This PDF is a selection from an out-of-print volume from the National Bureau of Economic Research

Volume Title: The International Transmission of Inflation

Volume Author/Editor: Michael R. Darby, James R. Lothian and Arthur E. Gandolfi, Anna J. Schwartz, Alan C. Stockman

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-13641-8

Volume URL: http://www.nber.org/books/darb83-1

Publication Date: 1983

Chapter Title: Movements in Purchasing Power Parity: The Short and Long Runs

Chapter Author: Michael R. Darby

Chapter URL: http://www.nber.org/chapters/c6138

Chapter pages in book: (p. 462 - 477)

15 Movements in Purchasing Power Parity: The Short and Long Runs

Michael R. Darby

Purchasing power parity is a customary starting point for explanations of price changes in a country maintaining a pegged exchange rate with a reserve country whose price changes are taken as given. Alternatively, movements in the exchange rate may be explained by relative changes in the price levels of two floating countries. One might argue that much of the difference between the monetary approach to the balance of payments and exchange rates and other approaches is to be found in the empirical question of whether purchasing power parity holds well enough for the problem being analyzed.

"Does purchasing power parity work?" has been a controversial empirical issue for decades, suggestive of a root conceptual problem. This chapter argues that the controversy over purchasing power parity (PPP) indeed arises from murky concepts rather than differences in data. A framework is proposed to identify those problems for which PPP "works" and those for which it does not. It is shown that in a stochastic framework, growth rates may coverge to the PPP relations even though the levels of the variables become unpredictable. This occurs because uncorrelated "permanent" shifts in PPP cumulate for the levels but average out for growth rates.

The empirical results do not really speak to the issue—so prominent in part III above—of whether a nonreserve country can exercise short-run monetary control under pegged exchange rates. The results do show, however, that even if short-run monetary control is possible, harmonization of money growth rates is not sufficient to maintain a pegged exchange rate and a balance-of-payments feedback rule is required.

An earlier version of this chapter appeared as "Does Purchasing Power Parity Work?" in the *Proceedings of Fifth West Coast Academic/Federal Reserve Economic Research Seminar* (San Francicso: Federal Reserve Bank of San Francicso, 1982).

The argument is presented in four sections: Section 15.1 analyzes the implications of alternative concepts of PPP. Section 15.2 examines the theoretical basis for supposing that the parity value takes a random walk. Section 15.3 reports estimated stochastic processes for the observed purchasing power ratio and discusses the implications of these estimates for alternative concepts of PPP. The chapter is concluded by a discussion of the implications of the results for monetary policies consistent with maintenance of a pegged exchange rate.

15.1 Concepts of Purchasing Power Parity

People who ask whether purchasing power parity works normally examine either of two distinct concepts:[1] the level concept and the growth concept. The level concept refers to the ability to predict the price level conditional upon the exchange rate and foreign price level or else the exchange rate conditional upon the two price levels. The growth concept refers to predictions of the inflation rate given the growth rates of the exchange rate and the foreign price level or to predictions of the growth rate of the exchange rate given the two inflation rates. It is generally unappreciated that the properties of the prediction errors of these two concepts may differ sharply.

The difference between the two concepts may be seen by reference to a simple discrete stochastic model. Define the purchasing power ratio (PPR) as the ratio of the domestic price level to the product of the exchange rate and the foreign price level, or, measuring the variables in logarithms,

$$(15.1) \qquad \psi_t \equiv P_t - E_t - P_t^* .$$

Suppose further that the stochastic process governing the log PPR is a martingale so that

$$(15.2) \qquad \psi_t = \psi_{t-1} + \epsilon_t ,$$

1. I treat the level—as well as growth rate—concept in relative purchasing power rather than absolute terms. Some writers require that all prices be the same across countries, but this absolute purchasing power parity is generally conceded to fail without necessarily reducing the usefulness of the parity idea. A third concept of purchasing power parity is sometimes assumed in theoretical modeling—that a parity value exists for any moment (although it might change unpredictably in the next period) so that $dP/dX = dE/dX + dP^*/dX$ holds. If this third concept holds as in Stockman (1980), nonreserve central banks have no monetary control under pegged exchange rates. That issue is examined in part III of this volume. Most of the literature (and this paper) is concerned with the unconditional *predictive* power of PPP, but, despite popular opinion to the contrary, this can tell us little about the theoretical implications of the monetary approach, only about its predictive power. No attempt is made here to review the huge literature on purchasing power parity, but see the May 1978 issue of the *Journal of International Economics* for a number of recent perspectives.

where ϵ_t is white noise with mean zero and variance σ^2. For the moment the random walk process (15.2) is only for illustrative purposes although previous estimates by Frenkel (1980*a*, *b*), Roll (1979), and Stockman (1978*b*) suggest it is not too far from the truth.

