in very general terms. No attempt has been made to specify the relevant fundamentals, so it is intended to encompass all the different approaches to be described. It has the advantage that it can also be used to clarify exchange rate misalignment, as different types of misalignment will have differing implications.

Drawing on the analysis of Clark and MacDonald (1997) the exchange rate can be characterised in terms of a dynamic reduced form relationship which relates it to a set of explanatory variables as follows:

$$e_t = \beta' Z_t + \theta' T_t + \varepsilon_t \quad (1)$$

where e_t is the exchange rate in time t, Z is a vector of economic fundamentals that are expected to influence the exchange rate in the medium to long term, T is a vector of transitory factors (including current and lagged variables as well as dynamic effects from the fundamentals, Z) which have an impact on exchange rate in the short term, ε_t is a random disturbance and β and θ are vectors of coefficients.[6] Within this framework therefore the choice of fundamentals will be determined by the theoretical framework, while the value of the fundamentals will be determined by the type of equilibrium of interest.

To illustrate this, it is possible to define the various equilibrium concepts described in the last section using this simple terminology. Hence, the closest model of the current equilibrium exchange rate would be given by:

$$e_t^{ST} = \beta' Z_t + \theta' T \quad (2)$$

i.e. a measure which abstracts from the influence of unexpected shocks. Of course this is the best forecast for the exchange rate at any point in time.[7]

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[6] One caveat with this approach is that it assumes that fundamentals are the key driving variables underlying movements in the exchange rate. In practice, particularly in the short run, this may not be true. Andersen *et al* (2003) and Faust *et al* (2003) both find that the news component of macroeconomic announcements has an impact on the exchange rate in the immediate aftermath (measured in minutes) of the announcement. However, these movements only represent a small fraction of daily exchange rate volatility, making the impact of the announcements harder to detect at longer frequencies.

[7] This assumes that the random disturbance is not subject to systematic pressures such as bubbles.

An alternative measure of short term equilibrium would simply take account of current levels of fundamentals and would abstract from transitory factors. This is given by:

$$\hat{e}_t^{ST} = \beta' Z_t \quad (3)$$

Similarly it is possible to define a measure of medium-term exchange rate equilibrium ($\hat{e}$):

$$\hat{e}_t = \beta' \hat{Z}_t \quad (4)$$

which is consistent with fundamentals being at their trend values, but where they may still be adjusting towards some longer run steady state. The difference between the equilibrium measures given by Equations 3 and 4 will therefore give an indication of the extent to which movements in the exchange rate from its medium term level are accounted for simply by the fact that the economy itself is away from equilibrium.

Finally, in the long run, when the economy has reached the "point from which there is no endogenous tendency to change" [Milgate (1998) p179], this equilibrium becomes:

$$\bar{e}_t = \beta' \bar{Z}_t \quad (5)$$

At any point in time all these different types of equilibrium will be present within the system.

Of course the next question is how useful (if at all) this information is for policy makers and in that sense several scenarios arise:

- Firstly consider the role of the random disturbance, which is what distinguishes e^{ST} from the actual exchange rate. If there is evidence that the behaviour of this random disturbance has changed then this might be an indication of the existence of a bubble, perhaps caused by misperceptions about fundamentals.[8] Many factors will determine the appropriate policy response to a speculative bubble in the exchange rate including, for example, how long the bubble is expected to last and on how quickly it will be reversed. For an extended discussion of the issues surrounding the appropriate policy response to asset price bubbles, see Bernanke and Gertler (1999) Cecchetti *et al* (2000). A decision to act or not, will not undermine the usefulness of that information.

- Next consider the transitory factors (which are given by the difference between e^{ST} and $\hat{e}^{ST}$). These essentially describe the dynamic path of the economy to past shocks both to

[8] Unless there is complete certainty that the method of obtaining estimates of ε completely captures the impact of the relevant fundamentals and the transition path generated by past shocks, this can only be an indication. In addition it assumes that any risk premium (see below) is defined as being dependent on fundamentals, rather than simply the unexplained part of any empirical estimate.

the exchange rate and to fundamentals. Estimates of this provide some information on the transmission mechanism.[9] Monetary policy will not be able to influence the medium and long run values of fundamentals, however, it may well be able to influence the transition path back to equilibrium.[10] In addition, when setting monetary policy it can be useful to understand the dynamic responses of the economy to shocks to different factors.

- Finally consider the information which is provided by a measure of equilibrium given by Equation 4. If fundamentals are not at their equilibrium levels (or in other words ($Z-\hat{Z}$) is not equal to zero) there is no reason why this exchange rate ($\hat{e}$) should be the observed rate.[11] Nonetheless information on this rate is still useful. Consider for example the situation where firms' pricing policy for either imports or exports is influenced by beliefs about whether observed changes in the exchange rate are temporary or permanent. Under these circumstances a medium or long run measure of equilibrium can be used to identify how an observed change in the exchange rate is likely to be passed through into import or export prices and hence on likely inflationary pressures.

In concluding this section, it is worth emphasising that, so far, the different equilibrium exchange rate concepts have been deliberately defined without referring to the array of acronyms that have been proposed in the economics literature or to the different empirical techniques that have been used to measure these equilibria. Such measures include FEERs, DEERs, BEERs, PEERs, NATREX, APEERs, ITMEERs and CHEERs. What is important for policy makers is to know how the different definitions of equilibrium are related to the myriad of different methods for calculating equilibrium exchange rates, as the policy implications and relevance for a given question of each of them may differ. These approaches will be defined and explained in Section 4. In terms of how they relate to theoretical framework we have suggested for modelling equilibrium exchange rates, the key distinctions will be in terms of whether any nominal and/or real rigidities have washed out.[12] In practice translating the taxonomy to given measures of equilibrium exchange rates can be difficult.

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[9] Naturally this difference is a partial estimate of the transmission mechanism, concentrating on the impact of the rest of the economy on the exchange rate. An alternative strategy for understanding the transmission mechanism would be to use a complete model to capture the feedbacks from the exchange rate to the economy. These type of feedbacks are available when the method used to calculate equilibrium is based on model simulations.

[10] The question of whether any misalignment of the exchange rate is appropriate or not therefore needs to be considered in the more general context of whether the monetary policy response itself is appropriate or optimal.

[11] The same is true for the difference between medium and long term values of fundamentals.

[12] In general there has been less theoretical work on equilibrium exchange rates, in part because of the attractions, not least in terms of analytical tractability, of assuming PPP (see below). A notable exception to this is Benigno and Thoenissen (2002).

3 Choosing an equilibrium exchange rate measure

The work of von Neumann and Morgenstern (1944) suggests that it is not possible to distinguish analytically between a set of models for which equilibrium exists. Instead they have to be distinguished according to their significance, which is judged relative to the question of interest. The aim of this section is to help set out some of the potential selection criteria. We start by discussing which definition of the exchange rate our concepts relate to and how different definitions may influence the question of interest. We then go on to discuss how the question of interest may influence the approach to equilibrium exchange rate.

3.1 How is the exchange rate defined?

So far we have been deliberately vague about which measure of the exchange rate we are referring to: whether it is nominal or real and if real which price deflator is used; or even if it is a bilateral or effective measure. Knowing which measure is used and why is important. For some people the obvious measure of the exchange rate to look at is a nominal bilateral exchange rate, as it is that which is determined directly in the financial markets. However, most of the theories of equilibrium exchange rates that we have refer to real effective (whole economy) measures of the exchange rate, albeit using different definitions of the relevant price index.[13] Associated with any given real exchange rate equilibrium are an infinite number of combinations of nominal exchange rates and relative price levels. If the equilibrium exchange rate is a real rate, then it will not matter for the economy what the corresponding level of the nominal exchange rate is.[14] The factor that will determine the level of the nominal exchange rate will be monetary policy at home and abroad.

Real exchange rates can be defined in a variety of ways depending on the question at hand. A general expression for the effective real exchange rate of country *i* (E_i) is given by:[15]

$$E_{it} = \prod_{j=1}^{n} \left(\frac{P_{it} S_{ijt}}{P_{jt}^{*}} \right)^{\varpi_{ij}} \tag{6}$$

[13] In practice, in the short run at least, real and nominal exchange rates tend to move very closely together.
[14] This point is often confused in discussion of the equilibrium value of particular exchange rates. For example, in choosing a particular bilateral exchange rate which sterling might lock into vis-à-vis the Euro upon entering EMU, it is too simplistic to argue, as is often done, that a particular nominal exchange rate is economically unsustainable. In principle, any initial value of the nominal exchange rate is sustainable so long as relative inflation rates can adjust so as to bring about a movement in the real exchange rate to its warranted equilibrium. Of course, that is not to deny that if the initially chosen rate is misaligned in real terms, this transition may be potentially costly in terms of lost output.
[15] In general effective exchange rate indices are calculated as a geometric rather than an arithmetic mean. This has the useful property that any calculation of percentage change will be independent of the base year chosen.

where P_i measures the domestic price level in country *i*; P^*_j the foreign price level in country *j*; S_{ij} is the relevant nominal exchange rate (defined as foreign currency per unit of domestic between countries *i* and *j*); and ϖ_{ij} is the weight of country j in country i's effective exchange rate index.[16] As such an increase in E_i implies that the currency has appreciated, or alternatively that it has become less competitive.

Although it can sometimes be useful to think about whether particular bilateral exchange rates represent an equilibrium, in general most concepts of equilibrium are likely to relate to the whole economy and hence effective rates. Of course this says nothing about how this effective rate should be measured: whether it should use simple trade shares as weights; allow for third party effects (the IMF's so-called MERM weights would do this); or whether weights should take into account the distribution of overseas investment holdings. It is possible to calculate measures of the associated bilaterals from a set of effective exchange rate measures using information about ϖ_{ij}, see Alberola *et al* (1999).

The domestic and foreign price levels themselves can be defined in a number of ways depending on which definition of the real exchange rate we are interested in. The choice of price index matters because real exchange rates defined using different price indices can move in very different ways, see for example Marsh and Tokarick (1994) and Chinn (2002), as well as the discussion in Begnino and Thoenissen (2002). The most commonly used definitions of the real exchange rate include measures based on:

- *Consumer price indices*. This will be appropriate if we are concerned with a comparison of price levels for goods bought by consumers in different countries.

- *The prices of tradable goods or output prices*. This will be used if we are concerned with the price competitiveness of goods exported by an economy.

- *The price of an economy's exports compared to the price of its imports*. This gives a measure of a country's terms of trade, or the relative purchasing power of domestic agents.

- *Relative unit labour costs*. This will be appropriate if we are focussing on the cost competitiveness of an economy.

[16] The sum of ϖ_{ij} will be unity by construction. If the real exchange rate of interest is a bilateral exchange rate there will only be one j.

- *The ratio of tradable to nontradable prices*. This is appropriate for assessing the real exchange rate within an economy.

Since these different price indices do not move together in the short run or even necessarily in the longer run, there is no unique measure of the real exchange rate on which it is appropriate to focus. In the rest of this paper, references will be made for the sake of simplicity to *the* real exchange rate. However, wherever the differences between these alternative measures are important, the distinction will be explained.

3.2 Modelling options

As Section 4 (below) makes clear, there is no single dominant approach to modelling equilibrium exchange rates. Different authors have used methods ranging from the purely statistical to the purely theoretical, with a myriad of options in between. The aim of this subsection is not to identify best practice, see Pagan (2003) for an excellent discussion of the strengths and weaknesses of different approaches along this spectrum in the context of forecasting inflation. Instead the section aims to provide a very brief review of some of the issues which face researchers choosing between "direct" estimation methods and "model simulation" approaches in the context of exchange rates. Of course it is possible to over-exaggerate the differences between them. In general both approaches share the simple principle that the real exchange rate can be characterised as one endogenous variable in a complete macroeconomic system. Where they differ is for example in the treatment of dynamics and the time frame they concentrate on. By and large, model based simulation approaches tend to have much stronger predictions for medium to long run equilibrium measures.

