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Purchasing power parity over two centuries: strengthening the case for real exchange rate stability
A reply to Cuddington and Liang

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Abstract

Cuddington and Liang (2000) [Purchasing power parity over two centuries? Journal of International Money and Finance, 19, 751–755] examine the long span of sterling–dollar real exchange rate data of Lothian and Taylor (1996) [Real exchange rate behavior: the recent float from the perspective of the past two centuries. Journal of Political Economy, 104, 488–509] and claim to reject long-run purchasing power parity by fitting time trends or by considering very high-order autoregresssive representations. This reply demonstrates, however, that the central claims of Lothian and Taylor are in fact *strengthened* by the implications of Cuddington and Liang's analysis in that, while the economic importance of introducing trend terms is slight, this leads to a faster estimated speed of mean reversion. © 2000 Elsevier Science Ltd. All rights reserved.

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1. Introduction

We welcome the comment of Cuddington and Liang in this issue (hereafter CL) on our 1996 paper on real exchange rates as contributing to the spirit of debate

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which surrounds all worthwhile scientific endeavor. However, far from conceding that Cuddington and Liang have dealt the knock-out blow to real exchange rate stability over the past two centuries, it is clear to us that the central claims of Lothian and Taylor (1996) (hereafter LT) are in fact *strengthened* by the implications of CL's analysis.

2. Methodological issues

The central message of the CL analysis is that, in an analysis of our sterling–dollar real exchange rate data over the period 1791–1990, if very long lags are considered in the augmented Dickey–Fuller (ADF) auxiliary regressions, then the resulting ADF statistics do not enable rejection of the unit root hypothesis at the 5% significance level, while if very short lags are considered, then there are significant time trends. CL conclude that this is evidence against long-run purchasing power parity (PPP). In this section we shall briefly mention a number of methodological issues which might be raised in this context.

2.1. Implausible lag lengths

Starting from a lag length of 15 years and sequentially testing down by looking at the *t*-ratio of the coefficient of the longest lag, CL choose a lag length of 14 years for the ADF statistic and find that the unit root hypothesis cannot then be rejected at the 5% level. Since this involves 14 lags of the change in the real exchange rate, this implies an AR(15) representation for the real exchange rate. This seems to us both statistically and economically implausible.

It is statistically implausible because the sample autocorrelation and partial autocorrelation functions for the sterling–dollar real exchange reported in LT (in Fig. 4 of that paper) reveal no evidence of serial correlation beyond AR(1).[1]

It also seems economically implausible — why would any one entertain the idea of adjustment lags in real exchange rates spreading over such a long period, some 15 years? CL argue that the longer lag lengths are perhaps not implausible given the persistence in real exchange rates, citing Rogoff (1996). This does not seem to us, however, a strong argument, since one should distinguish between the amount of time taken for the full effects of a shock to be felt and the amount of time for which a shock persists. To take an extreme example, with a random walk process the full effects of a shock are felt after only one period but persist forever. With an AR(15) unit root representation seriously, however, it would take 15 years for the full effects of the real exchange rate shock to be felt, *after* which they would persist forever.

[1] One way in which a high-order autoregressive representation might arise is through the presence of moving average components, which are essentially inverted. This is not evident, however, either in the sample partial autocorrelation function (LT, Fig. 4) or from direct estimation of moving average components (LT, footnote 15, p. 495).

Moreover, the whole thrust of Rogoff's (1996) 'purchasing power parity puzzle' is the *implausibility* of high real exchange rate persistence.

CL note that shorter lags in the autoregressive representation lead to the null hypothesis of unit root behavior being rejected at the 5% level, although with the presence of a statistically significant time trend.

2.2. Heteroskedasticity

In LT, we were careful to use heteroskedasticity-robust estimation methods, since real exchange rate variability is known to vary widely across nominal exchange rate regimes. This issue is ignored by CL, however, so that their ADF results are in fact invalid: White's (1980) test for heteroskedasticity applied to the residuals from their ADF regression with zero lags of the dependent variable and a constant and time trend, for example, yields a test statistic with a marginal significance level of virtually zero.[2] The Phillips–Perron statistic reported by CL is, however, valid in the presence of heteroskedasticity and implies rejection of the null hypothesis of unit root behavior of the sterling–dollar real exchange rate, albeit in the presence of a statistically significant time trend.

