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Purchasing Power Parity and Real Exchange Rates: Do Productivity Trends and Fiscal Policy Matter?

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Abstract

We present empirical evidence on the purchasing power parity hypothesis using a new data set from the late 19th century for a number of major currencies. We confirm the results of previous empirical studies which show that the simple PPP hypothesis does not hold even over long time horizons, whilst extending these results to a larger set of countries. We use structural VAR models to show that persistent deviations from PPP are attributable to productivity differentials (the Balassa-Samuelson hypothesis). and divergences in fiscal policies. Fiscal policy shocks are shown to have only a temporary impact on the real exchange rate.
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1. Introduction

There are few economic theories that have received as much scrutiny as purchasing power parity (PPP) and the determination of long-run real exchange rates. There is a vast empirical literature on these two related subjects, and the subject has also been reviewed in recent surveys by Froot and Rogoff (1995), and Rogoff (1995, 1996). The message which emerges from the existing literature is that we only have a very partial picture of why deviations from PPP are so persistent over time. Our inability to fully explain the dynamics of real exchange rates stems from our imperfect knowledge of the dynamics of price adjustment and of the fundamental variables driving long-run relative prices in the world economy. When we add to that an imperfect knowledge of the channels through which non-monetary shocks drive nominal exchange rates in the short run, it is not surprising that the jury is still out on this subject.

Our aim here is not to offer yet another comprehensive review of the empirical literature to date. Instead we shall perform two tasks. The first is to extend the existing historical studies on PPP which have been carried out on previously. We have put together a new data set which brings together historical series from a variety of sources[1] to allow us to estimate models for bilateral rates between up to six industrial countries, for the period 1861-1998. This provides a much more extensive testing area for the PPP hypothesis than other recent studies, using low-frequency data series. Second, we employ a VAR modeling framework for a further, and richer, econometric analysis of the disturbances which have affected real exchange rates over the last 140 years. Our structural VAR models provide clear support for the Balassa-Samuelson hypothesis, and also for the role of fiscal policy in determining persistent movements in real exchange rates. We also quantify the importance of these deviations from PPP, showing that they operate over different time horizons, in line with the predictions of intertemporal open economy models. This extends some recent work on the importance of the Balassa-Samuelson effect in determining real exchange rates in the OECD in the post-Bretton Woods era (see Canzoneri *et al.*, 1998).

The rest of the paper is structured as follows. In Section 2 we briefly review the current literature on PPP and discuss the various determinants of the real exchange rate. In Section 3 we present some basic benchmark tests of the PPP hypothesis on long runs of historical data using nominal exchange rates and relative prices, and provide a critical evaluation of these approaches. In Section 4, we look closer at the determinants of real exchange rates in the short and long-run, and present evidence on the role of productivity and fiscal policy effects. Section 5 concludes.

2. PPP and the determinants of the real exchange rate - whither next?

There have been a number of comparative empirical studies of PPP on long runs of historical data. (See for instance Kim, 1990, Glenn, 1992, Abuaf and Jorion, 1990, Cheung and Lai, 1994, Mark, 1996, Taylor, 1996, and Lothian and Taylor, 1997). The evidence from these historical studies is generally mixed. Most of them have used simple tests to verify whether the real exchange rate is stationary over long periods of time. Others have tested simple convergence hypotheses, e.g. whether the real exchange rate's adjustment towards the mean is linear or non-linear[2]. The results from these tests seem to depend crucially on the chosen sample and countries, as well as the type of unit root tests employed.

Simple plots of the real exchange rates for the countries in our data set (the US, the UK, France, Germany, Italy and Switzerland) highlight the main problems with the PPP hypothesis in the very long run. Figures 1 and 2 show some of the (log) real bilateral exchange

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[1] The sources of the data series used are described in the Data Appendix.
[2] See for instance Mark (1996), Michael *et al.* (1997).

rates for the US and the UK, computed using consumer price indices (CPI), for the period[3] 1861-1998.

It is apparent from these plots that real exchange rates display major and persistent fluctuations over the sample period. Four basic features about these persistent movements have been emphasized in the literature. First, the major fluctuations in the real exchange rate are not restricted to periods of war or major economic disturbance. Second, there is (mixed) evidence that macroeconomic effects, such as differential rates of productivity growth or divergences in fiscal policy, have had persistent effects on real exchange rates over some historical periods (see for instance Kaminsky and Klein, 1994, Canzoneri *et al.*, 1998). Third, the persistent fluctuations in the real exchange rate are more apparent in periods on floating exchange rates than in periods of fixed rates (see Mussa, 1986). This is apparent when one compares the inter-war years with the years of the classical Gold Standard, and the experience post-1971 to that during the Bretton Woods period. Fourth, during floating, the volatility in the real exchange rate almost mirrors that of the nominal exchange rate, as relative prices tend to be much less volatile[4]. This can be shown with reference to one of the exchange rates in our sample, the US Dollar-UK Sterling rate. Figure 3 shows the relationship between the real US-UK real exchange rate since 1861. It is apparent that the period of floating rates after 1972 displays the greatest degree of divergence between the behaviour of the nominal exchange rate and relative prices, even compared to the post-Gold Standard float.

The central critique of the PPP hypothesis stems from this observation that the nominal exchange rate does not move in line with movements in the aggregate price ratios between countries. As discussed in detail in Rogoff (1995, 1996), one source of this failure might be at the micro-level, due to persistent deviations from the law of one price in different tradable

[3] For Switzerland the period covered by our data is 1890-1998, and for Germany it is 1875-1998.

sectors. Most studies on sectoral price data show considerable market imperfections and deviations from the law of one price with very few exceptions in the case of homogenous commodities (see Isard, 1977, Giovannini, 1988). Engel (1993) and Engel and Rogers (1994) also find compelling evidence in favor of the hypothesis that relative price movements across different countries suffer from a substantial 'border effect', so that nearby cities in different countries suffer from greater relative price volatility compared to distant cities in the same country. The absence of effective arbitrage in the markets for individual goods combined with the volatility of floating exchange rates seems to combine to cause major aggregate deviations[5] from PPP.