In this case the best prediction of ψ_{t+n} given the information available at time t is simply ψ_t. The prediction error is

$$\psi_{t+n} - \psi_t = \sum_{i=1}^{n} \epsilon_{t+i}. \tag{15.3}$$

This has mean zero and variance $n\sigma^2$. Thus the variance of the prediction error increases with the forecast period and goes to infinity for long-run predictions ($n \rightarrow \infty$).

But suppose we were interested in the growth concept of PPP. The relevant identity is now

$$\Gamma_n \psi_t \equiv \Gamma_n P_t - \Gamma_n E_t - \Gamma_n P_t, \tag{15.4}$$

where the growth-rate operator Γ_n computes the average growth rate over n periods ($\Gamma_n X_t \equiv (X_t - X_{t-n})/n$). The average growth rate of ψ_t from t to $t+n$ is

$$\Gamma_n \psi_{t+n} = \frac{1}{n} \sum_{i=1}^{n} \epsilon_{t+i}. \tag{15.5}$$

By inspection, the optimal prediction and the mean of the prediction error (15.5) are zero. The variance of the prediction error is σ^2/n, which decreases with the forecast period and goes to zero for long-run predictions ($n \rightarrow \infty$). Note that only for one-period predictions are the error variances the same for the level and growth concepts of PPP.

It seems paradoxical that the longer the period over which we are predicting, the less accurate are our predictions of the price level and the more accurate are our predictions of the average inflation rate, both conditional upon the behavior of the exchange-rate converted foreign price level. This occurs because errors shift the price level in a permanent and cumulative fashion in the level case, but these uncorrelated shifts average out in the growth case.

15.2 Need the Purchasing Power Parity Ratio Take a Random Walk?

Some authors—most notably Roll (1979)—have asserted that under conditions such that the interest arbitrage relations holds, the logarithm of the PPR, ψ_t, must follow a random walk. There is some evidence that those conditions do not obtain for national interest rates, where risks of currency controls and default in the forward contract arise.[2] Nonetheless let us suppose a strong form of the efficient-market-interest-arbitrage approach holds and show that it is not strictly necessary for ψ_t to take a random walk.

The interest relation for continuously compounded nominal interest rates i_t and i_t^* is

$$i_t = \xi_t(\Delta E_{t+1}) + i_t^*, \tag{15.6}$$

where ξ_t denotes expected values conditional upon information at time t. Also, assume a simple Fischer relation holds:

$$i_t = r_t + \xi_t(\Delta P_{t+1}), \tag{15.7}$$

$$i_t^* = r_t^* + \xi_t(\Delta P_{t+1}^*), \tag{15.8}$$

where r_t and r^* are the respective real interest rates.[3] Substituting equations (15.7) and (15.8) in (15.6) and rearranging terms yields

$$\xi_t(\Delta P_{t+1}) - \xi_t(\Delta E_{t+1}) - \xi_t(\Delta P_{t+1}^*) = r_t^* - r_t. \tag{15.9}$$

Note that the left-hand side is simply $\xi_t(\Delta\psi_{t+1})$, the expected change in the log PPR. This can differ from zero if the real interest rates differ. If shocks do occur which affect investment or saving in the countries and if it is costly to adjust the international allocation of capital instantaneously, then such shocks can cause temporary self-reversing movements in the log PPR which do not present any profit opportunities on either the financial or real side. That is, even if assets were perfect substitutes, nontrivial investment functions would permit movements in relative real interest rates.

Thus the form of the stochastic process governing the evolution of the PPR is an empirical question. This process may be a random walk, but there are good theoretical reasons to expect a more complicated process. In particular a random walk with an overlaid self-reversing moving average process is suggested by the above analysis. Doubtless other, possibly stationary processes could be justified by relaxation of some of

2. Interest arbitrage clearly does apply in the Eurocurrency markets where there is no differential control and default risk, but Eurocurrency rates do vary relative to the respective domestic interest rates. As discussed in chapter 10 above, since central banks seem to exercise monetary control under pegged exchange rates, we may infer that different national assets are not perfect substitutes. This latter finding implies, of course, that interest arbitrage won't hold with respect to the various national interest rates. See Dooley and Isard (1980) for an excellent treatment of these issues.