3.2.1 Model based approaches

One approach to capturing movements in equilibrium exchange rates is to use a model. How complicated the model needs to be will in turn be determined by the question of interest. It will also depend on whether the emphasis of the investigation is theoretical or empirical understanding. Krugman (2000) makes a strong case for sticking to relatively *ad hoc* models if the nature of the investigation is empirical because of their proven ability to fit key stylised facts.

What will be important will be how the model approaches the role of the real exchange rate

within the economy. Essentially real exchange rates are relative prices and therefore movements in real exchange rates help to shift resources in order to reconcile demand and supply. The emphasis on thinking about the real exchange rate as the relative price which reconciles supply and demand is given its most explicit formulation within the underlying balance models (see Section 4.3 below). However, this type of mechanism is implicit within any macromodel. Section 3.1 discussed the fact that there are a large number of definitions of the real exchange rate and that it is perfectly possible for these exchange rate measures to be moving in different ways over time. As such relative movements in these different measures will shift resources between sectors as well as economies. Which of the measures is seen as being most important will depend on beliefs about the key adjustment mechanisms. For example in Obstfeld and Rogoff (1995), real exchange rates measured using consumer prices remain constant, but the terms of trade shift in response to shocks because countries produce different goods.

In a closed economy, where the net trade component is absent, real interest rates move to equilibrate savings and investment in the face of shocks (for example to consumer preferences, productivity or to government spending). In a small open economy real interest rates are pinned down by the world real interest rate via uncovered interest parity (UIP), see section 4.1 (below).[17] Therefore shocks to domestic demand will no longer be offset by endogenous responses in real interest rates.[18] Since net trade is affected by the real exchange rate, shocks to domestic demand (or to the other variables affecting net trade, say world output) must be reconciled with aggregate supply by endogenous movements in the real exchange rate itself. If trade elasticities are infinite, then very small changes in real exchange rates will trigger infinitely large changes in net trade. Under those circumstances therefore the real exchange rate will need to do very little work to reconcile aggregate supply and demand, so that in the long run at least the real exchange rate will be constant. In general, however, empirical estimates of trade elasticities suggest that these tend to be far from infinite, suggesting that movements in the real exchange rate will play an important role in enabling economies to adjust towards macroeconomic equilibrium whereby demand and supply are reconciled.[19]

[17] Although UIP appears to embody quite a specific assumption about how exchange rates evolve, it is actually consistent with a wide range of models if we are prepared to interpret the expectations formation mechanism in a number of ways and if we interpret the risk-premium sufficiently flexibly. For example, the UIP condition can be interpreted as a limiting case of a portfolio balance model.

[18] Of course world real interest rates will move to equilibrate the demand for savings and investment in the world as a whole.

[19] MacDonald and Marsh (1997) also raise this point. See Goldstein and Khan (1985) and Hooper and Marquez (1995) for surveys of the empirical literature on trade elasticities.

There are many reasons why equilibrium exchange rates may vary over time and why the short, medium and long run equilibrium for exchange rates may also differ. For example equilibrium exchange rates may vary because of differences in consumer preferences, the existence of differentiated products, imperfectly competitive markets and the existence of nontradables (see Section 4.1 below). These factors all call for a richer model of equilibrium and once some or all of them have been incorporated then the resulting equilibrium will also potentially depend on a variety of additional factors including: productivity differentials, both between economies and different sectors within a given economy; demographics; and fiscal policy. It is easy to see that the choice of model will dictate not only the size, but also potentially the sign of the impact of shocks.

3.2.2 Estimation based approaches

Direct estimation methods take an approach that involves estimating the reduced form model for exchange rates explicitly. In principle, such approaches should yield the same estimate of equilibrium as measures based on the same fundamental determinants that take a more structural approach. But in practice the theoretical underpinnings to direct estimation methods tend to be slightly more ad hoc. Accordingly, for example it is possible to use this type of approach to estimate equilibrium bilateral exchange rates directly. In addition the treatment of dynamics tends to be based on criteria such as goodness of fit rather than theoretical priors. This therefore makes many estimation based methods better suited to tasks such as forecasting.

The issue which dominates how equilibrium exchange rates are estimated is that of the data properties of the real exchange rate and whether it is stationary or nonstationary. If real exchange rates are stationary this implies that they revert to a constant value at least in the long run, which is equivalent to finding purchasing power parity, and in one sense the search for a measure of medium and long term equilibrium can end there.[20] Section 4.1 discusses some of the evidence for PPP. However, even if real exchange rates are stationary there is still the issue of how quickly this equilibrium is approached. For example, Murray and Papell (2002), find that the estimated half lives associated with deviations in the real exchange rate are within the 3-5 years suggested in Rogoff (1996) for the countries in their sample. However, Murray and Papell (2002) also find that, in the majority of cases, the upper bound of the confidence intervals are infinite, suggesting that the estimated half lives provide little information about the speed of mean reversion.

[20] Of course the finding that the real exchange rate is stationary may occur because the fundamentals it depends on are themselves stationary. However, as PPP is not a theory of exchange rate determination (it contains no information on how exchange rates and prices adjust) this is perfectly compatible with PPP.

In cases where this mean reversion is a medium or a long term phenomenon it might still be useful to investigate whether there are measures of equilibrium available which explain short term movements in the real exchange rate. One issue here is whether adjustment to this long run equilibrium will be a linear process. For example, Taylor *et al* (2001), find evidence to suggest the adjustment towards a stationary long run may be non-linear and that this may account for why unit root tests of the real exchange rate often find that the real exchange rate is nonstationary.

If, however, real exchange rates are nonstationary then any estimate of the equilibrium must take account of this property. In order to provide a meaningful measure of equilibrium, the results from the chosen methodology have to be able to explain movements in the real exchange rate. Essentially therefore the estimated equilibrium must also be nonstationary, but the difference between the equilibrium and the actual real exchange rate must itself be stationary. Some methodologies deal with this issue directly by using cointegration, which essentially estimates a stationary reduced form relationship between the real exchange rate and the variables which are thought to explain it.[21] The equilibrium exchange rate is then derived as the statistical long-run of the estimated relationship, for example by taking the predicted value from the relevant cointegrating vector.

3.3 Picking a model

At any point in time there will be a set of equilibrium exchange rates which will depend in part on the time frame of interest. Simply because the actual exchange rate is not at its long run equilibrium level does not mean that it is not in some sense in equilibrium. There may be many reasons why the actual exchange rate should differ from long run equilibrium in the short run, including the influence of both nominal and real inertia.

Deciding what type of equilibrium to model will depend on the question of interest. For example questions relating to the impact of the underlying structure of the economy will be best answered using a framework which incorporates these features. An estimate of equilibrium derived using univariate statistical methods, for example, will have little to say about the impact of changes in the trend rate of productivity growth. Univariate methods may though be helpful in deriving estimates of short run movements in exchange rates.

For a given question, identifying which of several competing models is the most appropriate will be based on several criteria, including the model's forecast performance; ability to match

[21] In cases where more structural models have been used, one test of their validity is whether the resulting estimates cointegrate with the real exchange rate. See Section 3.3, below.

key moments as well as co-movements between different variables; and whether it has a sensible long run path. This section aims to provide a very brief review of these criteria. Which of these criteria is seen as the most important will again depend on the question of interest.

3.3.1 Equilibrium exchange rates and the predictability of exchange rate movements

Probably the best known criteria for judging exchange rate models, in part because of the spectacular lack of success, is the out-of-sample forecast test. The argument runs that a good model of the exchange rate should be able to out predict a forecast of no change, because it embeds within it information on the economic fundamentals that affect exchange rates. However, Meese and Rogoff (1983) found that although traditional (monetary) models might fit well in-sample, their out-of-sample forecasting performance was extremely poor.[22] In short, it proved to be impossible to out forecast a random walk (or prediction of no change) when modelling the exchange rate.

The Meese and Rogoff (1983) finding has dominated the exchange rate literature ever since. See for example the discussion in Rogoff (2001). While exceptions have been found, in general these exceptions are not found to be particularly robust to changes in sample period or the currencies used. In general, however, it is thought that exchange rate models are better at predicting over longer horizons, see for example Mark (1995). Even using non-linear models it is often difficult to beat a random walk except at long horizons, see for example Kilian and Taylor (2003). One reason for this excess volatility (compared to other fundamentals) may be the existence of noise traders, see for example Jeanne and Rose (2002).[23] An important development in the exchange rate literature which we do not cover here is therefore the market microstructure literature which attempts to understand how trading behaviour influences exchange rates. Instead we confine ourselves to a discussion of the models linking macroeconomic fundamentals and exchange rates.

3.3.2 Evaluating co-movements

As well as (or indeed instead of) wanting an explicit forecast for the actual exchange rate, it is often hoped that models of equilibrium exchange rates will be able to throw some light on

[22] Cheung *et al* (2002), suggest that newer models such as behavioural equilibrium models may not do any better in this respect that their traditional alternatives. It is worth noting however that Cheung *et al* (2002) separate out the dynamics when they conduct these tests and these dynamics are often thought of as an integral part of BEERs. In other words they concentrate on a model of the type given by Equation 3, rather than Equation 2.
[23] Taylor and Allen (1992) and Cheung *et al* (2000) present evidence for the prevelance of different types of trading strategies employed in the FOREX market. While fundamentals are seen as important by some, they are by no means the dominant consideration.

what is actually happening in the economy. For example can the relative moves of variables such as the exchange rate, consumption, output and prices be explained by changes to productivity? For this type of analysis the crucial test of a model of equilibrium is: Does it capture the relationship of interest? This means that not only must the model include the key variables of interest but its predictions for their impact on each other must also make sense empirically. Models can therefore be judged on whether they predict sensible comovements in the variables of interest. See for example Finn (1999). What is important here will be the conditional as well as the unconditional comovements. If a particular type of shock occurs only infrequently then the comovements that it generates would not be expected to dominate the behaviour of the data in normal times. One way to extract information on the empirical impact of shocks is to use VAR analysis. See for example Kim (2001) as well as Section 4.5.1 below.

3.3.3 The issue of the long run

As noted above, models of exchange rates based on economic fundamentals often struggle to explain short run movements in exchange rates, although there is some indication that they may be better predictors at longer horizons. Clearly that is not good news if the aim of the exercise is to forecast exchange rate movements. However, not all models of exchange rate behaviour are intended to be used for forecasting. Instead many models, including for example underlying balance models, aim to capture medium to long run concepts of equilibrium whereby economic fundamentals themselves are also in equilibrium. As there will be many reasons why at any point in time an economy is away from equilibrium, judging this type of model based on their forecast performance is clearly undesirable. The question then is how best to judge their long run performance. Two issues come to mind here. The first is whether or not they actually explain long run trends in exchange rates and the second is whether the models on which the calculations are based embody a sensible long run solution.