Despite the presence of disparities in the prices of similar goods across frontiers, one might expect there to be some convergence towards PPP on aggregate. Tests of the *relative* PPP hypothesis are based on a comparison of national macroeconomic price indices in a common currency, e.g. on the real (CPI-based) exchange rate magnitudes described in this paper. Given differences in index composition and adjustment, relative PPP is said to hold when relative price *changes* match nominal exchange rate *changes* across countries. To explain what factors might affect the level relationship between the nominal exchange rate and the price indices, it is convenient to start by decomposing the real exchange rate definition. Thus, we start by defining the real exchange rate with respect to the CPI as follows (all variables in logs):

$$q_t \equiv e_t + p_t^* - p_t \qquad (1)$$

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[4] See the evidence presented for a variety of currencies and historical periods in Frankel (1986), Rogers (1995), Mark and Choi (1997), Eichengreen (1988), and Abuaf and Jorion (1990).

[5] As noted in studies of absolute PPP, based on common baskets of goods across countries (see Rogoff, 1995), there are major deviations on aggregate as well as for individual goods.

where q is the real exchange rate, e is the nominal (spot) exchange rate, and p and $p*$ are, respectively, the domestic and foreign consumer price index. The CPIs will be weighted averages of traded (T) and non-traded goods (NT):

$$
\begin{aligned}
p_t &\equiv a p_t^{NT} + (1-a)\, p_t^{T} \\
p_t^{*} &\equiv b p_t^{*NT} + (1-b)\, p_t^{*T}
\end{aligned}
\tag{2}
$$

with different weights α and β in the home and foreign country. Next, let us define a real exchange rate measure in terms of the relative price of traded goods:

$$
q_t^T \equiv e_t + p_t^{*T} - p_t^T \tag{3}
$$

This implies that the real (CPI) exchange rate can be expressed as:

$$
q_t = q_t^T + b\,(p_t^{*NT} - p_t^{*T}) - a\,(p_t^{NT} - p_t^T) \tag{4}
$$

The level of the CPI real exchange rate will be affected by any factor which impacts on q_t^T or on the relative price of traded or non-traded goods in either country.

The factors affecting q_t^T, $(p_t^{*NT} - p_t^{*T})$ and $(p_t^{NT} - p_t^T)$ are several, both short-run and long-run. Let us first focus on the long-run influences (i.e. real shocks). First, as far as q_t^T is concerned, the prices of traded goods across countries might not be equalized by competitive forces, because of product heterogeneity, barriers to trade, or transport costs. However, we might still expect a given ratio of traded goods prices to persist through time, providing no real shocks hit the two economies. A shock to q_t^T might be real primary commodity price shocks if the two countries depend to different degrees on primary commodity imports. A second source of shifts in q_t^T might be caused by fiscal shocks in Keynesian aggregative models (e.g. Mundell-Fleming-Dornbusch), where a fiscal expansion causes a real appreciation and a ‘crowding-out’ of net exports.

However, the fiscal impact on the terms of trade can be very different in an intertemporal model in which the impact on the real exchange rate can also come via the relative price of traded and non-traded goods, $(p_t^{*NT} - p_t^{*T})$ and $(p_t^{NT} - p_t^{T})$. If government spending tends to be biased towards non-traded goods, a domestic fiscal expansion can cause an appreciation of the real exchange rate[6]. Whether fiscal policies have temporary or permanent impacts on the real exchange rate in these models depends critically on a number of factors: the assumptions made regarding factor mobility across the traded and non-traded goods sectors; whether Ricardian equivalence holds[7] (see Frenkel and Razin, 1995, Obstfeld and Rogoff, 1997); and on the possible distortionary effects of tax changes to finance government spending (see Alesina and Perotti, 1995). If factors or production are mobile across sectors, Ricardian equivalence holds, and there are no distortionary taxation effects, the impacts of *demand-side* effects on the real exchange rate, including fiscal policy, must be temporary.

Finally, even if factors are mobile across sectors and Ricardian equivalence holds, *supply-side* shocks can cause persistent or permanent shifts in the real exchange rate, through their impact on the relative price of traded and non-traded goods, $(p_t^{*NT} - p_t^{*T})$ and $(p_t^{NT} - p_t^{T})$. The most common explanation in this category is the Balassa-Samuelson effect (see Balassa, 1964, Samuelson, 1964). The argument is that productivity growth tends to be faster in the traded than in the non-traded goods sector. Then, given wage equalization across the two sectors and a given degree of competition in the traded goods sector, the prices of traded goods will rise less rapidly over time than those of non-traded goods. Hence a faster-growing country should experience a real exchange rate appreciation relative to a slower-growing country. Significantly, even if productivity shocks are temporary and not permanent,

[6] Other biased demand side effects can occur over time due to differences in the income elasticities of demand of traded and non-traded goods.
[7] In addition to fiscal policy demographic factors can also have an intertemporal impact on the real exchange rate, as 'vintage effects' are induced across different time periods (see Obstfeld and Rogoff, 1994, 1997).

they can have persistent effects due to intertemporal consumption smoothing effects (see Rogoff, 1992).

Turning next to the short-run effects on the real exchange rate, most standard aggregative models of the open economy of the Fleming-Mundell-Dornbusch variety predict that monetary shocks which cause deviations in the nominal exchange rate will only have a temporary effect on the real exchange rate. The duration of the impact depends on the degree of nominal rigidity in wage and price adjustment, and indeed on the relative speed of wage and price adjustment in the traded and non-traded goods sectors. The amplitude of nominal and real exchange rate fluctuations under flexible rates depend on the role of exchange rate expectations in asset markets, as is well known from 'overshooting' models.