3. This abstracts from the effects of income taxes on nominal interest rates discussed in Darby (1975). To consider taxes, we would also have to consider differential taxation of interest and exchange gains, which would greatly complicate the analysis.

the assumptions. Let us turn to some estimated processes and see in what, if any, senses PPP works.

15.3 Estimated Stochastic Processes for the Purchasing Power Ratio

This section reports estimates of the stochastic process governing the log PPR for our standard seven countries: the United Kingdom, Canada, France, Germany, Italy, Japan, and the Netherlands. They will adequately serve to illustrate the senses in which PPP does and does not work. We define ψ_t, the logarithm of the ratio of the domestic price level to the exchange-rate converted U.S. price level, in three alternative ways according to whether wholesale price indices, consumer price indices, or implicit price deflators for GNP (sometimes GDP) are used. Since parts II and III of this volume imply that central bank intervention to maintain pegged rates can move the log PPR independently of fundamental forces, it is desirable to confine the analysis to the period after the breakdown of the Bretton Woods system. To obtain a sufficiently long post–Bretton Woods sample for estimating ARIMA processes, data for July 1971 through December 1978 were taken from the International Monetary Fund as detailed in the appendix to this chapter.

In every case ψ_t appeared to be nonstationary so that there is no *fixed*, long-run parity level of the PPR. A similar finding was made by Stockman (1978*b*) and is implicit in Frenkel's (1980*a*) inability to reject the hypothesis that the PPR follows a random walk.[4] The estimated ARIMA processes are reported in table 15.1. All are of the form ARIMA(0,1,q)—that is, moving average processes MA(q) applied to $\Delta\psi_t$, the first difference in the log PPR:[5]

$$\Delta\psi_t = \mu + \epsilon_t - \sum_{i=1}^{q} \theta_i \epsilon_{t-i}. \tag{15.10}$$

The drift term μ is admitted to allow for the possibility of trend movements in relative price levels. These may occur because of trends in movements of the relative prices of individual commodities weighted differently in the two national price levels.[6] Random shifts in relative prices are the most obvious explanation for permanent shifts in the log

4. Frenkel preferred the model AR(1) with an autoregressive parameter in the neighborhood of 0.9, in which case ψ_t is (barely) stationary and slowly tends toward a long-run value. If this is so, ARIMA(p,1,q) models will be overdifferenced; tests for this are reported below, but it is very difficult to distinguish a very slow autoregressive adjustment to a long-run parity value from a random walk for ψ_t.

5. At most q moving average parameters were fitted, since some series appeared to be MA(0) or MA(1) plus a seasonal component (usually quarterly or semiannual) which was also fitted.

6. See Stockman (1978*a*, 1980). Balassa (1964), and Samuelson (1964) provide different explanations for a trend.

Table 15.1 **Estimated ARIMA Processes for ψ_t, the Logarithm of the Purchasing Power Ratio [All Fitted Processes Are ARIMA (0,1,q)]**

	Price Index Definition		
Statistics	WPI	CPI	Deflator
		United Kingdom	
q	1	1	0
μ	0.0020(0.0033)	0.0026(0.0977)	0.0067(0.0087)
MA parameters	$\theta_1 = -0.4009(0.0997)$	$\theta_1 = -0.4689(0.0977)$	. . .
$\hat{\sigma}$	0.0223	0.0192	0.0459
$Q(12)$ [d.f.]	8.80 [11]	6.50 [11]	11.00 [12]
		Canada	
q	1	9	1
μ	0.0001(0.0014)	−0.0006(0.0008)	0.0002(0.0051)
MA parameters	$\theta_1 = -0.2075(0.1059)$	$\theta_1 = -0.1784(0.1001)$	$\theta_1 = -0.5187(0.1791)$
	. . .	$\theta_9 = 0.4086(0.1150)$	. . .
$\hat{\sigma}$	0.0107	0.0095	0.0186
$Q(12)$ [d.f.]	7.90 [11]	11.70 [10]	13.0 [11]
		France	
q	6	6	
μ	0.0019(0.0019)	0.0043(0.0027)	NA
MA parameters	$\theta_2 = 0.1150(0.1071)$	$\theta_1 = -0.2820(0.0894)$	
	$\theta_6 = 0.1694(0.1100)$	$\theta_3 = -0.2249(0.1012)$	
	. . .	$\theta_6 = 0.3389(0.1074)$	
$\hat{\sigma}$	0.0246	0.0221	
$Q(12)$ [d.f.]	13.90 [10]	7.30 [9]	
		Germany	
q	6	6	0
μ	0.0032(0.0019)	0.0050(0.0025)	0.0163(0.0092)
MA parameters	$\theta_6 = 0.3757(0.1046)$	$\theta_1 = -0.2706(0.1022)$	. . .
	. . .	$\theta_6 = 0.3550(0.1132)$	. . .
$\hat{\sigma}$	0.0275	0.0252	0.0495
Q12) [d.f.]	9.40 [11]	2.90 [10]	14.9 [12]
		Italy	
q	4	7	4
μ	0.0018(0.0015)	0.0020(0.0027)	0.0040(0.0035)
MA parameters	$\theta_4 = 0.2718(0.1055)$	$\theta_1 = -0.2725(0.1049)$	$\theta_4 = 0.6427(0.2336)$
		$\theta_7 = -0.2359(0.1093)$	. . .
$\hat{\sigma}$	0.0190	0.0177	0.0349
$Q(12)$ [d.f.]	6.40 [11]	10.70 [10]	11.6 [11]