3. Economic issues

Given the methodological issues raised in the previous section, the implication of the CL analysis is that the sterling–dollar real exchange rate appears to be stationary around a linear time trend over the period considered. The next question is whether or not this trend factor is *economically* as well as *statistically* significant.

Re-estimating the AR(1) representation for the sterling–dollar real exchange rate for the period 1792–1990 and including a linear time trend yields:

$$q_t = \underset{(0.045)}{0.807} q_{t-1} - \underset{(1.47\times10^{-4})}{3.11\times10^{-4}} t + \text{constant} + \text{residuals}, \tag{1}$$

where the figures in parentheses are heteroskedasticity-consistent estimated standard errors. This corresponds to the AR(1) specification estimated for sterling–dollar in LT, augmented by a time trend, and to the ADF regression with zero lags reported in Table 1 of CL, except that, in contrast to CL, we calculate heteroskedasticity-robust standard errors.

We have to concede from Eq. (1) that there is, indeed, a *statistically* significant time trend present. Moreover, re-estimating this equation with from two to 15 lags led to quantitatively and qualitatively almost identical results in terms of the magnitude of the estimated time trend coefficient, its statistical significance, and the sum of the autoregressive coefficients.

[2] White's (1980) statistic is asymptotically distributed as $\chi^2(3)$ under the null hypothesis of homoskedasticity; the value of the statistic obtained was 51.95.

The *economic* significance of this factor is, however, another matter. The estimated time trend coefficient is −0.000311. Since the real exchange rate is expressed in logarithms, this implies a long-run trend depreciation of sterling against the dollar of 0.0311/(1−0.807) or about 0.16% per annum. This does not seem to us to be of great moment economically.

Over the sample period considered, Britain underwent the first industrial revolution and became the world's leading industrial and economic power before declining relatively during the twentieth century. During the same period, the United States transformed itself from an exclusively rural economy to take Great Britain's mantle as the leading international economic power. It therefore seems reasonable to suppose that real effects such as the Harrod–Balassa–Samuelson (HBS) effect would have made themselves felt over the sample. In LT we certainly did not deny the possibility of permanent shifts in the real exchange rate; our overall objective was stated clearly:

> It also seems likely that, over a period of 200 years, there will have been important real shocks to the real exchange rate, some of which may have had permanent components. Our aim is to examine whether the hypothesis of a stationary real exchange rate is a good first approximation that describes the salient characteristics of real exchange rate behavior even over such a diverse period as the last two centuries (LT, pp. 493–494).

A particular concern, as the title of our article indeed suggested, was whether the simple AR(1) model that we had estimated continued to perform adequately under the current float. Based on both formal tests of stability and dynamic simulations, we found that it did. The existence of a linear trend does not overturn that conclusion. To have explained long-run real exchange rate behavior over the 200 year period as a whole to within 0.16% per annum, moreover, seems to us to have attained our overall objective quite well.

4. Strengthening the Lothian–Taylor results and resolving the PPP puzzle

On the other hand, including the time trend in the autoregressive representation for the real exchange rate may be viewed as *strengthening* our claim for significant mean reversion in the real exchange rate. Note that the estimated first-order autoregressive coefficient in Eq. (1) is 0.807, implying mean reversion in the real exchange rate of some 20% per annum, as opposed to the speed of mean reversion of about 11% per annum according to the original LT estimate. Put another way, this implies a half-life of shocks to the sterling–dollar real exchange rate of about 3 years, which is almost exactly half the estimated half-life without allowing for a time trend (i.e., about 6 years — see LT, p. 502). Hence, allowing for a time trend in the data, while not strongly economically significant in itself, does appear to strengthen our claim of significant mean reversion in the real exchange rate and goes some way to resolving Rogoff's PPP puzzle concerning the speed of mean reversion of real exchange rates.