One way to judge whether a given technique provides a good model of long run exchange rate behaviour is to think in terms of the consistency test proposed by Cheung and Chinn (1998). For the forecast or outcomes of the model to be consistent they must firstly have the same statistical properties as the actual exchange rate series being modelled. If the actual exchange rate is nonstationary, then the predicted equilibrium must also be nonstationary, otherwise it will be unable to capture its movements. Secondly the actual and the model outcomes must combine to produce a stationary residual, so that the difference between the two series cannot increase without bounds (as would be the case if the residual were nonstationary). In other words the

predicted exchange rate series must acts as an attractor for the actual series. Finally the coefficients on the two series that combine to give this stationary residual must be unitary, so that if the predicted equilibrium moves the actual exchange rate will also move one-for-one (on average). This is essentially what Barisone *et al* (2003) do in their test of the validity of the FEER model.

The second criteria is whether the model embodies a sensible long run. In the very long run it is usually assumed that all variables within the economy, including asset stocks, will reach their steady state growth path. This can be thought of as full stock-flow equilibrium.[24] If a given model does not have a stock equilibrium embedded in it, shocks will act to move the long run equilibrium. This means that calculations of equilibrium will be subject to a starting point problem, whereby current conditions determine the eventual equilibrium, rather than equilibrium being given by the equilibrium outturns of economic fundamentals.

On this final point is that it is worth noting that just because DSGE models are theoretically more rigorous than many macroeconometric models, does not mean that they cannot suffer from an undefined long run. This is particularly true of many small open economy models, where steady state net foreign assets are often undefined. As a result temporary shocks will shift the steady state through their affect on wealth. Since log-linear approximations are taken around the initial steady state within DSGE models these approximations will become arbitrarily bad over time. One question is always whether the approximation errors are small enough to ignore for the experiments of interest. The problem of tying down the steady state level of net foreign assets can be addressed in a number of ways, see Schmitt-Grohe and Uribe (2003).

As was stated at the beginning of this section, the aim here has not been to provide a model of the exchange rate (equilibrium or otherwise). Instead it has been to provide a general framework which can be used to think about the assumptions that are implicit within both empirical and theoretical work on equilibrium exchange rates. The relevance of individual assumption may well depend on exactly how equilibrium has been defined. The next section therefore discusses different approaches to measuring equilibrium exchange rates and how these relate to each other.

[24] As the underlying balance models make clear, it is generally thought that flow equilibrium will be reached before stock equilibrium because of the slow speed of adjustment for capital.

4 Estimating equilibrium exchange rates

There is, sadly, no completely comprehensive and logical mapping from one equilibrium exchange rate methodology to another. However, the remaining subsections discuss some of the more popular methods of estimating equilibrium exchange rates. The list includes BEERs, PEERs, CHEERs, ITMEERs, APEERs, FEERs, DEERs, and NATREX. We also touch on how the Balassa-Samuelson hypothesis and monetary models are linked to equilibrium exchange rates. The list we consider is undoubtedly not exhaustive, as new methods and acronyms are being invented all the time.[25] However, it seems to be enough to be getting on with. Having set out what we mean by different concepts of equilibrium in Section 2, we also attempt to place the different methodologies used to estimate equilibrium exchange rates (of which there are many) within this framework. Needless to say the mapping between the different time frames is often far from perfect. However, in general the monetary models, BEERs, ITMEERs and CHEERs are most closely related to short run equilibrium concepts; FEERs and DEERs are all interested in medium run equilibrium; while APEERs, PEERs, NATREX models aim to capture some concept of long run equilibrium. Alternative methodologies such as SVARs and DSGE models do not provide any information on the level of the real exchange rate but can provide helpful information on the likely response of the exchange rates in the face of shocks and also on their short, medium and long run response. Table 1 provides an overview of these different methods.

This section starts with a discussion of the arbitrage conditions that theory suggests should influence exchange rates. Uncovered interest parity (UIP) provides part of the theoretical underpinnings for several of the exchange rate models discussed, as well as representing an arbitrage condition. The literature on UIP is therefore briefly reviewed as background. PPP is importance in part because it has very strong predictions about the behaviour of exchange rates in the long run, namely that the real exchange rate is constant. The subsection also deals with the related concept, Balassa-Samuelson, which assumes that PPP holds for part of the economy (the tradables sector), but not for nontradables. The evidence in favour of these arbitrage based explanations of movements in the real exchange rate are at best mixed. If they are not good measures of exchange rate equilibrium, then alternatives need to be found. In order to do this, it is important to consider the role of the real exchange rate within the economy, as this will help provide insights on what factors measures of equilibrium exchange rates might need consider.

The next subsection looks at various models of short run exchange rate behaviour: monetary models, CHEERs, BEERs and ITMEERs. Monetary models of the exchange rate are based on the assumption of PPP holding (at least in the long run). Information on relative money demand

[25] In addition we make no attempt to compare the estimates of equilibrium that are given by the different methodologies. See Koen *et al* (2001) for a comparison of estimates for the euro. Detken *et al* (2002) compare estimates from four different approaches to calculating equilibrium.

is then combined with this assumption to help model movements in nominal exchange rates. CHEERS start with the assumption of PPP, but assume that this is relevant mainly in the long run and therefore supplement PPP with a relationship based on UIP to capture shorter term movements in the real exchange rate. BEERs and ITMEERs also aim to calculate short run equilibria, with ITMEERs aiming explicitly to provide a forecast (and hence to estimate e^{ST}). In each case the starting point is similar to that of CHEERs, but is supplemented with risk premia considerations as well as factors which could cause the long run exchange rate to vary over time.

The next subsection deals with two medium run definitions of how to calculate real exchange rate equilibrium, given by FEERs and DEERs. Essentially these are both underlying balance models whereby the equilibrium is defined as the level of the real exchange rate that is compatible with internal and external balance, but where asset stocks may still be changing over time.

The next subsection deals with long run definitions of equilibrium which unlike PPP allow the long run equilibrium to move over time. The first of these, APEERs, aims to capture permanent changes in the real exchange rate using purely statistical techniques. It is one of only two equilibrium exchange rate measures (the other being PPP) which only uses information on real exchange rates as part of the calculation. The equilibrium calculated using APEERs therefore does not react to changes in other variables. PEERs extend the BEER approach to use statistical methods to capture permanent movements in equilibrium exchange rates. Finally the NATREX models aim to capture long run exchange rate movements, where equilibrium is tied down using the assumption that asset stocks will be constant.

The final subsection looks at two approaches which examine the impact of shocks on the exchange rate, but which do not explicitly provide a level of the equilibrium exchange rate (at least in the medium to long run). The SVAR approach provides information on both the path of the exchange rate and its responsiveness to different shocks. The DSGE approach to modelling exchange rates is essentially the theoretical analogue of the SVAR approaches as it provides one mechanism for identifying which shocks are important. For this reason DSGE models are also briefly discussed.

Table 1: Summary of Empirical Approaches to Estimating Equilibrium Exchange Rates

	UIP	PPP	Balassa-Samuelson	Monetary Models	CHEERs	ITMEERs	BEERs	FEERs	DEERs	APEERs	PEERs	NATREX	SVARs	DSGE
Name	Uncovered Interest Parity	Purchasing Power Parity	Balassa-Samuelson	Monetary and Portfolio balance models	Capital Enhanced Equilibrium Exchange Rates	Intermediate Term Model Based Equilibrium Exchange Rates	Behavioural Equilibrium Exchange Rates	Fundamental Equilibrium Exchange Rates	Desired Equilibrium Exchange Rates	Atheoretical Permanent Equilibrium Exchange Rates	Permanent Equilibrium Exchange Rates	Natural Real Exchange Rates	Structural Vector Auto Regression	Dynamic Stochastic General Equilibrium models
Theoretical Assumptions	The expected change in the exchange rate determined by interest differentials	Constant Equilibrium Exchange Rate	PPP for tradable goods. Productivity differentials between traded and nontraded goods	PPP in long run (or short run) plus demand for money.	PPP plus nominal UIP without risk premia	Nominal UIP including a risk premia plus expected future movements in real exchange rates determined by fundamentals	Real UIP with a risk premia and/or expected future movements in real exchange rates determined by fundamentals	Real exchange rate compatible with both internal and external balance. Flow not full stock equilibrium	As with FEERs, but the definition of external balance based on *optimal* policy	None	As BEERs	As with FEERs, but with the assumption of portfolio balance (so domestic real interest rate is equal to the world rate).	Real exchange rate affected by supply and demand (but not nominal) shocks in the long run	Models designed to explore movements in real and/or nominal exchange rates in response to shocks.
Relevant Time Horizon	Short run	Long run	Long run	Short run	Short run (forecast)	Short run (forecast)	Short run (also forecast)	Medium run	Medium Run	Medium / Long run	Medium / Long run	Long run	Short (and long) run	Short and long run
Statistical Assumptions	Stationarity (of change)	Stationary	Non-stationary	Non-stationary	Stationary, with emphasis on speed of convergence	None	Non-stationary	Non-stationary	Non-stationary	Non-stationary (extract permanent component)	Non-stationary (extract permanent component)	Non-stationary	As with theoretical	As with theoretical
Dependent Variable	Expected change in the real or nominal	Real or nominal	Real	Nominal	Nominal	Future change in the Nominal	Real	Real Effective	Real Effective	Real	Real	Real	Change in the Real	Change relative to long run steady state
Estimation Method	Direct	Test for stationarity	Direct	Direct	Direct	Direct	Direct	Underlying Balance	Underlying Balance	Direct	Direct	Direct	Direct	Simulation

4.1 The real exchange rate and the role of arbitrage

There are two main arbitrage conditions which dominate any discussion of exchange rates: uncovered interest parity (UIP) and purchasing power parity (PPP). The aim of this subsection is to discuss some of the main issues surrounding these two conditions. The background for the Balassa-Samuelson hypothesis is also discussed. The Balassa-Samuelson model assumes that the forces of arbitrage which underlie PPP will only affect traded goods and therefore that productivity differentials between traded and nontraded goods sectors will influence real exchange rates defined using the consumer price index (which therefore also incorporate nontraded goods).

4.1.1 Uncovered Interest Parity

A common place to start when considering movements in the exchange rate are arbitrage conditions, and in particular those given by the risk-adjusted uncovered interest rate parity (UIP) condition. This condition equalises the *ex ante* risk-adjusted nominal rate of return on domestic and foreign currency assets. As such the expected change in the nominal exchange rate is determined by the interest rate differential and any risk premium so that:

$$s_t = E_t s_{t+1} + i_t - i_t^* + \sigma_t \qquad (7)$$

where s_t is the (logged) nominal exchange rate at time t, i and i* the nominal interest rates on one period bonds at home and abroad, σ the foreign currency risk premium (which is potentially time-varying) and E_t is the expectations operator denoting the expectation of a variable taken at time t.

Since here we are more interested in the real exchange rate, it is straightforward to re-express this simple UIP condition in real terms (by subtracting the expected inflation differential from both sides of the equation) so that:

$$e_t = E_t e_{t+1} + r_t - r_t^* + \sigma_t \qquad (8)$$

where e is the real exchange rate, and r and r* are the respective domestic and foreign *ex ante* real interest rates. This expression thus equalises the ex ante risk-adjusted real rate of return on domestic and foreign currency assets. An alternative way of expressing Equation 8 would be to use forward substitution to replace successive values of the expected exchange rate so that: [26]

[26] This UIP decomposition is explained in greater detail in the context of the nominal exchange rate in Brigden *et al* (1997).

$$e_t = \sum_{j=0}^{n-1} E_t \delta_{t+j} + \sum_{j=0}^{n-1} E_t \sigma_{t+j} + E_t e_{t+n} \qquad (9)$$

where $\delta_t = (r_t - r_t^*)$.