According to these models we have to look to real shocks to provide an explanation for persistent movements in the real exchange rates, whilst we would expect monetary shocks to have only temporary effects, which are reversed following wage and price adjustment[8]. Productivity, fiscal and demographic disturbances can all have highly persistent, or even permanent, effects on q.

The main point which emerges from the current literature is that simple tests of stationarity and cointegration only provide a limited perspective on the PPP debate. A key issue which remains to be resolved is whether deviations from PPP over long horizons can be systematically attributed to fiscal and productivity shocks.

Whilst there have been numerous attempts to test the importance of the Balassa-Samuelson and fiscal policy effects on post-war data (see Canzoneri *et al.*, 1998, Chinn,

[8] However, there are forces which might make even nominal shocks quite persistent. Hysteresis in labor markets and vintage effects in investment, where new technology is embodied in new capital equipment, are important factors in explaining persistence effects in output and employment (see Darby *et al.*, 1996). A reduction in demand through a nominal shock may therefore have medium-run effects on productivity growth by inducing a slow-down in investment expenditure and hence in technology adoption. More generally, there is evidence to suggest that business cycles can have an impact on long-run productivity growth through a variety of channels (see Aghion and Saint-Paul, 1993) and therefore might impact on the real exchange rate.

1997), there have been very few investigations of the dynamic interactions between these variables and the real exchange rate on long historical series[9]. We aim to fill this gap by providing an assessment of the relative impact of these variables on real exchange rates using VAR analysis for a number of the countries in our sample. This provides a more systematic assessment of the degree to which fiscal and productivity variables are important in explaining persistent deviations from PPP. In addition, it allows us to test whether the deviations from PPP are purely a post-Bretton Woods phenomenon or not.

3. Testing the PPP hypothesis: Unit Roots and Real Exchange Rates

As noted above, many early tests of PPP took the form of unit root tests, or cointegration tests. Unit root tests were applied to real exchange rate series to check if, over certain sample periods, there was a tendency for the real exchange rate to display mean reversion (see for instance Darby, 1983, Hakkio, 1984, Frankel, 1986, Edison, 1987, Meese and Rogoff, 1988). Various unit root tests have been employed, but most of the studies tend to find it difficult to reject the null hypothesis that a unit root is present in real exchange rates in the post-1973 float. This is not surprising, given the graphs shown in Figures 1-2.

In order to compare the properties of our data series with those used in previous empirical studies, we tabulate Augmented Dickey Fuller (ADF) tests for the bilateral real exchange rates between the six countries, constructed using both CPI and WPI indices (see Table 1). When WPI indices are used to construct the real exchange rates, the null hypothesis of a unit root in the series is rejected for most bilateral rates, except some of the Swiss Franc and French Franc rates. In the Swiss Franc case, non-stationarity probably captures the real appreciation of the

[9] The only exception is the study by Kaminsky and Klein (1994), which models the Sterling-Dollar rate during the classical Gold Standard period using a variety of different fiscal policy variables.

SFr post World War II. These essentially confirm earlier studies on long-run historical data[10], which tend to find that, for *some* major industrialized economies the unit root hypothesis can be rejected given a sufficiently long data span. However, CPI-based real exchange rates still tend to display non-stationarity, and the CPI results are much more sensitive to the chosen sample. The fact that WPI-based real exchange rates are more likely to be found to be stationary is also well-known, and is attributable to the fact that WPI indices have a smaller non-traded goods component than CPI indices.

Table 1: Unit Root Tests on Bilateral Real Exchange Rates

	WPI Rate						
		Ita	UK	US	F	Ger	Swi
	Ita	-	**-2.94**	**-3.32**	-2.40	**-4.47**	**-3.04**
	UK	-2.74	-	**-3.04**	-2.37	**-3.29**	-2.39
CPI Rate	US	**-4.57**	**-3.19**	-	**-6.17**	**-3.54**	-2.48
	F	**-3.39**	**-3.03**	**-4.92**	-	**-3.37**	-1.69
	Ger	**-4.93**	-2.14	**-3.25**	**-3.57**	-	**-4.03**
	Swi	-2.72	-1.03	-1.43	-1.54	-2.30	-

Notes: (a) ADF Tests are computed using two lags. The test statistic is obtained from an ADF test which includes only a constant. The 95% c.v. for the first test is -2.89 given our sample size (1875-1998 for Germany's bilateral rates and 1861-1998 for all other rates). The tests were computed using Microfit 4.0.
(b) Numbers in ***bold*** *denote a statistic where the null of non-stationarity is rejected at the 5% significance level.*

Cointegration tests offer an alternative approach to testing for mean reversion in real exchange rates, As explained in Froot and Rogoff (1995), they provide a more flexible approach because of the less restrictive assumptions it makes about the relationship between traded and non-traded good prices in the two countries. Essentially cointegration tests are applied to the nominal exchange rate and the two countries' price indices, and one can test also whether a unit coefficient of opposite sign can be applied to the price indices, implying that the real exchange rate is stationary. Existing evidence employing cointegration tests[11] tends to show again that under floating rates cointegration is less likely to be found, and Froot

[10] See Frankel (1986), Edison (1987), Abuaf and Jorion (1990), Lothian and Taylor (1996).

and Rogoff (1995) report a greater tendency for these studies to find a stationary real exchange rate than univariate unit root tests.

In Table 2, we report the results obtained by applying the Johansen VECM estimation procedure (see Johansen, 1995) to each bilateral CPI-based real exchange rate. For each case, we report the number of significant cointegrating vectors found (if any) using both the maximum eigenvalue and trace tests statistics, and whether unit restrictions of opposite sign can be imposed on the two countries' price index.

