A History of Yen Exchange Rates

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Abstract

The history of Japanese exchange rates, though short by British or American standards, is exceedingly rich, both from the standpoint of variation in the data and in the institutions governing exchange rate arrangements and Japanese monetary conditions. This paper reviews that history and traces the evolution of yen-dollar and yen-sterling exchange rates from 1874 until the present, comparing their behavior to that of the dollar-sterling rate. It shows the relationships of all three nominal exchange rates to indexes of purchasing power parity, and it investigates the links among exchange-rate regimes, exchange rates themselves and other macroeconomic variables. Two conclusions emerge: (1) Purchasing power parity — at least in relative form — held remarkably well for the yen over the longer run. (2) The variability of real yen exchange rates under the current float does not, in fact, differ greatly from the often substantial and largely self-reversing movements observed historically.

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1. INTRODUCTION

The history of Japanese exchange rates, though short by British or American standards, is exceedingly rich, both from the standpoint of variation in the data and in the institutions governing exchange rate arrangements and Japanese monetary conditions. In the approximate century and a quarter that followed the Meiji restoration of 1867, Japan experienced three episodes of floating exchange rates, two episodes — one very brief — on the gold standard, a period of heavily managed floating rates during the interwar years, the dollar peg of the Bretton Woods era, and the exceptionally severe inflation and accompanying substantial yen depreciation of the World War II years.

In this paper I review that history. I trace the evolution of yen-dollar and yen-sterling exchange rates from 1874 until the present and compare the behavior of both to that of the dollar-sterling rate. I go on to analyze the relationship of all three to indexes of purchasing power parity and to examine the links among exchange-rate regimes and the behavior of exchange rates themselves and of other important macroeconomic variables.

2. HISTORICAL DESCRIPTION OF EXCHANGE-RATE BEHAVIOR

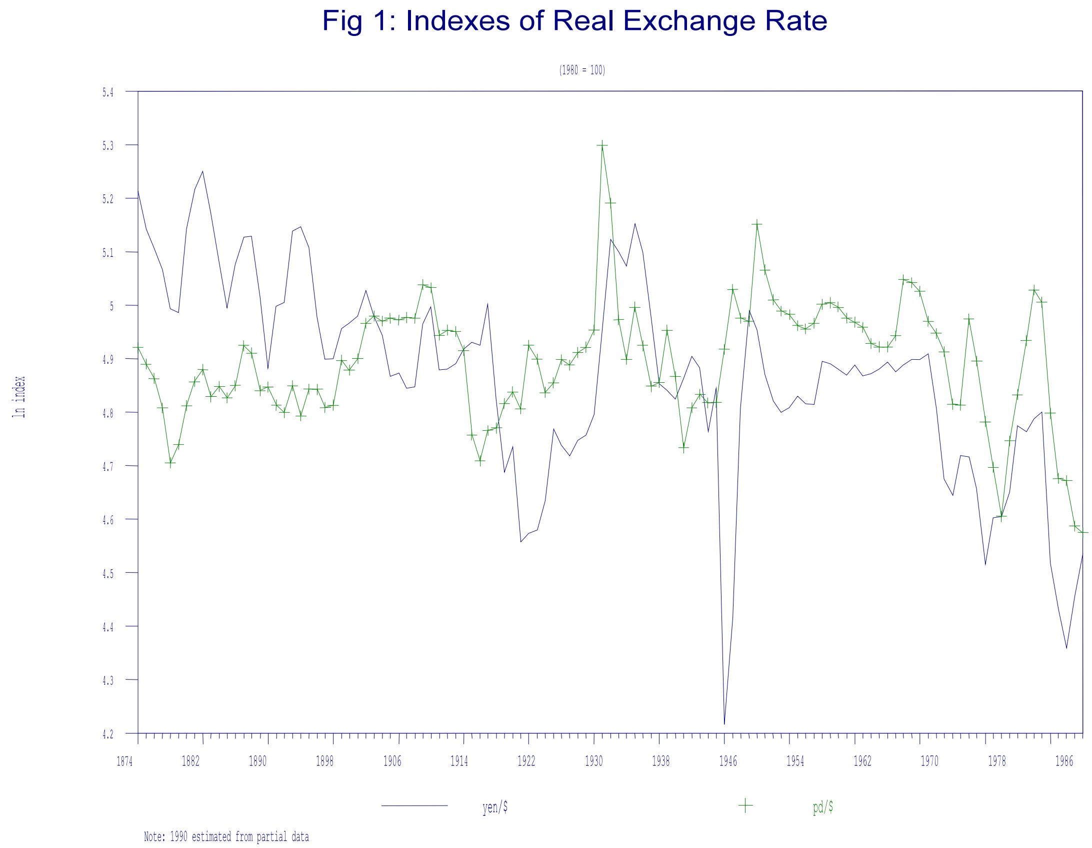
Following the Meiji restoration, Japanese trade with the rest of the world increased dramatically. From a base of essentially nil at the time of Admiral Perry's first visit in 1853, exports rose to approximately 15% of GDP shortly after the turn of the century and to over 20% of GDP by the 1920s.[1]