Perhaps the most important point to note in the context of this paper is that the UIP arbitrage condition is only informative in explaining the adjustment path of the exchange rate back to its equilibrium. To put more simply, the UIP condition does not tie down the *level* of the real exchange rate, only the rate of change. The level of the real exchange rate today will jump to adjust for changes in expected real interest rate differentials, risk premia and the expected future level of the real exchange rate. In the longer term therefore the *level* of the real exchange rate must be determined by other factors. At first glance, this finding would appear to be at odds with the widely believed view that nominal exchange rates are primarily determined in the world's foreign exchange markets, where massive speculative capital flows swamp the flows associated with trade transactions. In fact, none of the above explanation is inconsistent with that view, indeed speculative transactions on the foreign exchange markets may well have an important role in the short term. However, we must look elsewhere for an explanation of the equilibrium real exchange rate itself.[27]

One of the problems with validating the existence of UIP itself is that in general expectations about the future value of exchange rates are unavailable and certainly are not measured with sufficient accuracy to be matched to real time interest rate differentials. In addition risk premia are unobservable. Most tests of UIP have concentrated on trying to establish whether *ex post* changes in exchange rates can be explained by interest rate differentials. In general the results from this type of exercise have had very limited success, as the interest rate differential is often found to be incorrectly signed. See for example the survey in Lewis (1995).[28] One final thing worth noting that in empirical terms UIP by itself has not been very successful at predicting exchange rate movements. One reason for this empirical failing might, of course, be shifts in the expected long run, or equilibrium, exchange rate which are not usually taken account of in UIP estimates. McCallum (1994) suggests one reason for the apparent failure of UIP may be policy behaviour. Christensen (2000) finds that this explanation no longer appears to hold empirically when the policy reaction function is estimated directly.

[27] It is also important not to confuse UIP considerations with capital flows which are ultimately determined by the net balance of saving and investment flows within a country. See Niehans (1994) on this point.

[28] Naturally there are exception. Flood and Rose (2001) for example find that the interest rate differential is correctly signed over the 1990s, although the coefficients are often small and occasionally insignificant.

4.1.2 Why should the equilibrium exchange rate vary? - The role of PPP

The previous section discusses how one possible explanation for the failure to observe UIP might be shifts in the equilibrium exchange rate. However, another well known arbitrage condition, that of purchasing power parity (PPP) would suggest that in fact equilibrium exchange rates should be constant.

PPP is a natural starting point to begin any consideration of equilibrium real exchange rates, not least because of its enduring popularity. In its strictest form, PPP predicts that price levels in different countries will always be equalised when they are measured in a common currency. In other words that the real exchange rate is constant and equal to unity.[29] The theoretical rationale behind PPP is often given as arbitrage in markets for individual goods. For example, if similar goods are priced differently in different countries, then demand will switch to the cheaper good. If sufficient arbitrage exists, then the forces of supply and demand will equalise prices, so that the law of one price holds. At an economy wide level, deviations of the real exchange rate from PPP will lead to changes in supply and demand which will move the real exchange rate back to PPP. More generally, however, PPP may also hold as a result of the impact of changes in the competitiveness on the location of production. For example in the longer term differential labour costs will also have an impact on the desirability of different locations. There will tend to be a movement in production from the "overvalued" to the "undervalued" economy not as a result of consumer arbitrage, but because of arbitrage in capital.[30]

This section discusses the theoretical explanations for why PPP might not hold in practice.[31] The explanations fall into two parts. The first represent reasons which PPP may not hold, even if the Law of One Price (LOOP) is observed. The second set of explanations for why PPP may not hold are based on reasons why LOOP itself may not hold. Finally it goes on to discuss the empirical evidence for PPP.

Why PPP may not hold even if LOOP does

Although PPP is a distinct concept, it can be seen from above that it is closely linked to LOOP, whereby a process of international arbitrage causes the price of each and every good and service sold on international markets to be equalised. Of course if LOOP always holds, then PPP will also hold by definition provided (a) all goods and services are tradable, (b) the

[29] In practice most measures of the real exchange rate use price indices, rather than price levels, and therefore PPP will simply imply that the real exchange rate will be constant. In addition, most empirical tests of PPP only assume that the real exchange rate will be constant in the long run.
[30] This mechanism is likely to be long term rather than medium term in duration.

composition of goods bought by consumers in each country is identical, or in other words that consumer preferences are identical across countries, and (c) that countries produce the same goods. The trouble is that if any of these conditions are violated then even if LOOP holds, PPP may not, or at least not for all definitions of the real exchange rate.

(a) To start with consider a situation where *consumers' preferences in different countries differ*. This will influence the composition of their consumption basket and hence their consumer price index.[32] As inflation rates for different goods may differ, this implies that there may be trends in the real exchange rate.[33]

(b) Suppose instead consumer preferences are identical, but they also *include goods which are not traded internationally.* (The reasons why goods may be nontraded are discussed below.) LOOP only applies to traded goods and services. In principle, the existence of nontradables allows the exchange rate adjusted prices of goods sold in different countries to drift apart without any necessary tendency for the divergence to be corrected. Even so, under quite general assumptions, the existence of nontradables will not be sufficient to cause persistent real exchange rate divergences unless the relative price inflation of tradable to nontradable goods differs between countries. One way this can happen is via productivity differences between countries. The most widely cited example of this type of effect is the so called Balassa-Samuelson effect whereby countries with faster growing productivity in the tradable sector will have an appreciating real exchange rate (see Section 4.1.3 below).

(c) Finally, *if countries specialise in producing different goods* that can potentially cause the breakdown of PPP even when LOOP holds, depending on the definition of the real exchange rate under consideration. In exactly the same way that relative prices of goods within a single economy can vary according to demand and supply conditions, so the relative price of different goods made in different countries can change. The real exchange rate will not be constant therefore if it is measured either using producer prices, or using the terms of trade (formally defined as the ratio of export prices to import prices).[34] In general therefore, where countries produce differentiated products, PPP can only hold for all possible definitions of the real exchange rate if trade elasticities are infinite.

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[31]See MacDonald (1995), Breuer (1994) and Froot and Rogoff (1995) for some recent surveys on PPP.
[32] Differences in the construction of price indices across countries cause additional complications which may also mean that PPP will be violated in practice. These include differences in indirect taxation and the treatment of housing costs.
[33] Obstfeld and Rogoff (2000) show how transport costs may provide an explanation for home country bias in the goods countries consume.
[34] In the case where consumer preferences are identical and there are no nontraded goods then PPP will hold when the real exchange rate is defined using consumer prices, providing LOOP holds.

Why LOOP itself may not hold

Of course there are also reasons why LOOP itself may not hold and this in turn could also be linked to the failure of PPP. The first of these reasons is the existence of trade barriers and transport costs. Of course, a nontradable good is simply an extreme example of this type of friction where the transportation cost is either infinitely high (e.g. the Eiffel Tower) or else it constitutes a disproportionately high fraction of the cost of the good or service (it is after all *possible* to travel from London to Paris to have a haircut).[35] So long as any of these frictions exist, it will be possible for prices to differ between countries in these markets by any amount up to the size of the transactions costs. More generally, there may be adjustment costs which imply that it takes time for consumers and/or producers to respond to a price differential between markets. See for example the discussion in Obstfeld and Rogoff (2000).

Another reason why LOOP may fail is provided by the nature of the competitive structure of the markets for different goods. In general, most trade amongst OECD countries tends to be in differentiated manufactured goods.[36] If in addition firms have a degree of market power, this potentially gives them the possibility of pricing-to-market, see for example Krugman (1987). When pricing-to-market occurs any mark-ups become destination specific, so the full impact of any change in the exchange rate may not be fully passed through and the LOOP will not hold.

The above are all reasons why PPP and LOOP may not hold in theory.[37] The next subsection considers whether PPP holds in practice.

Empirical support for PPP

As was discussed above, one of the defining features of how to approach estimating equilibrium exchange rates is whether or not real exchange rates are stationary, or in other words whether they revert to a constant mean over some time frame. As this is what PPP implies, in statistical terms a test for PPP would be that real exchange rate series are stationary. Until the emergence of nonstationary panel techniques econometric studies on the real exchange rate typically confirmed the visual impression from the data that real exchange rate series are not stationary.

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[35] Bergin and Glick (2003) explore the implications of the fact that at the margin the decision to trade or not to trade a good is endogenous.

[36] This happens because countries specialise according to the Ricardian principle of comparative advantage (see eg Obstfeld and Rogoff (1996) Chapter 4). Note the presence of transactions costs will imply that some goods are produced by more than one country.

[37] In fact, even if none of these factors are present Noussair *et al* (1997) show within an experimental environment that both LOOP and PPP may not hold due to a combination of perceived exchange rate risk and differing speeds of convergence towards equilibrium. For LOOP and PPP to hold, markets must be in equilibrium simultaneously.

See MacDonald (1995) and Breuer (1994), for surveys. In particular the results tend to depend on the length of the sample period, the degree of price variation observed and the choice of countries and in particular the choice of numeraire currency. Evidence in favour of PPP is more likely to be found if the tests include periods of substantial price variation (such as periods of hyper inflation); if they are based on long samples (of around 100 years) of annual data; and if the US dollar is not used as a numeraire. The first factor could reflect statistical problems in identifying stationarity, but even if PPP does hold during periods of hyperinflation, it is difficult to argue that this represents an equilibrium. The second provides support for long run, as opposed to medium run, PPP. The final factor undermines the case for PPP as a meaningful concept of equilibrium. If an equilibrium concept is to be useful then it must apply to the whole economy. If PPP holds for some currencies but not for others then it will not hold for effective exchange rates and it is the effective rate which is relevant for the whole economy.[38]

Given the enduring theoretical popularity of PPP, however, a variety of techniques have been used in an attempt to overturn these largely negative findings. One early trend was to use cointegration techniques to establish whether nominal exchange rates may be cointegrated with domestic and overseas price indices, leaving a stationary residual.[39] The estimated coefficients on prices in these cointegrating vectors, though, are often not unity. One interpretation of these results is that published price series are poor measures of 'true' prices, and so allowing non-unity coefficients allows the regressions to reveal true PPP. However, as Breuer (1994) points out, it is difficult to interpret these results as supporting PPP, particularly if the coefficients on the price series in the cointegrating vector are noticeably different from unity. They imply, of course, an absence of *measured* long run neutrality.

More recently a spate of papers using more powerful nonstationary panel techniques have tended to overturn the single equation results, with the majority of such studies finding evidence in favour of PPP. Such studies include: Frankel and Rose (1996), MacDonald (1996), Oh (1996), O'Connell (1998), Papell (1997) and Coakley and Fuertes (1997). With the exception of O'Connell (1998) these papers have all tended to find in favour of the mean reversion of the real exchange rate, or the existence of PPP. Papell (1997) does find that the results tend to depend on the size of the panel, although even with panels as small as five countries the probability of rejecting a unit root increases significantly compared to the single equation results. The negative results from O'Connell (1998) stem from accounting for cross sectional dependence. Chortareas and Driver (2001) find that the results of the panel unit root tests may

[38] In general the results for PPP are less favourable when the US is used as a numeraire currency. This may reflect the fact that the US is relatively closed and therefore that the forces of arbitrage are not as strong.
[39] Michael, *et al* (1997) argue that cointegration tests may be biased against finding evidence of long-run PPP because they ignore the non linearities implied by the presence of transaction costs. See also Dumas (1992) on this point.

well be test specific, which would suggest that the findings in favour of PPP should still be treated with a degree of scepticism.

The discussion above suggests that there are problems with the PPP approach.[40] Finally, even proponents of PPP accept that the rate of mean reversion is very slow (see MacDonald (2000)). All this suggests that alternative approaches to equilibrium are needed.