The results from Table 2 are quite clear, and point against the validity of the simple PPP hypothesis. Although a significant cointegration vector can be found in 11 out of 15 cases, only in two of these 11 cases can we impose a unit coefficient on the price indices (Lit/$ and DM/$). The contrast between the results in Table 1 and Table 2 is typical of the mixed messages that emerge from simple tests of PPP. The advantages and disadvantages of unit root and cointegration tests are well documented in the literature (e.g. low power, sensitivity of the results to the specification of the model, including the lag structure and the use of dummy variables to capture regime shifts).

[11] See *inter alia* Enders (1988), Fisher and Park (1991) Cheung and Lai (1993).

Table 2: Johansen Cointegration Tests on CPI-based Bilateral Real Exchange Rates

Rate	Lit/£	Lit/$	Lit/SFr	Lit/FFr	Lit/DM	$/£	$/DM	$/SFr	$/FFr	DM/£	DM/SFr	DM/FFr	SFr/£	SFr/FFr	£/FFr
ME	**0**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**0**	**0**
T	**0**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**0**	**0**
E	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**	**-1**
P*	**-0.88**	**-1.10**	**-0.29**	**-1.67**	**-0.98**	**-0.37**	**-0.99**	**-3.91**	**-0.97**	**-1.03**	**-0.70**	**-0.98**	**-0.85**	**-0.29**	**-0.73**
P	**0.92**	**1.03**	**0.90**	**1.59**	**0.97**	**0.93**	**1.03**	**3.47**	**0.87**	**0.99**	**0.99**	**0.96**	**1.13**	**0.90**	**0.85**
$c^{2}(2)$	**2.08**	**0.39**	**15.39***	**9.96***	**8.13***	**19.93***	**2.21**	**20.99***	**1.23**	**24.81***	**22.24***	**13.35***	**8.40***	**11.80***	**5.57**

Notes:

(a) The values in the rows ME and T denote the significant eigenvectors found by applying Johansen's maximum eigenvalue and trace tests; a zero indicates that no significant eigenvectors were found (no cointegration). The chosen specification for the Johansen VECM model is with restricted intercepts and no trends in the VAR. A two-lag specification was used for the VAR and dummy variables for the two world war periods were included in the VAR as I(0) variables. The models were estimated using Microfit 4.0.

(b) The values in the next three rows denote the (normalised) estimated coefficients in the first significant eigenvector on the nominal exchange rate (E), the foreign price (P), and the domestic price (P) respectively.*

(c) *The final row tests the null hypothesis that the coefficients on the price levels in the first eigenvector can be restricted to unity (so that the real exchange rate is stationary) using a likelihood ratio test. The test statistic is distributed as a* c^{2} variate with two degrees of freedom under the null. *A (*) indicates that the hull hypothesis is rejected at a 5% significance level.*

(d) Key to exchange rates: Lit – Italian Lira, £ - UK Sterling, $-US Dollar, SFr – Swiss Franc, FFr – French Franc, DM – German Mark.

(e) The sample periods used were: 1861-1998 for all currencies except bilateral DM rates (1875-1998) and Bilateral SFr rates (1890-1998).

In the case of real exchange rate series, these problems are particularly serious, as it is a series which is the sum of various economic time series with their own individual properties. This point is made forcefully by a number of authors, notably Engel (1996). Starting from the decomposition of the real exchange rate in equation (4), Engel argues that we might expect the relative price of traded goods, q_t^T to be stationary[12], whilst the relative prices of non-traded and traded goods in the two countries are non-stationary (due to, say, a Balassa-Samuelson effect). Engel then shows, using Monte-Carlo evidence, that standard unit root tests run into problems because the CPI real exchange rate, q, is the sum of a stationary and a non-stationary component, and its first difference will therefore contain a moving average component. As noted by Schwert (1989) this causes problems with the size of standard unit root tests: the tests wrongly reject the null hypothesis of a unit root in a large proportion of cases. Engel (1996) also shows that alternative testing procedures, which test the null hypothesis of stationarity (see Kwiatowski *et al*., 1992) have a problem of low power in the presence of MA terms[13]. In all cases the cards are stacked in favor of finding stationary real exchange rates, even though they contain a non-stationary component.

There may also be other reasons for doubting the results from simple integration and cointegration tests. From the previous discussion, it should be apparent that whether one expects to find unit roots in the real exchange rate depends critically on whether the relative productivity and other supply shocks which are omitted from the above models are temporary (one-off differential shocks or recurring). It also depends on whether temporary nominal and real shocks can have highly persistent or even permanent effects on relative prices. Given that

[12] Even though for the reasons discussed above, deviations from the mean might be large and persistent.

[13] Indeed, in applying the Kwiatowski *et al*. (1992) LM tests to our bilateral exchange rates we obtain results which are almost invariably consistent with those reported in Table 2. These results are not reported here for reasons of space, but are available from the authors on request.

the nature of both productivity and nominal shocks might well change over time[14], unit root tests of PPP may well be highly sensitive to the particular sample chosen or the particular countries being tested. Unlike cointegration tests applied to behavioral models (e.g. consumption or money demand equations) where structural change can sometimes be modeled or accounted for, cointegration tests conducted on jointly dependent variables such as PPP need not show a consistent picture over time. A corollary of this is that one cannot necessarily assume that adding to the sample size by extending the sample period, or by using panel data techniques to stack data across different countries[15] will produce more efficient estimates. The rate of convergence towards the mean of the real exchange rate PPP might simply vary over time depending on the nature of the shocks[16].

This implies that the use of more structural econometric models that seek to understand the shocks hitting the real exchange rate are likely to prove more helpful in understanding real exchange rate fluctuations.