Table 15.1 (continued)

Statistics	Price Index Definition: WPI	CPI	Deflator
		Japan	
q	0	0	0
μ	0.0050(0.0025)	0.0088(0.0026)	0.0253(0.0076)
MA parameters	...	...	...
$\hat{\sigma}$	0.0235	0.0248	0.0403
$Q(12)$ [d.f.]	9.00 [12]	11.40 [12]	18.7 [12]
		Netherlands	
q	6	6	NA
μ	0.0033(0.0017)	0.0065(0.0025)	
MA parameters	$\theta_6 =$ 0.3770(0.1055)	$\theta_1 =$ −0.2880(0.1028)	
	...	$\theta_6 =$ 0.2834(0.1153)	
$\hat{\sigma}$	0.0254	0.0233	
$Q(12)$ [d.f.]	9.40 [11]	6.00 [10]	

Notes. Standard errors appear in parentheses.

WPI and CPI data are monthly. Deflator data are quarterly. All estimations are for the period July 1971–December 1978, except some of the deflators were not yet available for the whole period; for these cases (*deflator only*) the estimation ends as follows: United Kingdom and Japan in September 1978, Italy in December 1977. The estimated standard error $\hat{\sigma}$ of the white noise process is the single-period standard error of forecast computed by the conditional method.

$Q(12)$ is the Box-Ljung variant of the Box-Pierce statistic for the "portmanteau lack of fit test." It is approximately distributed as χ^2(d.f.), where the degrees of freedom are indicated in square brackets following the value of Q. To reject the model at the 5% significance level, Q must exceed 21.0 for 12 d.f., 19.7 for 11 d.f., 18.3 for 10 d.f., and 16.9 for 9 d.f.; thus all the models pass this overall lack of fit test.

Estimation (backcasting method) was performed using BMDQ2T (a preliminary version of BMDP2T) on the UCLA computer.

PPR, so trends should be allowed also. If only trends were at work, then ψ_t would be nonstationary but the ARIMA(0,1,q) process would be noninvertible due to overdifferencing as discussed further below. The correct model to estimate would have the form

$$\psi_t = \alpha + \mu t + u_t. \tag{15.11}$$

We shall see that this deterministic but trended parity ($\alpha + \mu t$) does not appear to hold. Besides, with the exceptions of Japan, Netherlands, and perhaps Germany, the estimated values of μ in table 15.1 are all insignificant.

Of the forty processes estimated and reported in table 15.1, only five are strict random walks ($q = 0$). The rest of the cases may be viewed as a random walk to which one or more moving-average terms have been added. As suggested by Muth (1960), for the $q = 1$ cases we can view

$(1 - \theta_1)\epsilon_t$ as the permanent shift in the parity value of the log PPR and $\theta_1 \epsilon_t$ as the transitory change in log PR during the (one-period) adjustment process. If $0 < \theta_1 < 1$, then the initial change in ψ_t is greater than the change in the parity value so that a partially self-reversing correction occurs the following period. If, however, $-1 < \theta_1 < 0$, then the initial change in the log PPR is less than the change in the parity value and two periods are taken for full adjustment. For $q > 1$, similar albeit more complicated adjustment patterns are indicated for the first $q + 1$ quarters until the permanent shift

$$\left(1 - \sum_{i=1}^{q} \theta_i\right)\epsilon_t$$

in the parity value is reflected in the log PPR.