4.1.3 Balassa-Samuelson

One of the explanations for why PPP may not hold revolves around the distinction between tradable and nontradable goods. If the forces underlying PPP relate to arbitrage in the goods markets then there would be no reason for PPP to hold for definitions of the real exchange rate which included goods and services which were not traded.

It is this insight which is behind the Balassa-Samuelson effect.[41] The Balassa-Samuelson model uses the decomposition of the price level into traded and nontraded prices, where α is the proportion of nontraded goods within the economy. Applying this to the real exchange rate and taking logs it can be shown that the real exchange rate can be written as:

$$e_t = (s_t + p_t^T - p_t^{T*}) - \alpha(p_t^T - p_t^{NT}) + \alpha^*(p_t^{T*} - p_t^{NT*}) \qquad (10)$$

where a star indicates a foreign variable, the superscript T refers to traded goods and NT to non traded goods. The real exchange rate therefore is a combination of the real exchange rate for traded goods and the ratio of the relative prices of traded to nontraded goods in the two economies. If productivity growth in the tradables sector is higher in one country, then relative nontradables-to-tradables prices will grow more quickly.[42] So its CPI-based real exchange rate will appreciate relative to other countries.[43] As with PPP, however, these effects are more likely to explain medium and long run movements in the real exchange rate, as they are not designed to capture cyclical differences.

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[40] The empirical evidence has concentrated on PPP, rather than LOOP because it is the former which is actually related to exchange rate equilibrium. However, the evidence in favour of LOOP is if anything even weaker, (see for example Frankel and Rose (1995) and Haskel and Wolfe (1999)). Evidence also suggests that there is more to the problem than simply transport costs, see for example Engel and Rogers (1996).

[41] The basic Balassa-Samuelson model assumes that there are constant returns to scale in production, that labour is mobile between the traded and nontraded sectors, but is fixed internationally, while capital is internationally mobile. Balassa-Samuelson effects are also based on the assumption that PPP holds within the tradables sector.

[42] This is because the rising wages in the tradables sector associated with increased productivity will spillover into the nontradables sector, causing prices to rise.

[43] Devereux (1998) shows that these effects may go in the opposite direction if strong productivity growth in the tradables sector feeds through into the distribution sector.

Econometrically, the Balassa-Samuelson hypothesis has a simple interpretation. If PPP holds for tradables and Balassa-Samuelson effects are present, then the tradables real exchange rate should be stationary but the relative movements in the nontradables-tradables price ratio should cointegrate with the CPI-based real exchange rate. Of course if Balassa-Samuelson effects are absent then the observed non-stationarity in the CPI-based real exchange rate can be (at least partly) explained by the real exchange rate defined in terms of tradables.

Typically, empirical studies have tended to find that these types of effects do have some influence on real exchange rate movements but that these are not sufficiently large to explain the large movements in real exchange rates (see Engel (1993) and Rogers and Jenkins (1995)). In particular, there is little evidence that the real exchange rate for tradables is stationary. In addition, the volatility of the real exchange rate for tradables explains a far higher proportion of the volatility of the real exchange rate defined using CPIs than is explained by the volatility of the relative price of tradables to nontradables. However, there is evidence to support the hypothesis that movements in relative productivity can explain changes in the relative price of tradables to nontradables in the very long run, see for example Kohler (2000), Canzoneri *et al* (1999) and Chinn (1997).

4.2 Attempts to understand short run exchange rate movements

In theoretical terms, the set of measures that aim to capture short run equilibrium exchange rate movements are often the hardest to pin down. This is particularly true because at very short frequencies the volatility of the exchange rate is much greater than the volatility of fundamentals.[44] Models of short run equilibrium exchange rate movements are therefore often based around the model's ability to forecast exchange rate movements, rather than an overriding theoretical framework. This emphasis on forecast performance came out of the Meese and Rogoff (1983) findings that the first category of short run models considered here, namely monetary models, were unable to beat a forecast of no change for the exchange rate. The remaining three models considered within this section are loosely based around UIP, with the biggest differences linked to the treatment of the risk premia and long run movements in exchange rates.

4.2.1 Monetary models

Monetary models of the exchange rate can be traced to a desire to improve on the ability of PPP to explain the behaviour of nominal exchange rates and an acknowledgement that exchange rates

[44] De Grauwe and Grimaldi (2002) present a model which suggests that one explanation of this may be the existence of traders in the market who use chartist methods rather than fundamentals to forecast exchange rates. See also Jeanne and Rose (2002).

will be influenced by asset markets as well as goods markets. The emphasis is therefore on how to explain short term movements in nominal exchange rates rather than the desirable properties for a medium term equilibrium real exchange rate. Although Frenkel and Goldstein (1986) list the monetary/portfolio balance approach as a single methodology, in fact the concept covers a variety of differing approaches. This paper will not attempt to provide a comprehensive summary of these. See Frankel (1993), MacDonald and Taylor (1992) and Taylor (1995) for more extensive surveys.[45] Basically, however, the models can be distinguished by the degree of capital substitutability and whether or not prices are sticky, see in particular Frankel (1993) on these distinctions.

The starting point of this literature can be traced to a notion of perfect capital mobility and the idea that if the foreign exchange market is working efficiently then covered interest parity (or that the interest differential will be equal to the forward discount) will hold. The monetary approach to the balance of payments takes as its basis perfect capital substitutability and the idea that uncovered interest parity will hold. However, the exact model that emerges depends on the assumptions made about price adjustment. The monetarist model assumes flexible prices and that PPP holds continuously, see for example Frenkel (1976). The alternative assumption of sticky prices with PPP holding only in the long run generates the overshooting model, see for example Dornbusch (1976). The portfolio balance approaches are based on the assumption that there is imperfect substitutability of capital, so that the UIP condition only holds with the addition of a risk premium. Within the portfolio balance framework, models can be categorised depending on whether they employ a small country model, a preferred local habitat model, or a uniform preference model.

The monetary approach uses the fact that the nominal exchange rate can be seen as the relative price of two monies. Within the simplest version of this approach, the monetarist model, the money supply and demand conditions can be substituted into a PPP equation, so that nominal exchange rates, s_t, are solved by:

$$s_t = (m^s - m^{s*})_t - \phi y_t + \phi^* y_t^* + \lambda r_t - \lambda^* r_t^* \qquad (11)$$

where m^s is the money supply, y is real income, r is the nominal interest rate, * denotes a foreign variable and all variables except interest rates are in natural logarithms. Within this framework an increase in domestic interest rates will generate a depreciation in the exchange rate, even though domestic assets will be more attractive. This is because an increase in interest rates reduces the demand for domestic money creating an excess supply of money. To restore money market equilibrium prices must rise, and hence for PPP to hold a depreciation is needed. By assumption the model displays neutrality to the determination of nominal magnitudes. However,

[45] See also Groen (2000).

the assumption that PPP holds continuously implies that this model of exchange rates cannot explain or generate changes in real exchange rates, such as might be needed if there were a sustained relative productivity shock. This is also true of the long run behaviour of the overshooting model, which also collapses to PPP. This "long run" is likely to be equivalent to the medium term time horizon appropriate for the FEER. This is because the monetary models do not consider the dynamics of asset accumulation.

Portfolio balance models also have the exchange rate determined by the demand and supply of financial assets. However, the models incorporate the fact that exchange rates determine the current account, which in turn affects net holdings of foreign assets and therefore wealth, which will influence the demand for assets and therefore the exchange rate. The models distinguish between short term equilibrium exchange rates where demand and supply are equated by the asset market, and a long term equilibrium which is a complete stock equilibrium where wealth is stable. This model resembles the FEER approach in many ways, and indeed the resulting long run equilibrium exchange rate could be thought of as the long run FEER. However, in terms of a method of calculation the approach is quite different, as the calculated equilibrium exchange rate is obtained from a relationship between the components of wealth rather than from equilibrium output and sustainable capital flows. As Taylor (1995) notes, this can cause practical difficulties for estimating portfolio balance models because of data issues. The approach is also cast in nominal terms, as prices and real wealth are assumed to be homogeneous.

4.2.2 Capital Enhanced Equilibrium Exchange Rates (CHEERs)

An alternative approach to explaining the persistence of real exchange rates is to combine PPP theories with that of the UIP condition discussed earlier. MacDonald (2000) has dubbed such estimates as CHEERs (capital-enhanced equilibrium exchange rates). The idea underlying this approach is that while PPP may explain long run movements in real exchange rates, the real exchange rate may be away from equilibrium as a result of nonzero interest rate differentials (and that these may be necessary to finance the capital account). The approach therefore supplements the nominal UIP condition, given in Equation 7 but excluding any risk premia, with the assumption that the expected value of the nominal exchange rate can be predicted using relative prices if PPP holds. A cointegrating relationship is then estimated between relative prices, nominal interest rate differentials and the nominal exchange rate.[46]

[46] This type of approach usually models bilateral exchange rates and hence will not represent whole economy equilibrium.

In general, the CHEER approach has tended to suggest higher estimated speeds of convergence than is found for simple PPP estimates, see for example Johansen and Juselius (1992), MacDonald and Marsh (1997), and Juselius and MacDonald (2000). Partly for this reason the approach has been successful in forecasting movements in bilateral exchange rates, and has proved able to significantly out forecast a random walk even at horizons as short as two months (see MacDonald and Marsh (1997)). The approach is most closely linked to the first of the two concepts of short run equilibrium given by Equation 2 in Section 2.2, as the emphasis is on forecasting and the speed of convergence so that dynamics are important. The implicit assumption behind the approach, however, is that in the very long run when interest rate differentials are zero, the real exchange rate will be constant, or in other words that PPP will hold.

4.2.3 ITMEERs

Another concept of equilibrium which emphasises forecasting has been suggested by Wadhwani (1999) who has proposed an intermediate-term model-based equilibrium exchange rate (ITMEER). The starting point is again nominal UIP, this time including a risk premium. This risk premium is made up of two components.[47] The first component is made up of returns on other assets (stocks and bonds) to help explain exchange rate movements. The idea is that all assets must be priced off the same set of underlying risks and should therefore help predict excess currency returns. The second component is motivated by the assumption that risk will also in part be a function of the deviation in the real exchange rate from its equilibrium level. This equilibrium is assumed to be a function of relative current accounts (as a percentage of GDP), relative unemployment,[48] relative net foreign assets to GDP ratios and the relative ratio of wholesale to consumer prices.[49] In each case the approach uses the actual levels of these variables, rather than either their levels relative to equilibrium or the equilibrium levels themselves. Unless the equilibrium associated with these variables is constant, their actual levels will be an imperfect proxy of disequilibrium. In addition, unlike most of the alternative approaches to directly estimating equilibrium exchange rates discussed here, the framework does not use cointegration analysis.

ITMEERs are essentially attempting to capture e^{ST} in Equation 2 and so forecast the exchange rate. Indeed the emphasis is on forecasting nominal bilateral rather than real exchange rate

[47] The variables used to represent these components varies across currencies and in that sense are relatively ad hoc.
[48] A rise in relative unemployment in country A is expected to cause its exchange rate to depreciate. Although this is motivated using the FEERs literature, the effect of this type of impact within that framework would have the opposite sign.
[49] This last term aims to capture productivity differentials between the traded and nontraded sectors and is based on the assumption that Balassa-Samuelson effects will explain internal inflation differentials, see Kohler (2000).

movements and in that sense the approach appears relatively successful. Nonetheless this emphasis would make it difficult to back out any associated medium or long run equilibria.