4. Modeling the Real Exchange Rate: VAR models

Our previous discussion highlights the need to supplement empirical evidence from univariate models with that from multivariate models which test the effect of different influences on the real exchange rate. A number of authors have sought to test the effect of some individual variables on the real exchange rate; e.g. the Balassa-Samuelson effect[17], or the

[14] To say nothing about the transmission mechanism of these shocks, which in intertemporal models will depend on demographic factors, the degree of substitutability of government spending and consumption spending, and the structure of labor markets.
[15] See for example Frankel and Rose (1995).
[16] Most of the long-run and panel studies find convergence rates to PPP which imply a half-life of deviations from PPP of 4-5 years. For reasons of space, we do not describe those models which allow for non-linearities in real exchange rate convergence (see for example Parsley and Wei, 1996, Mark, 1996, Bleaney and Mizen, 1996 and Michael *et al.*, 1997). Non-linearities do seem to be important in our data too. In preliminary tests, we found that the level terms in a non-linear ECM model along the lines of Michael *et al.* (1997) tend to be highly significant for our historical data.
[17] See Edison and Klovland (1987), Hsieh (1982), Obstfeld (1993), Canzoneri *et al.* (1998), Chinn (1997).

impact of government spending[18], although these empirical studies have mostly concentrated on the post-Bretton Woods float.

One of the problems with many of these investigations is that single-equation methods are employed to test the significance of additional explanatory variables, e.g. regressions of the real exchange rate on productivity differentials or relative fiscal policy magnitudes. These models therefore ignore the fact that there is unlikely to be a constant, time-invariant, long-run relationship between the real exchange rate and fiscal and productivity variables. They also ignore the fact that there is likely to be two-way dynamic interactions between the real exchange rate and the other variables. Finally, single-equation models do not allow us to attribute fluctuations in real exchange rates to different types of shocks.

A more natural vehicle to test the importance of additional influences on the real exchange rate is the use of multivariate semi-structural VAR models. Typical examples of this type of analysis can be found in Clarida and Gali (1994), Kaminsky and Klein (1994), and Rogers (1995), who base their analysis on a basic aggregative open economy macro-model. MacDonald (1996) uses a cointegrating VAR, by estimating the impact of fiscal and productivity variables on the long-run real exchange rate, and then using the Johansen cointegrating VAR on which the long-run restrictions have been imposed to examine the impulse responses of the real exchange rate to various fundamental variables in the VAR. The Clarida and Gali (1994) and MacDonald (1996) models are estimated on post-Bretton Woods data, whilst the Kaminsky and Klein (1994) and Rogers (1995) studies focus on the UK/US exchange rate, the first during the gold standard years and the latter for the historical data since the 19th Century.

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[18] See Froot and Rogoff (1991a, 1991b), Rogoff (1992).

Essentially, all these studies are based on simple aggregative open economy macro-models. Although they differ in the details[19], the essential structure of these models is the following:

$$y_t = a_1 q_t - a_2(i_t - E_t p_{t+1}) + e_t^g \qquad (5)$$
$$(m-p)_t = b_1 y_t - b_2 i_t + e_t^l \qquad (6)$$
$$i_t = E_t \Delta e_{t+1} + e_t^m \qquad (7)$$
$$E_t p_{t+1} = E_t p_{t+1} - p_t \qquad (8)$$
$$\bar{y}_t = \bar{y}_{t-1} + e_t^r \qquad (9)$$

where all the variables (except the exchange rate) and the shocks are described in 'relative' terms, i.e. as differences between the magnitudes in the two countries, and the model is expressed in terms of deviations from equilibrium. Equation (5) represents the relative IS curve, where the real exchange rate and the real interest rate $(i_t - E_t p_{t+1})$ impact on expenditure (*y*). The term e_t^g captures a relative fiscal shock. Equation (6) represents the 'relative' demand for real money balances (*m-p*), and e_t^l is a relative money demand shock. Equation (7) is the standard uncovered interest parity condition expressed in relative terms, where *e* is the nominal exchange rate and e_t^m is a relative money supply shock which impacts on the economy via its effect on the interest rate. Equation (8) defines the relative inflation rate in terms of the relative price level, *p*, and equation (9) simply defines the relative potential level of output $\bar{y}$ as a function of a relative productivity shock, e_t^r. To close the model we only need to make some assumption regarding price adjustment, and output adjustment towards its potential. The simplest way to do this is by either assuming that actual output is given by potential output, and that prices adjust each period to remove the gap between aggregate demand (y) and potential output, as in Dornbusch (1976) and Driskill (1981), or by

[19] For instance, MacDonald (1996) does not base his analysis on a standard structural VAR model, but around a cointegrating relationship where the real exchange rate depends on real-interest rate differentials and differences in fiscal and productivity variables. We return to this issue below.

assuming that output is demand-determined in the short run. Alternatively, more complex adjustment mechanisms can be considered. However, for most applications it is not necessary to consider the price-adjustment mechanism in detail.

This type of small structural model can be operationalized in the following way. The first is to focus on equations (5)-(7), assuming also that output is demand-determined in the short run. One can then estimate a semi-structural VAR model as in Gali (1992), where one imposes some identifying restrictions in order to recover the 'relative' structural or fundamental shocks (the ε's) from the reduced form residuals of the estimated VAR. A VAR based on the above model would include 4 variables (q, y, i, and (m-p)), by making some assumptions about the temporary nature of aggregate-demand side shocks[20].

The problem with this approach is that it involves making strong assumptions about some types of shocks (e.g. that fiscal disturbances work exclusively through aggregate demand and have no long-run effect on output). It also involves differentiating between different types of monetary shocks (money demand and money supply shocks) which seems inappropriate when we are dealing with data spanning different exchange rate regimes.