Given, however, the economic history of the United States and Great Britain over the sample period, if the time trend is proxying for HBS effects, it seems unnecessarily restrictive to assume that the effects are linear. Accordingly, we experimented with adding higher-order trend terms into Eq. (1) and settled on the following cubic trend specification (heteroskedasticity-robust standard errors given in parentheses, sample period 1792–1990):

$$q_t = \underset{(0.043)}{0.767} q_{t-1} - \underset{(2.42\times10^{-4})}{9.36\times10^{-4}} t + \underset{(3.74\times10^{-8})}{9.26\times10^{-8}} t^3 + \text{constant} + \text{residuals}. \qquad (2)$$

The coefficients on the trend coefficients are again significantly different from zero but small in magnitude, and it might again be argued that the composite trend term is statistically significant but economically insignificant: it ranges between a maximum of +2% and a minimum of −5% over the entire 200 year period.[3]

What is interesting, however, is the effect on the estimated autoregressive coefficient. This has now shrunk again, implying mean reversion of the real exchange rate of about 23% per annum, or a half-life of about 2.5 years. Thus, allowing for HBS effects in this very simple fashion, while it does not affect LT's claim to have provided "a good first approximation", certainly appears to go some way towards resolving Rogoff's (1996) PPP puzzle of apparently very slow adjustment in real exchange rates.[4]

5. Conclusion

We are grateful to Cuddington and Liang for their interest in our work. Addressing the issues they raise, as it turns out, actually has allowed us to strengthen the claims that we made earlier in Lothian and Taylor (1996).

Methodological issues apart, there does seem to be evidence of statistically significant trends in the real exchange rate over the past two centuries. Nevertheless, the economic importance of these trends in one sense is slight, implying trend movements in the equilibrium real exchange rate of only a fraction of a percentage point per annum.

The inclusion of linear and, in particular, non-linear trends in the autoregressive representation of the real exchange rate, however, also implies much smaller estimates of the half-life of shocks to the real exchange rate — as low as 2.5 years. This, in fact, buttresses our claim of a stable real exchange rate and, at the same

[3] A plot of the estimated trend component of the real sterling–dollar exchange rate from Eq. (2) (not shown) reveals a non-monotonic shape of the trend which seems economically plausible and broadly to fit the pattern that one might expect of a Harrod–Balassa–Samuelson effect of an appreciating currency of a relatively fast-growing economy: a trend appreciation of sterling against the dollar until about the mid-nineteenth century followed by a trend depreciation into the twentieth century.

[4] Note that the estimated autoregressive coefficient in Eq. (2) is very close to that reported for the franc–sterling real exchange rate in LT, suggesting that allowing for HBS effects in this simple fashion between the US and Britain in fact leads to greater consistency in LT's results.

time, appears to go some way towards resolving Rogoff's (1996) 'PPP puzzle' concerning the slow speed of adjustment of real exchange rates.[5]

We are currently engaged in work in this area that seeks to identify the Harrod–Balassa–Samuelson effect more directly, rather than relying on the proxy of linear and non-linear trend terms. At the same time, we are exploring the possibility that this adjustment is itself explicitly non-linear, due for example to the presence of transactions costs in international goods arbitrage (Taylor et al., 1999). These additional refinements are likely to shed further light on the real exchange rate adjustment process.

In general, however, the present exchange only serves to strengthen our 1996 claim that long-run purchasing power parity does indeed provide "a good first approximation that describes the salient characteristics of real exchange rate behavior even over such a diverse period as the last two centuries" (LT, pp. 493–494).

References

Cuddington, J.T., Liang, H., 2000. Purchasing power parity over two centuries? Journal of International Money and Finance 19, 751–755.

Hegwood, N.D., Papell, D.H., 1998. Quasi-purchasing power parity. International Journal of Finance and Economics 3, 279–289.

Lothian, J.R., Taylor, M.P., 1996. Real exchange rate behavior: the recent float from the perspective of the past two centuries. Journal of Political Economy 104, 488–509.

Rogoff, K., 1996. The purchasing power parity puzzle. Journal of Economic Literature 34, 647–668.

Taylor, M.P., Peel, D.A., Sarno, L., 1999. Nonlinear mean reversion in real exchange rates: towards a solution to the purchasing power parity puzzles. Mimeo, Warwick Business School. International Economic Review, forthcoming.

White, H., 1980. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica 48, 817–838.

[5] An alternative statistical characterization that achieves much the same result is the use of dummy variables as in Hegwood and Papell (1998). Using the LT sterling–dollar data, they identify breaks in 1863 and 1929. Including dummy variables to allow for these breaks reduces the half-life of adjustment from 5.78 years to 2.32 years or by 60%. What these dummy variables are actually capturing — HBS effects, episodic phenomena as Hegwood and Papell (1998) suggest, or simple measurement errors in the data — is an open question.