4.2.4 Behavioural Equilibrium Exchange Rates (BEERs)

Work on BEERs or Behavioural Equilibrium Exchange Rates is associated with Clark and MacDonald (1997 and 1999).[50] BEERs aim to use a modelling technique which captures movements in real exchange rates over time, not just movements in the medium or long run equilibrium level. Partly reflecting this, the emphasis in the BEER approach is largely empirical and captures what we have defined above as short-run equilibrium concepts.

The starting point for the BEER analysis is the real UIP condition.[51] This is adjusted for the existence of a time varying risk premium. In the empirical work this risk premium is proxied using the ratio of outstanding domestic government debt to foreign government debt, both as a percentage of GDP. However, even with the addition of a risk premium, the UIP relationship is difficult to implement as an empirical model because of the lack of observed expectations of future levels of the real exchange rate. Clark and MacDonald (1997 and 1999) therefore make the assumption that expected future exchange rates will be related to long run fundamentals.[52] The variables that Clark and MacDonald (1997 and 1999) use to represent long run fundamentals are: the terms of trade (tot) or the ratio of the unit value of exports to the unit value of imports; the relative price of traded to nontraded goods (tnt), proxied by the ratio of CPI to PPI; and net foreign assets as a ratio of GNP. In each case these variables are measured as relative to their foreign counterparts.

The equation for the real exchange rate which underpins the BEER analysis is therefore a function of real interest differentials, tot, tnt, nfa and the ratio of government debt. This collection of variables will also influence FEERs. However, both the reasons for their inclusion and the way in which they feature are slightly more ad hoc than would be true for most FEER calculations. For example the analysis does not impose any particular functional forms or links from economic theory. Instead the links are essentially data determined. The estimation technique employed by Clark and MacDonald (1997 and 1999) is the cointegration analysis due to Johansen, which allows the variables to be modelled as a system and for the existence of more than one cointegrating vector. In their modelling of the US, Germany and Japan, Clark and

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[50] Other examples of BEER estimates include Alberola *et al* (1999), Clostermann and Schnatz (2000), Maeso-Fernandez *et al* (2001), Osbat *et al* (2003) and Schnatz *et al* (2003).

[51] Clark and MacDonald (1997 and 1999) look at real effective exchange rates. Other researchers have used very similar approaches to model bilateral exchange rates, see for example Clostermann and Schnatz (2000).

[52] Conceptually, Clark and MacDonald (1999) in fact subdivide the Z_t in Equation 1 into medium and long run fundamentals. However, in estimation this subtlety is ignored. In practice it is sometimes difficult to determine which variables will influence expected future exchange rates and which will determine the risk premia. Researchers have

MacDonald (1999) find two cointegrating vectors in each case, one reflecting real interest rate differentials and the other the remaining variables in the system.

4.3 Underlying balance models – thinking about the medium term

In the medium term it is assumed that countries should be in both internal and external balance, but that asset stocks may still be changing. These are the key features of the underlying balance approach. To illustrate the basis for the underlying balance models, consider a very simple model where all variables (except asset stocks) have settled down on their steady-state growth paths. Assuming that superneutrality holds it is possible to present the model in real terms. This obviously abstracts from pricing considerations, which will be important in the short term. However, under the assumption of superneutrality, abstracting from pricing considerations is justifiable in the medium and long run on the grounds that the real economy will be independent of monetary policy over these horizons. A real exchange rate is consistent with a whole range of nominal exchange rate and price combinations, and in this time frame monetary policy simply determines the price level.

The first equation embodies output supply (y^S):

$$y_t^S = \bar{y}(A, K, \bar{L})_t \tag{12}$$

so that output depends on the level of technical progress (A), the capital stock (K) and labour supply ($\bar{L}$).[53] In the long run, of course, it is conventional to assume that output supply (or potential output) is determined exogenously.

For underlying balance to hold, output supplied will have to equal output demanded (since we are abstracting from capacity utilisation considerations), where the latter is given by:

$$y_t^D = DD_t + NT_t \tag{13}$$

where aggregate demand (y^D) is the sum of domestic demand (DD) and net trade (NT). Domestic demand will depend on income, wealth, the capital stock, the real interest rate and fiscal policy, while net trade will depend on income at home and abroad and the real exchange rate. In an open economy, UIP implies that the long run real interest rate will be equal to the world real interest rate minus the risk premium and any additional effects from trends in the equilibrium real exchange rate. The real exchange rate must then move to reconcile aggregate demand and aggregate supply: the real exchange rate is playing the role of a relative price

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therefore placed differing emphasis on these two factors, although similar variables are used within estimation.

[53] The supply equation will often be written in terms of a simple price adjustment mechanism such as a Phillips curve whereby inflation changes according to the gap between demand and supply but the long run solution of that relationship collapses to Equation 12.

which, just like any other relative price, must move to equilibrate demand and supply given supply constraints and demand preferences.[54]

The final relationship which can be used to help pin down underlying balance and hence the equilibrium exchange rate is given by the current account (CA):

$$CA_t = NT_t + BIPD_t = \Delta NFA_t = S_t - I_t \quad (14)$$

which is equal to net trade together with the balance of interest, profit and dividend flows plus net transfers (BIPD). By definition the current account is also equal to the change in net foreign assets (NFA) as well savings minus investment (S-I) for the economy as a whole. The external balance component of the underlying balance model is usually given by the assumption that the savings and investment balance for each individual economy is in some sense sustainable. It does not, however, imply that there will be a full stock flow equilibrium, as this could take decades to achieve. As such net foreign assets can still be changing over time.

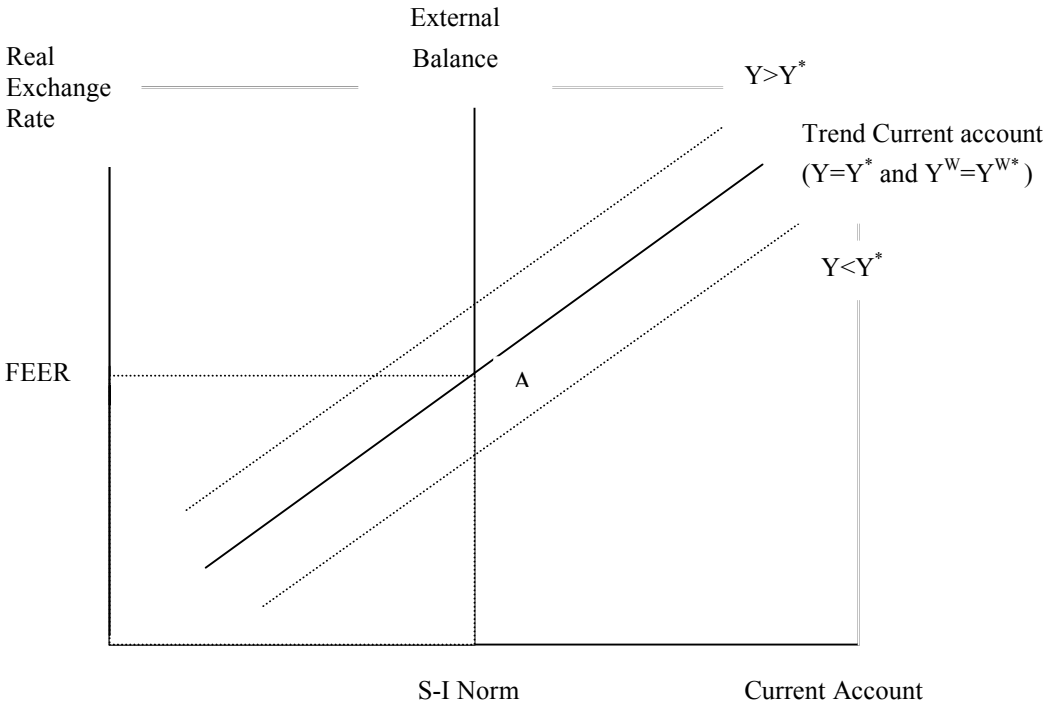

Figure 1: Stylised Model of the FEER

[54] In terms of the solution for the real exchange rate, demand conditions become particularly important once a model incorporates factors such as differences in consumer preferences and (depending on the real exchange rate under consideration) differentiated goods.

Figure 1 represents a highly stylised view of the economy, but it is useful to illustrate the FEERs approach. Consider the relationship between the current account and real exchange rates, where the real exchange rate is defined as units of domestic currency per unit of foreign, so that an increase represents a depreciation. For a given level of output, therefore, this relationship will be upward sloping so the current account improves (with imports falling and exports rising) as the real exchange rate depreciates. If domestic output increases this relationship will shift to the left as imports rise and therefore the current account deteriorates for any given real exchange rate. Similarly if foreign output were to increase then the relationship would shift to the right, with exports improving for a given real exchange rate.

The FEER is the real exchange rate that reconciles the two conditions of external and internal balance, both of which are assumed to be invariant to the real exchange rate.[55] Internal balance occurs when output is at potential (or when $Y=Y^*$) and for this level of domestic output (as with any other) there is an upward sloping relationship between the current account and the real exchange rate. When output is equal to potential at home and abroad ($YW=YW^*$) then this can be thought of as the trend current account. External balance is given by the level of savings minus investment (or current account) which is sustainable in the medium to long run. At point A, therefore, both internal and external balance will hold simultaneously, and the real exchange rate will be at the FEER.

For the given combination of S-I and Y^* and YW^*, the FEER will be constant. However, over time the factors will shift relative to each other and these shifts will be reflected in changes in the FEER. A simple example of such shifts would be if trend domestic growth were below world GDP growth, but that the world was otherwise symmetric. This would shift the trend current account to the right over time, so leading to an appreciation of the FEER (for an unchanged S-I norm).

What the FEER gives is a path which pins down movements in the real exchange rate in the medium to long run. In other words FEERs should act as an attractor for the real exchange rate, unless economies are permanently away from potential.[56] What the model of the FEER does not give is the path by which the economy returns to equilibrium. It is a model of the real exchange rate based on the assumption that all variables (except asset stocks) have settled down to their steady-state growth paths and abstracts from the pricing considerations which will be important in the short term.

[55] Barrell and Wren-Lewis (1989) and Driver and Wren-Lewis (1999) investigate the results of relaxing the assumption that potential output is invariant to the level of the real exchange rate. In general the impact on the FEER calculations of relaxing this assumption is found to be very small.
[56] Work by Barisone *et al* (2003) suggests that FEERs do have this attractor property.

The underlying balance approach involves the specification and estimation of equations in their structural form (ie in terms of trade equations, pricing relationships, expenditure functions, current account relationships etc.), then inverting the model so that the real exchange rate is expressed in terms of fundamental variables. The equilibrium exchange rate will be determined as the (appropriate) long run solution to the model.

This type of approach can be implemented either using a fully specified macromodel, where all variables are endogenous, or a partial equilibrium model which looks at a subset of the equations of interest. If a large scale macroeconometric model is used, the real exchange rates which prevail at horizons once nominal inertia has washed out will be FEERs, assuming that the model has a well defined long run equilibrium. The advantage of pursuing this approach is that all the relationships within the model are endogenous. The disadvantages can sometimes be in terms of loss of transparency. In practice, using a full macromodel is rarely implemented because empirical macromodels are too large and it becomes hard to disentangle the different influences. Instead, the partial equilibrium approach is typically adopted. As this involves estimating on a country by country basis, the relationship for the external balance (either in terms of the current account or in terms of savings-investment balances) is usually estimated directly. Different choices regarding which structural trade equations should be modelled and how the external balance should be captured explains the differences between the empirical estimates that have been made. Since underlying approaches necessarily involves the use of trade-weighted effective exchange rate measures, equilibrium exchange rate estimates of this type will tend to be on an effective basis.[57]

4.3.1 The Fundamental Equilibrium Exchange Rates (FEER) Approach

Possibly the most popular of the underlying balance models has been that of Fundamental Equilibrium Exchange Rates (hereafter FEER). Wren-Lewis (1992) defines a FEER as "a *method of calculation* of a real exchange rate which is consistent with *medium-term macroeconomic equilibrium*." What is important in that statement is the notion of medium term macroeconomic balance, as the FEER approach does not actually impose a unified methodology on how these calculations are done. Indeed as noted above the calculations can either be made using a full scale macroeconometric model or using a partial equilibrium approach.[58] Under the partial equilibrium approach, which is most commonly used in the

[57] If equilibrium exchange rates have been calculated on a consistent basis for more than one country, then estimates of the associated bilateral exchange rates can be derived using trade weights, see Alberola *et al* (1999). Alternatively if the model includes more than one country then bilaterals can also be estimated directly, see for example Wren-Lewis (2003).