Hence we choose to employ a smaller VAR here, which does not require us to explicitly model different types of monetary shocks, whilst still allowing us to quantify the importance of real and other shocks to the real exchange rate in the short and long-run. Taking the uncovered interest parity condition for an n-period bond, and subtracting inflation from both sides, we have the real interest parity condition:

$$q_t = E_t q_{t+n} - (r - r^*)_t \qquad (10)$$

where the variables are now no longer expressed in relative terms, starred variables refer to the foreign country, and r represents the *ex ante* real interest rate on n-period bonds. If one

[20] See Blanchard and Quah (1989).

assumes that nominal shocks will not impact on the expected future real exchange rate, $E_t q_{t+n}$, and that this depends solely on productivity and fiscal shocks, then we have:

$$q_t = \bar{q} - (r - r^*)_t \qquad (11a)$$
$$\bar{q}_t = \bar{q}_{t-1} - l_1(e_t^g - e_t^{g*}) - l_2(e_t^r - e_t^{r*}) \qquad (11b)$$

However, as noted in Section 2, the impact of fiscal shocks on the real exchange rate might not be permanent, and the impact of both fiscal and productivity shocks in an intertemporal model will depend crucially on a variety of factors. These include demographic factors, consumer preferences and production technologies, as well as factor mobility across sectors (see Froot and Rogoff, 1995). This suggests that, rather than focusing on the estimation of equations (11), a semi-structural VAR model should be estimated, which will allow us to examine the dynamic interactions between these jointly dependent variables.

The specification which we adopt here for our VAR models is the following:

$$Z_t = \begin{pmatrix} q \\ r - r^* \\ (g/y) - (g/y)^* \\ (y/n) - (y/n)^* \end{pmatrix}_t$$

$$Z_t = c + g\,D_t + B_1 Z_{t-1} + \cdots + B_n Z_{t-n} + v_t \quad E(v_t v_t') = \Omega \qquad (12)$$

where the vector of variables is made up of the real bilateral (CPI) exchange rate, the real interest rate differential, (*r*-*r**), the differential in the fiscal expenditure/gdp ratios, $(g/y)-(g/y)^*$, and the differential in productivity levels, which is proxied by the differential in GDP per capita[21], $(y/n)-(y/n)^*$. The real interest rate in each country is proxied by the nominal rate on long-term bonds minus the inflation rate in the preceding year. The average maturity of the bonds whose yields are used in the construction of *r* is comparable across

[21] Although GDP per capita is commonly used as a proxy in tests of the Balassa-Samuelson hypothesis (see Balassa, 1964), it has been criticized by others as an imperfect measure. However, given the long time span of our data, and the lack of useful data on employment and capital stocks over our sample periods, we have no choice but to use the GDP/population ratio.

countries. Finally c is a vector of constants and D is a vector of two dummies to capture the First and Second World War periods (they both take the value of 1 during war years and zero in other periods).

The standard approach in structural VAR analysis is to obtain estimates of the reduced form (12), which yields consistent estimates of the B_i and of Ω. To analyze the impact of the structural economic shocks on the real exchange rate one has to move from the reduced form (12) to the structural or primitive form:

$$A_0 Z_t = c' + g' D_t + A_1 Z_{t-1} + \cdots + A_n Z_{t-n} + e_t \qquad E(e_t e_t') = V \tag{13}$$

where $B_i = A_0^{-1} A_i \quad \forall i = 1,..n$ and $\Omega = A_0^{-1} V (A_0^{-1})$. The e_t vector contains the fundamental or structural economic shocks to each of the variables in the VAR:

$$e_t' = \begin{pmatrix} e_{q,t} & e_{r,t} & e_{g,t} & e_{y,t} \end{pmatrix}$$

The $e_{r,t}$ shock captures any nominal shocks working through the real interest rate differential, and one would not expect these to have a long-run impact on the real exchange rate. The $e_{g,t}$ shock represents the impact of fiscal disturbances. Again, as noted above providing that there is factor mobility, Ricardian equivalence holds, and there are no distortionary taxation effects, one would not expect fiscal shocks to have a long-run impact on the real exchange rate (see Rogoff, 1992). The $e_{y,t}$ captures the impact of productivity shocks, and through the Balassa-Samuelson effect we might expect these to have a long-run impact on the real exchange rate[22]. Finally, the own fundamental disturbance on the real exchange rate, $e_{q,t}$ captures all other nominal shocks which are not related to movements in the real interest rate differential (e.g. deviations from interest parity) and real shocks which are

[22] As noted above, even temporary productivity shocks can have a permanent impact on the real exchange rate (see Rogoff, 1992, Froot and Rogoff, 1995).

not related to modeled fiscal or productivity disturbances (e.g. variations in consumer tastes and in technology).

The standard literature on structural VARs has suggested a variety of methods to identify the impact of the fundamental shocks ε on the variables of interest, and in particular the real exchange rate, q. This generally implies making the assumption that the fundamental shocks are uncorrelated[23], and imposing restrictions on the A_i suggested by economic theory. In this paper we rely on a number of zero restrictions on the A_0 matrix to solve the identification problem[24]:

$$A_0 = \begin{bmatrix} a_{11} & a_{12} & 0 & 0 \\ 0 & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \tag{14}$$

These involve imposing short-run restrictions on the way in which the fundamental shocks impact on the variables of the system. The assumptions made are the following: given the lags in the response of fiscal policy to other shocks, except those to output, the government expenditure series only responds instantaneously to $e_{y,t}$. The productivity series is deemed to respond instantaneously only to its own shock – this would seem to be a reasonable assumption to make, given that any endogenous responses of productivity growth to policy shocks will take time. The real interest rate differential is assumed not to respond instantaneously to the $e_{q,t}$ shock – the implication is that other shocks to the real exchange rate are not immediately reflected in the real interest rate differential. Although this assumption is more difficult to justify especially in a flexible exchange rate regime, our results do not seem to be sensitive to this restriction. Finally, the real exchange rate responds instantaneously to all the other fundamental shocks.

As an alternative to our recursiveness assumption, we could have used an identification scheme which relied on imposing certain long-run (Blanchard-Quah type) restrictions on the dynamic response of the variables to certain shocks. We have already indicated some of the firm predictions of economic theory regarding the long-run response of the real exchange rate to fiscal and monetary disturbances. However, especially in the case of fiscal policy, we wanted to examine the persistence profile of the impulse responses rather than simply assume that these effects disappear in the long run.