If there were no permanent shifts in the parity value of ψ_t, then

$$\sum_{i=1}^{q} \theta_i$$

would be 1. Table 15.2 reports t statistics of the form

$$(15.12) \qquad t = \frac{\sum_{i=1}^{q} \theta_i - 1}{\text{s.e. of } \sum_{i=1}^{q} \theta_i}.$$

Plosser and Schwert (1977) have pointed out that under the null hypothesis ($\Sigma\theta_i = 1$), the moving-average process is strictly noninvertible. In their examination of the case $q = 1$ and $\theta_1 = 1$, they showed that $\hat{\theta}_1$ was biased downward and their Monte Carlo experiments suggested that for sample sizes such as these a t greater than 3 or even 4 would be required to safely reject the null hypothesis at the 5% level of significance. Since this criterion is met in every case except for the Italian deflator definition, the hypothesis that there is a constant or deterministically trended parity value for the log PPR appears to be generally rejected. Note, however, that time-series tests for weak but persistent adjustment processes are prone to reject them; so it is perhaps appropriate to view the estimated processes as casting PPP in the worst light consistent with the data. It would be possible to impose a deterministically trended parity or force in more positive moving-average terms, either of which would reduce estimated prediction errors over substantial lengths of time.

The basic hypothesis of sections 15.1 and 15.2—that the log PPR takes a random walk with perhaps a moving-average adjustment process added—appears to be consistent with the data. On this hypothesis there is no parity value[7] toward which the log PPR tends in the long run. The

7. This applies to either a constant or a deterministic time trend which could be used for making predictions.

Table 15.2 **Test t Statistics for Stationarity of $\psi_t - \mu t$**

	t Statistics†		
Country	WPI	CPI	Deflator
United Kingdom	−14.05	−15.03	−4.77§
Canada	−11.40	−5.03	−8.48
France	−5.02	−5.74	NA
Germany	−5.97	−5.53	−6.19§
Italy	−6.90	−4.43	−1.53
Japan	−10.60§	−11.18§	−6.47§
Netherlands	−5.91	−5.95	NA

†The t statistics (15.12) are for the null hypothesis $\Sigma_i \theta_i = 1$, which would imply that $\psi_t - \mu t$ is stationary (there is a deterministic parity value of log PPR) and that the moving-average process is noninvertible. These t ratios are biased downward under the null hypothesis, but judging from Monte Carlo experiments reported in Plosser and Schwert (1977), $t < -4$ should be sufficient to reject the null hypothesis at the 5% significance level or better.

§In those cases in which an ARIMA(0,1,0) process (random walk) was reported as the optimal process in table 15.1, an alternative model ARIMA(0,1,1) was fitted and the t statistic for $\theta_1 = 1$ is reported with a §.

further ahead we make predictions of ψ_t, the greater is the variance. On the other hand, the longer the period over which we predict the average growth rate of ψ_t, the smaller is the variance. This paradoxical result is illustrated in table 15.3, which reports the standard errors of prediction implied for the models of table 15.1 for periods ranging from one observation to six years in the future. For ease in interpretation and comparison, the average growth rates per period $\Gamma_n \psi_t$ have all been converted to annual rates. Thus the prediction error for the one-year-ahead level and the corresponding annualized growth rate are the same. Over shorter periods, the prediction error of the annualized growth rates is greater than that of the corresponding level. Over longer periods the standard errors of the growth rates fall toward zero while those of the levels rise toward infinity. As was illustrated for the random walk case in section 15.1, these progressions toward zero and ∞, respectively, progress roughly with $1/\sqrt{n}$ and $\sqrt{n}$, respectively.[8] Thus at twenty-four years the level standard errors will be about double and the growth standard errors about half of those indicated for six years.

To interpret table 15.3, note that the growth rates are in decimal form so that the Canadian CPI-PPR six-year average growth rate has a standard error of 1.06% per annum. On the other hand, the corresponding British standard error is 3.98% per annum, nearly four times greater. These standard errors pretty well bracket the range for growth rates, with

8. For non–random walk cases, the early prediction errors are reduced by knowledge of past shocks, but this knowledge soon becomes unimportant. Nonetheless, the square-root rule is only approximate for these cases.