[58] Such partial equilibrium calculations are typically only performed for a single point in time and this lead to the accusation that there was no way of determining how much relevance FEERs have in explaining movements in real exchange rates over time. Barisone *et al* (2003) investigate this issue and find that FEERs have more

literature, the net trade and balance of interest, profit and dividend (ipd) relationships are specified and the trend current account is calculated under the assumption that real exchange rates are at their actual levels, but that output at home and abroad are at trend. The difference between the trend current account and the actual current account will therefore be the result of cyclical factors, together any errors in the specification of the trade and ipd equations. The FEER is then calculated as the real exchange rate that reconciles this trend current account with an assumption about the level of the savings and investment balance for each individual economy which will be in some sense sustainable.

Of the two components of macroeconomic balance, internal and external, it is external balance, or the sustainable level of savings and investment, which has attracted the most controversy. The earliest attempts to derive FEER estimates include Artis and Taylor (1995), Barrell and Wren-Lewis (1989), Currie and Wren-Lewis (1989a and b), Williamson and Miller (1987), Williamson (1989, 1993 and 1994a), Frankel (1996) and Frenkel and Goldstein (1986). One distinguishing feature of these early FEER estimates was the relatively simple way that the equilibrium current account was modelled. This tended to be rationalised in terms of a measure of sustainable capital flows which were usually assumed to be a constant proportion of GDP and was often arrived at in a fairly ad hoc manner (see for example Williamson and Mahar (1998)).[59]

An alternative and more satisfactory approach to deriving the equilibrium current account has more recently been developed by researchers at the IMF (see Faruqee and Debelle (1998) and Masson (1998)). Since net domestic savings and the current account of the balance of payments are by identity equal, they focus on the determinants of the difference between domestic savings and investment. Specifically, they explain medium term net domestic savings in terms of demographic factors and the government deficit (adjusted for the cycle). See also Bussiere *et al* (2003) for a recent application of this approach.

One criticism of the FEER concept often made is that it does not constitute a true equilibrium since stock-flow equilibrium is not achieved. One consequence of this is that FEERs will be subject to hysteresis effects since the medium-term current account will be affected by temporary shocks (see Artis and Taylor (1995) for an articulation of this criticism of FEERs). Shocks will cause wealth stocks to move away from equilibria and the time horizon over which these wealth-income ratios are restored to their target levels may be much longer than that required for internal and external balance to be achieved. In principle, of course, it would be possible to calculate the long-term equilibrium value of savings-investment balances and calculate the long term

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success than PPP in explaining movements in real exchange rates over time. This is demonstrated by the fact that while real exchange rates themselves are found to be nonstationary, the difference between FEERs and real exchange rates are stationary.

[59] Driver and Wren-Lewis (1999) examine the sensitivity of the resulting FEER estimates to these assumptions

equilibrium exchange rate accordingly. In practice, little interest has been shown in doing this mainly because such an equilibrium is probably only relevant to the very long term.

It is worth noting though that the process of deriving a FEER does not have to involve the estimation of a full dynamic model. Rather, FEER calculations are attempting to identify $\hat{e}$ in Equation 4 above (where the relevant levels of the fundamentals are their medium term equilibrium levels), not to model the process of how the economy might arrive at that exchange rate. This does not imply, however, that FEER calculations could not be used to calculate a version of exchange rate short-term equilibrium consistent with current values of economic fundamentals, or in other words $\hat{e}^{ST}$ in Equation 3. This could be obtained using the values of actual output and the current account in place of potential output and sustainable capital flows. Such an exchange rate would not be a true equilibrium. For example there would be no guarantee that the actual value of the current account would be sustainable. However, it might help to distinguish the extent to which deviations from the FEER are the result of cyclical considerations.[60]

4.3.2 Desired Equilibrium Exchange Rates (DEERs)

One additional potential shortcoming of the FEER concept can be the slightly arbitrary definition of "medium term" fundamentals. Depending on how the calculations are performed this potentially places a strong emphasis on an essentially normative issue, that of optimal policy, a link which is reinforced by Williamson's use in much of his work on FEERs of the phrase "*target* current account" to describe sustainable capital flows.[61] This link between the FEER and particularly fiscal policy has led many economists [including Williamson himself: Williamson 1994b, p181] to argue that the FEER is inherently normative, and tied to some kind of "desired" policy trajectory.[62] In the light of this, some economists have defined an alternative equilibrium concept known as the DEER, or the Desired Equilibrium Exchange Rate (see Bayoumi *et al* (1994) and Artis and Taylor (1995)) where the real exchange rate is conditioned on some measure of optimal fiscal policy.

However, just because a calculated medium term equilibrium exchange rate is conditional on fiscal policy assumptions, does not imply that it has to be normative. A normative exercise

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about sustainable capital flows. See also Dvornak *et al* (2003) and Brook and Hargreaves (2000).

[60] One problem is that in the short term it is not possible to invoke neutrality, implying that dynamics will matter. Depending on the model used to calculate the FEER, such dynamics may, or may not, be available.

[61] In this sense the term sustainable is possibly also misleading. Within this context it refers to medium term (average) capital flows rather than an upper limit for the absolute size of the current account.

[62] In the case of Williamson, there is an additional reason why the FEER is seen as an essentially normative concept, which is because:

"FEERs are intended to be used as intermediate targets in securing the international coordination of economic policy" [Williamson, 1994b, p185].

would use the "optimal" path. However, it would be just as easy to use the most likely path for fiscal policy, or structural fiscal policy, and where the two differed, so would the calculated FEER and DEER.

4.4 Measuring the medium to long run

This section presents a set of alternative ways of calculating long run equilibrium exchange rates which are distinct from PPP. In other words, these are measures that allow real exchange rate equilibrium to vary even in the long run. The measures are quite different in their approach, ranging from the purely statistical to a more model based method of calculation. The statistical methods are categorised as long run because they aim to calculate permanent changes in the exchange rate. However, it is important to note that this definition of permanent is not based on any assumption about asset stocks being in equilibrium. As such it could be argued that they should be classified as medium run.

4.4.1 Statistical methods: APEERs

An alternative and rather different way to estimate equilibrium exchange rates is to use techniques which rely directly on the statistical properties of the real exchange rate. In particular, these methods aim to decompose the real exchange rate itself into its "permanent" and "transitory" components. For example, Huizinga (1987) and Cumby and Huizinga (1990) use Beveridge-Nelson decompositions to extract the permanent component of real exchange rate movements. This has been dubbed by MacDonald (2000) as the atheoretical permanent equilibrium exchange rate (APEER), because of the absence of any explicit theory about exchange rate behaviour.

4.4.2 Permanent Equilibrium Exchange Rates (PEERs)

The emphasis in BEER approaches is on modelling the behaviour of exchange rates, and therefore BEER-type calculations do not require that fundamentals are at their equilibrium levels. As such, BEERs will only coincide with measures of medium-term equilibrium such as FEERs when the condition $Z_t - \hat{Z}_t = 0$ holds. Even at that point, however, exchange rates can still be misaligned, with the misalignment reflecting transitory factors and random errors.

Recognising this distinction Clark and MacDonald (2000) have more recently defined the Permanent equilibrium exchange rate (PEER) which is derived directly from the BEER estimates

but separates out the factors underlying the BEER into their permanent and transitory components.[63] This can be done using the statistical techniques due to Gonzalo and Granger (1995).[64] This technique makes no attempt to directly measure what the longer run levels of the individual fundamentals are and as such is a statistical rather than an economic definition of equilibrium. However, despite the different estimation technique used in its derivation, this PEER concept is comparable with the FEER concept.

4.4.3 The Natural Real Exchange Rate (NATREX) Approach

Another concept which is closely related to FEERs is that of the NATREX or Natural Real Exchange Rate. Work on the NATREX is mainly due to Jerome Stein: see Stein (1994), Stein and Allen (1995) and Stein and Paladino (1998). Stein (1994) defines the NATREX as "the rate that would prevail if speculative and cyclical factors could be removed while unemployment is at its natural rate" [Stein, 1994, p135]. In addition, the NATREX is the real exchange rate which equates the current account to *ex ante* saving and investment, where these are evaluated at the level implied by fundamentals, where fundamentals relate to productivity and thrift and are exogenous. On this basis, this definition is very similar to the medium term equilibrium concept embodied in the FEER. However, in addition, the NATREX is also defined by its proponents as that real exchange rate which is consistent with portfolio balance, so that domestic real interest rates equal world real interest rates.[65] This implies that the NATREX should be interpreted as a long-run equilibrium concept. Indeed, in discussing the NATREX, Stein and Paladino (1998) distinguish between medium and long term considerations. For example, in the medium term an increase in social consumption (for example because government consumption increases) implies that the associated real exchange rate must appreciate to reduce excess demand. This in turn implies that the current account will deteriorate. In the longer term the decline in the current account implies that there will be a related deterioration in net interest flows on foreign debt because of the impact on net foreign assets. This implies a further worsening of the current account. Therefore at the prevailing exchange rate there will now be a short fall in demand relative to the planned level of savings minus investment. In the longer term therefore the real exchange rate needs to depreciate until net foreign assets are stabilised. This process has to be associated with a change in the planned level of savings less investment (so that they become zero). Such arguments are similar to those associated with the long run FEER. In discussing the long run FEER, Wren-Lewis and Driver (1998) speculate that this could take decades to achieve as there may be good reasons even in the medium term for capital flows to take place.

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[63] Other examples of PEER estimates include Alberola *et al* (1999), Hansen and Roeger (2000) and Maeso-Fernandez *et al* (2001).

[64] Hansen and Roeger (2000) warn that in some cases the estimated equilibrium will be sensitive to the decomposition method and that the Gonzalo and Granger (1995) may exaggerate the "goodness of fit".

[65] If real UIP is assumed (Equation 8) then this last condition implies that changes in the real exchange rate will only occur if there is a risk premium.

In estimation the NATREX model considers a variety of fundamentals, which depend in part on whether the economy is considered small or large. In the analysis of the US given in Stein (1994) fundamentals are defined as productivity at home and abroad (given by real GDP growth) and the rate of time preference, given by the ratio of social consumption (or private and government consumption) to GNP in the US. In each case these fundamentals are measured using a 12 quarter moving average of the underlying series in order to eliminate cyclical elements. The change in fundamentals is measured using the real long interest differential. In the analysis of Australia presented in Lim and Stein (1995) the list of fundamentals is given by productivity, the terms of trade, the real foreign interest rate and social thrift (for Australia).