The other issue which has to be confronted at the outset is the stationarity of the VAR[25]. We confirmed that all our estimated VARs are stationary by examining the roots of the characteristic polynomial $|\mathbf{B} - l\,\mathbf{I}| = 0$ where $\mathbf{B}$ is the companion matrix of the reduced form parameter matrices B_i. In estimating our VAR reduced form, we used a specification with two lags (n=2). Tests for reduced lag structures based on the AIC indicate that n=2 is an appropriate specification for all our VAR models. Ljung-Box tests for residual autocorrelation were also conducted for each VAR equation and in the vast majority of cases (90% of the individual estimated equations, the null hypothesis of no serial correlation was not rejected at the 5% significance level. We found no cases where the null hypothesis of no serial correlation was rejected at the 1% significance level.

The VAR models in (12) were estimated for country pairs between four of the industrialised countries in our sample (the US, UK, Italy and France). Germany was excluded because of gaps in the fiscal, productivity and interest rate data during the two World Wars. In the case of Switzerland, we did not have consistent data on the GDP deflator for the period

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[23] An exception to this is the use of generalised impulse responses (see Koop *et al.*, 1996).
[24] See Lutkepohl (1991) for an outline of the Bernanke-Sims orthogonalization.
[25] One alternative to estimating the VAR in (12) would have been to estimate a cointegrating VAR. However, as noted above, imposing cointegrating restrictions on our model would have involved making some assumptions about the long-run relationship between the series in our VAR, and in some cases (i.e. the fiscal and productivity variables) these theoretical predictions should be tested empirically.

1861-1929. This meant that we could only have estimated our model on a much smaller (mainly post World War II) sample, and hence we excluded it from our VAR models.

For each of the country pairs, we report the impulse response functions to the three key fundamental shocks $\left(e_{r,t} \quad e_{g,t} \quad e_{y,t}\right)$ given our identification scheme. Standard errors for the impulse responses are computed using the bootstrapping procedure[26] described in Runkle (1987). These are then used to construct an interval containing 95% of the simulated results.

In what follows we focus mainly on the effects of relative fiscal and productivity shocks on the real exchange rate. The effect of the relative interest rate shock $e_{r,t}$ on the real exchange rate in each of the VAR models for the six real exchange rates is shown in Figure 4. Recall from (11a) that we would expect a positive relative interest rate shock to lead to a real appreciation in the short run so as to satisfy the real interest rate parity condition. The impulse responses in Figure 4 all display the predicted pattern, with the sole exception of the $/FFr rate. As expected, in all cases the impact of monetary shocks on the real exchange rate is temporary. However, interestingly in some cases the deviations are quite persistent (5 years in the case of the $/£ rate, and 9 years in the case of the FFr/Lit rate). This reflects the degree of persistence in the real exchange rate due to sluggish price adjustment.

The impulse responses for the six real exchange rates following a unit shock in $e_{g,t}$ and $e_{y,t}$ are shown in Figures 5 and 6. Turning first to Figure 5, we can note the following points. First, with the exception of the $/Lit rate, the movement in the real exchange rate has the predicted negative sign – i.e. a fiscal expansion generates a real appreciation. The perverse result in the case of the $/Lit rate may be picking up the fact that fiscal expansions in Italy were usually seen as pre-cursors of monetary accommodations. This was the case even during periods of fixed nominal rates (indeed Italy had a much more patchy adherence to the Gold

Standard in the period 1861-1913). Second, as predicted in intertemporal open economy models (see Froot and Rogoff, 1995, Obstfeld and Rogoff, 1994), the impact of the fiscal shock exhausts itself in the long-run. This confirms that fiscal disturbances cannot provide an explanation for long-run deviations from PPP. However, where the effect is significant (for the \$/Lit, \$/£, and FFr/Lit rates) the deviations can be persistent and last about 5-7 years. This is certainly sufficient to explain why simple cointegration tests of PPP on shorter samples of high-frequency data tend to reject the basic PPP hypothesis.

Turning next to Figure 6, we see that the dynamic response of the real exchange rate to $e_{y,t}$ is again in line with the predictions of economic theory. A number of points should again be highlighted. First, in all cases the medium to long-run response of a positive relative productivity shock is to appreciate the domestic real exchange rate, as predicted by the Balassa-Samuelson effect. In a number of cases the impact effect is temporarily positive, but this is probably attributable to the fact that our productivity variable is a GDP-based proxy and hence it is likely to reflect in part a response to a cyclical fluctuation. Second, in three cases (\$/£, £/FFr, and £/Lit), the effect of the productivity shock is to cause a permanent real appreciation.

Table 3 sets out the forecast error variance decomposition, which shows the proportion of the forecast error variance for each variable from innovations in the four fundamental shocks for different time horizons (2, 5, 10 and 30 years). Again, this confirms that, in the cases where the fiscal and productivity variables have a significant impact on the real exchange rate, this tends to be more pronounced in the medium to long run. This again conforms to what one might expect from economic theory.

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[26] 500 simulations were used for the procedure. Note that the distribution might not be symmetric.