Table 15.3 **Standard Errors of Prediction for ψ_t and Annualized $\Gamma_n \psi_t$**

Periods†		WPI		CPI		Deflator	
n		Level ψ_t	Growth $12\Gamma_n\psi_t$	Level ψ_t	Growth $12\Gamma_n\psi_t$	Level ψ_t	Growth $4\Gamma_n\psi_t$
				United Kingdom			
1	[−]	0.0223	0.2676	0.0192	0.2304	...	...
3	[1]	0.0494	0.1976	0.0443	0.1772	0.0459	0.1836
12	[4]	0.1058	0.1058	0.0957	0.0957	0.0917	0.0917
24	[8]	0.1512	0.0756	0.1369	0.0685	0.1297	0.0649
48	[16]	0.2149	0.0537	0.1947	0.0487	0.1834	0.0459
72	[24]	0.2636	0.0439	0.2389	0.0398	0.2247	0.0375
				Canada			
1	[−]	0.0107	0.1284	0.0095	0.1140	...	...
3	[1]	0.0212	0.0848	0.0185	0.0740	0.0186	0.0744
12	[4]	0.0443	0.0443	0.0352	0.0352	0.0547	0.0547
24	[8]	0.0630	0.0315	0.0424	0.0212	0.0808	0.0404
48	[16]	0.0894	0.0224	0.0540	0.0135	0.1166	0.0292
72	[24]	0.1096	0.0183	0.0635	0.0106	0.1437	0.0240
				France			
1	[−]	0.0246	0.2952	0.0221	0.2652	NA	NA
3	[1]	0.0411	0.1644	0.0464	0.1856		
12	[4]	0.0701	0.0701	0.0989	0.0989		
24	[8]	0.0923	0.0462	0.1339	0.0670		
48	[16]	0.1254	0.0314	0.1851	0.0463		
72	[24]	0.1515	0.0253	0.2249	0.0375		
				Germany			
1	[−]	0.0275	0.3300	0.0252	0.3024	...	...
3	[1]	0.0477	0.1908	0.0518	0.2072	0.0495	0.1980
12	[4]	0.0792	0.0792	0.0942	0.0942	0.0991	0.0991
24	[8]	0.0985	0.0493	0.1230	0.0615	0.1401	0.0701
48	[16]	0.1287	0.0322	0.1662	0.0416	0.1982	0.0486
72	[24]	0.1531	0.0255	0.2003	0.0334	0.2427	0.0405
				Italy			
1	[−]	0.0190	0.2280	0.0177	0.2124	...	...
3	[1]	0.0329	0.1316	0.0360	0.1440	0.0349	0.1396
12	[4]	0.0543	0.0543	0.0820	0.0820	0.0698	0.0698
24	[8]	0.0722	0.0361	0.1225	0.0613	0.0711	0.0356
48	[16]	0.0987	0.0247	0.1778	0.0445	0.0735	0.0184
72	[24]	0.1195	0.0199	0.2195	0.0366	0.0758	0.0126

Table 15.3 (continued)

Periods† n	WPI Level ψ_t	WPI Growth $12\Gamma_n\psi_t$	CPI Level ψ_t	CPI Growth $12\Gamma_n\psi_t$	Deflator Level ψ_t	Deflator Growth $4\Gamma_n\psi_t$
			Japan			
1 [–]	0.0235	0.2820	0.0248	0.2976	...	...
3 [1]	0.0408	0.1632	0.0430	0.1720	0.0403	0.1612
12 [4]	0.0816	0.0816	0.0860	0.0860	0.0806	0.0806
24 [8]	0.1154	0.0577	0.1216	0.0608	0.1140	0.0570
48 [16]	0.1632	0.0408	0.1719	0.0430	0.1613	0.0403
72 [24]	0.1998	0.0333	0.2105	0.0351	0.1975	0.0329
			Netherlands			
1 [–]	0.0254	0.3048	0.0233	0.2796	NA	NA
3 [1]	0.0439	0.1756	0.0484	0.1936		
12 [4]	0.0726	0.0726	0.0912	0.0912		
24 [8]	0.0900	0.0450	0.1219	0.0610		
48 [16]	0.1172	0.0293	0.1672	0.0418		
72 [24]	0.1392	0.0232	0.2026	0.0338		

Note. Growth rates are reported on an annualized basis.
†The number of periods for the deflator is in square brackets.

the WPI definitions (with the exception of Britain and Canada) having smaller standard errors than the CPI definitions and the ranking of the deflator definitions mixed. The standard errors on the levels refer to the log PPR, so they indicate approximate proportionate errors. That is, two-thirds of the time after six years, the actual level of the CPI-definition Canadian PPR will be within 6.6% ($e^{0.0635} - 1 = 0.0656$) of the predicted level.