The definition of the real exchange rate used in empirical work on the NATREX also varies. For large countries the nominal exchange rate is deflated either using GDP deflators or CPI, while for small countries unit labour costs are used, see Stein and Paladino (1998). The reason for this distinction is the argument that for small open economies prices are determined on world markets. In fact if countries produce differentiated products under imperfect competition this does not necessarily have to be true.

Empirical work on the NATREX is also done over two time horizons, the medium and the long run. In the medium run, the real exchange rate responds to real interest rate differentials, as well as being dependent on exogenously determined fundamentals. Stein (1994) models this relationship for the US by estimating an equation which relates the real exchange rate to real US GNP growth, real foreign GNP growth, the current account to GNP ratio for the US and the real long run interest rate differential. The growth rates are proxies for the growth of the capital stock at home and abroad, while the current account is a proxy for the rate of change of foreign debt. The growth rates and current account are set to their 12 quarter moving average, while the real interest rate differential is lagged one period.

In the long run the capital stock and foreign debt are also endogenous and will be related, together with the real exchange rate, to long run fundamentals, or productivity at home and abroad and the rate of time preference at home and abroad. However, it is not always possible to obtain measures of the appropriate variables. Therefore the modelling strategy for the long run of the US, Stein (1994) relates the real exchange rate and foreign debt to productivity at home and abroad and the rate of time preference at home. Foreign debt is again proxied using the ratio of the US current account to GNP. Productivity at home and abroad are proxied by the 12 quarter moving average of the GNP growth rate to abstract from cyclical elements. In the case of the rate

of time preference in the US, this is given by social consumption (ie private and public consumption) as a proportion of GNP. As this is a ratio, cyclical factors should cancel. In addition, Stein (1994) finds that the 12 quarter moving average of this variable is not useful in the regressions. The focus of the empirical analysis is on the trajectories, not the steady states, which might take decades to achieve.

Although the variables considered are similar, it is clear that the estimation strategy employed for the NATREX differs slightly from other methods of calculating longer run equilibrium exchange rates. Indeed it belongs more naturally in our discussion on direct methods which relate actual real exchange rates to the actual level of the appropriate variables.[66] Such estimation can either be in the form of single equations, or could encompass more complex models. The hope, however, is that it will produce an unbiased and efficient estimate of the parameters which make up the β vector associated with the fundamentals, Z, in Equation 1. The equilibrium exchange rate is obtained by inserting the equilibrium levels of the relevant fundamentals, $\hat{Z}$ or $\overline{Z}$ (see Equations 4 and 5). In contrast the NATREX analysis attempts to estimate β using $\hat{Z}$ or $\overline{Z}$ directly, so that the calculated equilibrium is obtained directly by setting the regression residuals to zero. Given the problems associated with adequately measuring $\hat{Z}$ and $\overline{Z}$, this may have implications for the efficiency of estimates of β.

4.5 Understanding the role of shocks

An important empirical and theoretical question is what impact will shocks (for example to supply) have on real exchange rates. This section highlights two general methods (one empirical and one theoretical) which aim to answer this type of question. These are not methods which can be used to calculate a level of the real exchange rate. Nonetheless they are important tools for allowing us to understand why exchange rates move in the way that they do.

4.5.1 Structural Vector Autoregressions (SVARs)

In considering how the real exchange is determined, it is useful to adopt as general a framework as possible. Of course, because the real exchange rate is endogenous to the whole macroeconomic system, we should expect it to be affected by all the shocks which impinge on the economy. A variety of techniques exist which allow us to obtain a reduced-form expression that captures all or some of these effects. For example, by estimating a structural VAR, we can make assumptions about how different shocks will affect the exchange rate and hence decompose the value of the real exchange rate into its different components (see for

[66] Not all NATREX calculations take this approach. Detken *et al* (2002) estimate a NATREX model using structural rather than reduced form methods.

example Clarida and Gali (1995) and Astley and Garrett (1998)). Such techniques therefore require the researcher to have theoretical prior views on how particular shocks affect the exchange rate. So it is inevitably necessary to consider a structural model of the economy.

For example, Clarida and Gali (1994) use structural VAR techniques to decompose the *change* in real exchange rate movements into the effects of supply, demand and nominal shocks.[67] Typically this type of approach finds that demand shocks can explain a far higher proportion of exchange rate movements than supply shocks. However, these findings will be sensitive to decomposition used, see Labhard and Westaway (2002).

MacDonald and Swagel (2000) suggest that the permanent component of movements in the real exchange rate will be that given by the contribution of the supply shocks, thus stripping out the influence of the demand and nominal shocks. See also Detken *et al* (2002). In some senses these estimates are related to medium-term FEER-type measures. The correspondence is not exact however: first, because theory would suggest that equilibrium exchange rates may also be influenced by permanent demand shocks; second because even if the effects of demand shocks were to be included, these SVAR-based methods will tend to incorporate the short-run dynamic effects of the demand and supply shocks which would be stripped out from conventional measures of the medium-term equilibrium; and finally because the SVAR methodology is related to the change in the exchange rate rather than its level it is difficult to translate the methodology into levels space as it will depend on an arbitrary start point, which may or may not represent equilibrium.

4.5.2 DSGE approaches to the exchange rate

Dynamic Stochastic General Equilibrium (DSGE) models have proved to be extremely popular within the so-called New Open Economy literature, see Lane (2001) for a survey. For all its popularity, this class of model cannot provide information about the level of the real exchange rate, because results from DSGE models are presented as deviations from steady state. However, they are ideally suited to thinking about what impact shocks will have on exchange rates and relative prices. As such they can provide valuable insights into the likely source of shocks hitting the economy, based on the observed correlations between variables and how these match up to the predictions from the models. In addition, because they include explicit expressions for consumers' utility they can also be used for welfare analysis.

[67] In the case of Clarida and Gali (1994) the VAR also contains the change in relative foreign output and relative inflation. The identification scheme used is one whereby output is only affected by supply shocks in the long run, while real exchange rates can be influenced by both demand and supply shocks. It is the fact that these models are specified in terms of the change in the real exchange rate, allowing researchers to use normal SVAR or VAR analysis, rather than forcing them to estimate a cointegrating (VECM) relationship which distinguishes them from the BEER and PEER methodology discussed earlier.

Probably the best known model within this class is the so-called Obstfeld-Rogoff *Redux* model, see Obstfeld and Rogoff (1995 and 1996). This uses a very simple two country model, where firms' prices are sticky for one period in the producers' currency and where the law of one price holds for individual goods, so that PPP holds continuously and the real exchange rate defined in consumer prices is constant. Consumer preferences are the same in both countries, but because countries produce different goods both nominal exchange rates and the terms of trade will shift following shocks to the money supply, productivity and government spending. Clearly the assumption that PPP holds even in the short run is very strong (see the evidence in Section 4.1.2 above). Benigno and Thoenissen (2002) suggests various ways to break this link, at least in the short run including the existence of nontraded goods, home bias in consumption and pricing-to-market.

While one of the attractions of DSGE models is that they have a strong theoretical basis, changes to the theoretical priors can often yield very different results. For example Driver (2002) shows that the impact of a money supply shock within the Obstfeld-Rogoff *Redux* model changes when countries also trade in commodities as well as manufactured goods. Ultimately which version of the transmission mechanism makes most sense is an empirical question, so that the results from DSGE models are often compared to those from SVARs in order to determine whether the impact of shocks is the one expected.

One of the most controversial aspects of the transmission mechanism in the new open economy macroeconomic literature is how firms respond to exchange rate changes.[68] (See, for example, Obstfeld (2002).) At one end of the spectrum it is assumed that firms set prices in their domestic currency (producer currency pricing) and fully pass through any changes in the exchange rate into the prices they charge in foreign markets. Under the alternative assumption of local currency pricing, it is assumed that prices are set in the buyer's currency and, in the short run at least, changes in exchange rates will have no impact on these prices. Local currency pricing may therefore be part of the explanation for the so-called 'exchange rate disconnect' puzzle: that is, that large movements in the exchange rate have not been associated with large movements in import and export prices and the consumer price index, as might be suggested by a standard model. See for example Devereux and Engel (2002). The two extremes of producer currency and local currency pricing therefore clearly suggest very different transmission mechanisms from the exchange rate to the rest of the economy.

Producer versus local currency pricing also has very different implications for the risks facing firms. One way of disentangling the most sensible transmission mechanism may therefore be

[68] Bergin (2003) attempts to test the importance of this assumption empirically in the context of a DSGE model.

to think about firms' behaviour. For example if a firm can lock a foreign buyer into a contract involving a given quantity of goods at a price set in the firm's own currency then it is largely insulated from exchange rate changes. However it may not be in the firm's interest to attempt to negotiate this type of contract if its rivals are offering the buyer the opportunity buy the goods at a price set in the buyer's currency, allowing the purchaser to minimise exchange rate risk. Exactly how the choice of currency denomination in contracts is determined is a complex issue. Bacchetta and van Wincoop (2002), for example, present a model where currency denomination is determined by four main factors: the extent of differentiation of goods within an industry; the market share of an exporting country's firms; the overall size of the exporting country; and the cyclicality of real wages. Devereux *et al* (2002) suggest that pass-through will also be linked to the degree of exchange rate volatility, with pass-through falling as volatility increases, and that both domestic and foreign firms will choose to set prices in the currency where the volatility of money growth (or monetary policy shocks) is lowest.[69]

5 Conclusions

This paper has examined the concept of equilibrium real exchange rates. In theoretical terms, it has explained why the assumption of purchasing power parity, frequently adopted in simple theoretical models, may be inadequate when various real world complications are introduced. Importantly these richer models imply that the real exchange rate is ultimately determined as an endogenous variable in the macroeconomy. And while acknowledging that speculative factors may have an important role to play in determining short run exchange rate movements, the paper has argued that the exchange rate will ultimately be determined by "fundamental" factors relating to the real economy.

The paper has emphasised the distinction between short, medium and long run exchange rate equilibria. It has argued that "misalignment" with respect to these different equilibrium concepts may have quite different policy implications. A measure of the real exchange rate may be away from its medium term equilibrium because the fundamental factors on which it depends are themselves away from equilibrium: for example monetary policy maybe temporarily tight in response to a demand shock causing the exchange rate to appreciate above its medium term equilibrium. On the other hand, the exchange rate may diverge from its equilibrium despite the fact that the fundamentals are in equilibrium themselves. In these circumstances, the policy implications will depend on what the source and nature of the shock to the exchange rate is perceived to be. Deliberately, this paper does not set out to explore

[69] Corsetti and Pesenti (2002) present a model that suggests that monetary union becomes optimal when local currency pricing dominates. Empirically both Taylor (2000) and Gagnon and Ihrig (2001) have linked the recent reduction in exchange rate pass-through to changes in monetary regimes.

these important policy-related issues in depth. This is left for future work. Rather it is designed to convey the message that exchange rate misalignments can be defined in a variety of ways and for any given definition the link between the misalignment and the policy response is not mechanical.

In the final section, the paper has examined the different approaches that have been taken to deriving empirical estimate of these equilibrium concepts. Previously, there have been few attempts to explain how these different empirical estimates and their associated acronyms can be related to each other. For the first time, a taxonomy of the different approaches is provided explaining what horizon each equilibrium concept refers to, what theoretical assumptions are adopted in its construction and how the measure has been estimated. This description is not intended to provide a recommendation of which approach is best. Rather it is to emphasise that different measures of *the* equilibrium real exchange rate may be conceptually distinct.

This paper covers a lot of ground both in terms of describing the underlying theoretical basis for equilibrium exchange rate concepts and for the associated empirical estimates. As such this paper is designed to provide a conceptual framework for ongoing work related to both the theoretical and empirical aspects of equilibrium exchange rates.

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