Table 3: Forecast Error Variance Decomposition for the Real Exchange Rate

	Monetary and Other Shocks ($e_{r,t}+e_{q,t}$)				**Fiscal Shock ($e_{g,t}$)**				**Productivity Shock ($e_{y,t}$)**			
Ex. Rate	2 years	5 years	10 years	30 years	2 years	5 years	10 years	30 years	2 years	5 years	10 years	30 years
£/$	92.5%	75.5%	66.1%	54.9%	6.0%	17.7%	20.4%	19.1%	1.4%	6.7%	13.4%	25.9%
$/Lit	72.1%	68.7%	67.5%	65.1%	16.7%	22.1%	23.5%	25.0%	11.1%	8.4%	8.7%	9.8%
£/Lit	84.7%	88.1%	89.6%	85.9%	2.0%	1.9%	2.3%	5.6%	13.2%	10.0%	8.3%	8.5%
$/FFr	97.6%	97.5%	95.1%	93.9%	0.5%	0.7%	0.9%	1.0%	1.8%	1.7%	4.0%	4.9%
FFr/Lit	95.6%	90.9%	90.0%	90.0%	3.1%	7.7%	8.7%	8.7%	1.1%	1.3%	1.3%	1.3%
£/FFr	81.4%	80.7%	81.4%	82.2%	2.8%	2.1%	1.6%	1.8%	15.8%	17.3%	17.0%	16.0%

Can the fiscal and productivity variables explain the persistence in the real exchange rate, and deviations from the simple PPP hypothesis? The best way to assess this is to compare the PPP cointegration results set out in Table 3, with the significance of the impulse responses to the fiscal and productivity shocks for the six bilateral exchange rates for which VARs were estimated. This is done in Table 4. Where there has been a deviation from the simple PPP hypothesis (all of the six bilateral rates except the $/Lit rate), we would expect there to be a significant fiscal or productivity shock effect which might explain the deviation from the simple PPP hypothesis. In five out of the six cases the pattern conforms to what one might expect. In the case of the Italian Lira/US Dollar rate, as expected, the fiscal and productivity shocks do not have a significant and correctly signed impact on the real exchange rate. In all the other cases the fiscal and productivity variables have the predicted effect, with the sole exception of the French Franc/US Dollar rate where the fiscal effect is correctly signed, but is not significant. From Table 4 it seems apparent that, over long historical periods (and not just since the breakdown of Bretton Woods as some recent empirical evidence would seem to indicate), fiscal policy and the Balassa-Samuelson effect provide an explanation for persistent deviations from the simple PPP hypothesis.

Table 4: Deviations from simple PPP and Fiscal/Productivity Effects

Exchange Rate	Cointegration Test Holds?	Significant Fiscal Effect?	Significant Prod. Effect?
£/$	No	Yes	Yes
$/Lit	Yes	No	No
£/Lit	No	No	Yes
$/FFr	No	No	No
FFr/Lit	No	Yes	No
£/FFr	No	No	Yes

Notes:
(a) The cointegration PPP test is said to hold if one significant cointegration vectorcan be found and unit restrictions can be imposed on the price index variables.
(b) *A 'significant fiscal effect' is one where the fiscal shocks a correctly signed (negative) effect on the real exchange rate which is significant, at least in the short run.*
(c) *A 'significant productivity effect' is one where the productivity shock has a correctly signed (negative) effect on the real exchange rate which is significant in the long run.*

4. Conclusions

Traditionally the literature on real exchange rates has focused on issues such as whether PPP holds in the long-run, and why deviations from PPP seem to be so persistent. A consensus has emerged in open economy macroeconomics that traditional univariate tests of PPP are inappropriate once one accepts the fact that the real exchange rate is affected in the medium- to long-run by real shocks, such as fiscal policy, productivity trends, and other supply-side factors such as demographic influences. The focus then has to shift on trying to identify the nature of the shocks driving real exchange rate movements and to explain their persistence. This task has begun only relatively recently, and our paper offers some preliminary comparative results in this direction, using long-run historical data for several countries.

Our findings may be summarized as follows. First, we show that fiscal and productivity shocks seem to provide a convincing explanation of deviations from the simple PPP hypothesis. For those countries where the real exchange rate is non-stationary we find significant medium to long-run effects from fiscal and productivity shocks. Second, we extend the existing empirical literature by showing that the importance of fiscal and Balassa-Samuelson effects is not restricted to the post-Bretton Woods era. Third, we explicitly test some predictions of modern open economy macroeconomics. For instance, we confirm that fiscal shocks only have a temporary (though persistent) impact on the real exchange rate, and that even temporary productivity shocks can have a permanent impact on the real exchange rate (see Rogoff, 1992, Froot and Rogoff, 1995).

In future work, we intend to extend our VAR analysis to compare the results which can be obtained by estimating our models in different exchange rate regimes. We could also focus on differences across historical periods, as effects such as the Balassa-Samuelson effect depend on production technologies and these will have changed markedly over the period covered by our sample. In order to do this, time-varying estimation techniques have to be applied to our VAR models. This will be the subject of a future paper.

Data Appendix

Our data set contains the following series:

PY – GDP at Current Prices
P - GDP Deflator
PW -Wholesale price index (WPI)
PC – Consumer Price Index (CPI)
E – Nominal Exchange Rate
G – Fiscal Expenditure at Current Prices
R – Yield on Long-term Government Bonds
N - Population

The sample period is 1861-1998, except in the case of Germany, where the data starts in 1875, and there are gaps for the GDP and fiscal series during the two world wars, and Switzerland, where the GDP deflator data starts in 1929.

Real GDP and government expenditure series were obtained by deflating the current price series using the GDP deflator.

The pre-1950 GDP, fiscal and price data were obtained from Flora (1983, 1987), *State Economy and Society in Western Europe, 1815-1975. Vols. I and II*, Campus: Frankfurt, and Mitchell (1992), *International Historical Statistics – Europe 1750-1988*, New York: Stockton Press. and Mitchell (1993), *International Historical Statistics – The Americas 1750-1988*. New York: Stockton Press. The pre-1950 data on interest rates were obtained from Spinelli and Fratianni (1991) *Storia Monetaria d'Italia*, Milano: Mondadori; Friedman and Schwartz (1982) *Monetary Trends in the UK and the US* , Chicago: Chicago University Press; and Homer and Sylla (1995) *A History of Interest Rates*, New Brunswick: Rutgers University Press. The data for the post-1950 period was obtained from standard sources (*IFS, WEFA*), and spliced together to obtain continuous series for the whole sample period.

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