In view of table 15.3, can we say that PPP works? In an absolute sense, most of the average growth rate standard errors seem large even at six years, and it would take generation-long averages to halve these. The level standard errors are similarly large and growing. This would seem to suggest that PPP does not work. This answer appears too easy for a number of reasons: (1) Statistically, the standard errors in table 15.3 may be biased upward by omission of statistically insignificant but cumulatively important weak adjustment factors. Further, some observers would argue that the standard errors may be inflated by greater instability in ψ_t in the early post–Bretton Woods years than in recent years. (2) If one country is inflating much more rapidly than the other, the standard error will be a small fraction of the predicted change or average growth rate of the exchange rate. Only when relative price levels are fairly similar are the other factors important by comparison. (3) Finally, the other factors causing permanent movements in the log PPR are unpredictable (see Roll 1979); so PPP provides the best—although perhaps a poor—*predictor* of differences in real interest rates.[9]

The large standard errors of table 15.3 certainly do indicate the importance of efforts aimed at explaining movements in the value of the PPR relative to a deterministic PPP. It is not possible from these results, however, to infer whether these movements imply the absence of effective price arbitrage or merely period-to-period movements in the arbitrage parity values.

15.4 Conclusions and Implications for Monetary Policy

The key implication of these results for monetary policy is that it is not possible to maintain a pegged exchange rate or achieve an exchange-rate growth goal by manipulating monetary growth according to relative price levels. The fact that there are permanent shifts in the parity value of the purchasing power ratio implies that a policy targeted on a deterministic parity will result in deviations from the actual parity which become arbitrarily large as time progresses. Therefore, to maintain a pegged rate system, even if short-run sterilization policies are effective, a current and/or lagged balance-of-payments feedback rule must be used so that the domestic price level will fluctuate relative to the foreign price level according to the movements in the parity value. Similarly an exchange-rate growth goal can be achieved only if a feedback rule based on either actual exchange-rate growth or exchange intervention is followed. If two countries both follow either constant inflation-rate or money-growth rules, the level of their exchange rate (although not its growth rate) becomes increasingly unpredictable the further into the future one considers.

Nelson and Plosser (1980) have recently presented evidence that a large number of macroeconomic series are stationary and invertible in the first differences and therefore do not follow deterministic models such as equation (11). For all of those series, we have a result analogous to that in this paper: The variance of the levels increases without limit and the variance of the average growth rate goes to zero as the prediction interval goes to infinity. Consider, for example, the implications of random permanent shifts in the trend growth path of the money demand function, as well as transitory shifts.[10] Then even given the growth path of nominal

9. See section 15.2 above.

10. Lothian and Gandolfi in chapter 14 above fitted a second-order autoregressive process on the levels rather than fitting a process to the first differences as suggested by Nelson and Plosser and done for the log PPR in this chapter. As noted in chapter 14, given the estimated parameters, the fitted processes are de facto first-order autoregressive processes on the first differences.

money over a long period, we can only predict the future price level with great undertainty although the average inflation rate is almost perfectly predictable.

Permanent shifts—whether in the real demand for money or the purchasing power ratio—imply an opportunity for economists to explain the shifts by underlying real factors.[11] But they do place important restrictions on the evolution of the factors causing the permanent changes. As to purchasing power parity, while it may be the best predictor, it is not a very good one. There is much room for economic explanations of the permanent shifts in the purchasing power ratio. Does purchasing power parity work? For what?

Acknowledgments

The author acknowledges comments from Deborah Allen, Dan Friedman, Michael Melvin, and Charles Plosser. Michael T. Melvin and Andrew A. Vogel provided able research assistance. Pigott and Sweeney (1980) in an unpublished paper have independently arrived at similar conclusions by a rather more complicated and (I believe) problematic route.

Appendix

All data series were taken from the International Financial Statistics tape of the International Monetary Fund, dated April 1979. The actual series used are listed.

EXCHANGE RATES

Country	IMF Code	Description
United Kingdom	112_AF	market rate/par or central rate (£/$US)
Canada	156_AF	market rate/par or central rate ($Can/$US)
France	132_AF	market rate/par or central rate (FF/$US)
Germany	134_AF	market rate/par or central rate (DM/$US)
Italy	136_AF	market rate/par or central rate (L/$US)
Japan	158_AF	market rate/par or central rate (¥/$US)
Netherlands	138_AF	market rate/par or central rate (Dfl/$US)

11. For example, shifts in the real demand for money may be explained by real income taking a random walk and by random occurrence of institutional innovations. Or permanent changes in purchasing power parity may reflect changes in commercial policy and changes in the relative prices of goods with differing weights in the price indices.

WHOLESALE PRICE INDICES

Country	IMF Code	Description
United States	111_63	wholesale prices, 1975 = 100
United Kingdom	112_63	wholesale prices, 1975 = 100
Canada	156_63	wholesale prices, 1975 = 100
France	132_63	wholesale prices, 1975 = 100
Germany	134_63	wholesale prices, 1975 = 100
Italy	136_63	wholesale prices, 1975 = 100
Japan	158_63	wholesale prices, 1975 = 100
Netherlands	138_63	wholesale prices, 1975 = 100

CONSUMER PRICE INDICES

Country	IMF Code	Description
United States	111_64	consumer prices, 1975 = 100
United Kingdom	112_64	consumer prices, 1975 = 100
Canada	156_64	consumer prices, 1975 = 100
France	132_64	consumer prices, 1975 = 100
Germany	134_64	consumer prices, 1975 = 100
Italy	136_64	consumer prices, 1975 = 100
Japan	158_64	consumer prices, 1975 = 100
Netherlands	138_64	consumer prices, 1975 = 100

IMPLICIT PRICE DEFLATORS

These series are the ratio of the nominal to real product series for each country as follows:

Country	IMF Code	Description
United States	111_99A	GNP (billions of $US)
	111_99A.R	GNP, 1975 prices (billions of $US), seasonally adjusted
United Kingdom[12]	112_99A	GNP (£)
	112_99B	GDP: 1975 prices (£)

12. For the United Kingdom, the IMF tape contains no nominal GDP or real GNP data. Judging from the ARIMA process reported in table 15.1, the difference is close enough to proportionate to present no problem in this case.

Canada	156_99A	GNP ($Can)
	156_99A.R	GNP: 1975 prices ($Can), SA
Germany	134_99A	GNP (DM)
	134_99A.R	GNP: 1975 prices (DM), SA
Italy	136_99B	GDP (L)
	136_99B.R	GDP: 1975 prices (L), SA
Japan	158_99A	GNP (¥)
	158_99A.R	GNP: 1975 prices (¥), SA

References

Balassa, B. 1964. The purchasing power parity doctrine: A reappraisal. *Journal of Political Economy* 72 (December): 584–96.

Darby, M. R. 1975. The financial and tax effects of monetary policy on interest rates. *Economic Inquiry* 13 (June): 266–76.

Dooley, M. P., and P. Isard. 1980. Capital controls, political risk, and deviations from interest-rate parity. *Journal of Political Economy* 88 (April): 370–84.

Frenkel, J. A. 1980*a*. Flexible exchange rates in the 1970's. NBER Working Paper, no. 450, February.

———. 1980*b*. Exchange rates, prices, and money: Lessons from the 1920's. *American Economic Review* 70 (May): 235–42.

Muth, J. F. 1960. Optimal properties of exponentially weighted forecasts. *Journal of the American Statistical Association* 55 (June): 299–306.

Nelson, C. R., and C. I. Plosser. 1980. Trends and random walks in macroeconomic time series. University of Rochester Center for Research in Government Policy and Business Working Paper no. GPB80-11, August.

Pigott, C., and R. J. Sweeney. 1980. Purchasing power parity and exchange rate dynamics: Some empirical results. Unpublished paper, circa April.

Plosser, C. I., and G. W. Schwert. 1977. Estimation of a non-invertible moving average process: The case of overdifferencing. *Journal of Econometrics* 6 (September): 199–224.

Roll, R. 1979. Violations of purchasing power parity and their implications for efficient international commodity markets. In M. Sarnat and G. Szego, eds., *International finance and trade*, vol. 1. Cambridge, Mass.: Ballinger.

Samuelson, P. A. 1964. Theoretical notes on trade problems. *Review of Economics and Statistics* 46 (May): 145–54.

Stockman, A. C. 1978*a*. International relative prices under fixed and flexible exchange rate systems. UCLA Department of Economics Discussion Paper no. 130, September.

———. 1978*b*. Evidence on the time-series behavior of deviations from purchasing power parity and implications for exchange-rate theories. UCLA Department of Economics, unpublished paper, November.

———. 1980. A theory of exchange rate determination. *Journal of Political Economy* 88 (August): 673–98.