For most of the nineteenth century, however, Japan was not on the gold standard. From 1867 to 1878, the Japanese monetary system was effectively a system of fiat currency and floating exchange rates. From 1878 until 1897, when Japan did finally adopt gold, Japan both *de jure* and *de facto* was on a silver standard. The result was a continuation of floating rates relative to the gold standard world.[2]

This flexibility in exchange rates enabled Japan to avoid the deflation that prevailed in Britain, America, and other countries on gold during these years. We can see this in Table 1.[3] Over the subperiod 1874 to 1887 Japanese wholesale prices showed virtually no net change, earlier inflation being offset by later deflation. Over the later subperiod 1888 to 1896, they actually rose by 35%. In the United States, wholesale prices declined by slightly over 40% between 1874 and 1887 and by another 21% between 1888 and 1896. In Britain, the deflation followed a largely similar pattern, cumulative declines in wholesale prices of 41% and 11% in the two subperiods, respectively.

In the foreign exchange market, the yen depreciated relative to both the dollar and sterling. For the full period 1874 to 1896, the increase in the yen-dollar rate averaged 3.15% per year and the increase in the yen-sterling rate, 3.03% per year. In both instances, the declines were more or less in line with the cross-country differences in inflation rates, but in neither case was the offset exact. In real terms, the yen appreciated somewhat against both currencies, while the dollar fell slightly against sterling. We can see this in the figures presented in the last three columns of Table 1 showing the average annual percentage changes in real exchange rates and in the plot of the real yen-dollar and real pound-dollar rates in

Figure 1.[4]



Purchasing power parity, therefore, held tolerably well as a first approximation. But for Japan in particular it was only that. One possibility for the slack in the relationship between changes in nominal exchange rates and the differential in inflation rates is measurement error in the Japanese price data, an overstatement of the levels of wholesale prices in the later relative to the later years of the period. An alternative is a shift in the equilibrium real exchange rate, resulting perhaps from increased productivity in the Japanese tradeable goods sector.[5]

In addition to these trend-like movements, both yen real rates exhibited fairly sizable year-to-year variability, well in excess of the variability of dollar-sterling, particularly in the subperiod from 1888 to 1896. This variability, however, had no obviously adverse effects on other real variables, either real trade flows or real output. Exports and imports increased substantially as already noted. Rates of growth of Japanese real income and industrial production were comparable to or higher than the rates in Britain and America. Between 1885 and 1900, real income in Japan increased at an average annual rate of 3.1% versus 2.35% in the United Kingdom and 2.79 in the United States. Over the longer period 1874-1896, industrial production increased by 4.75% per year in Japan versus 1.96% per year and 4.44% per year in the United Kingdom and the United States respectively.[6]

Table 1

Rates of change of wholesale prices, nominal exchange rates and real exchange rates in Japan, the United States and the United Kingdom, 1875-1989

	Wholesale prices			Nominal rates			Real rates		
Period	Japan	U.S.	U.K.	¥/$	¥/£	£/$	¥/$	¥/£	£/$
1875-1896	1.43	-2.77	-2.30	3.15	3.03	0.12	-1.07	-0.71	-0.36
1875-1887	-0.27	-3.10	-3.03	2.16	2.06	0.10	-0.66	-0.69	0.03
1888-1896	3.91	-2.30	-1.24	4.56	4.41		0.15	-1.65	-0.74
-0.91									
1897-1914	2.67	2.15	1.58	0.17	0.34	-0.17	-0.34	- 0 . 7 4	
0.40									
1915-1940	3.76	0.54	1.96	2.86	1.62	1.24	-0.36	-0.17	-0.19
1915-1921	10.58	5.10	9.90	0.35	-2.91	3.26	-5.13	-3.59	-1.55
1922-1928	-5.21	-5.81	-9.77	0.51	3.72	-3.21	2.69	1.20	1.49
1929-1940	3.29	-1.76	1.27	5.69	3.03	2.66	0.64	1.01	-0.37
1941-1953	40.24	5.92	6.74	34.13	32.37	1.76	-0.18	-1.13	0.94
1954-1973	1.37	2.16	3.24	-1.42	-2.11	0.69	-0.62	-0.24	-0.38
1974-1989	2.85	5.71	9.74	-4.24	-6.23	1.99	-1.37	0.67	-2.04

Source: See endnote 3.

Note: Figures are continuously compounded per cent per annum rates of change.

The difference between Japanese and U.S. and U.K. price behavior in this last quarter of the nineteenth century appears to a large extent to mirror international developments rather than domestic monetary policy actions in Japan. Throughout these years, countries were continually shifting from silver to a gold standard. At the same time that this shift in the relative demands for the two precious metals was taking place, discoveries of silver in the United States were increasing its supply. The result, as Irving Fisher (1911) documented, was an upward trend in the price levels of the countries that remained on silver and a downward trend in the price levels of countries on gold.

When Japan did make the switch to gold in 1897, price movements in the gold-standard world had begun to reverse. Gold discoveries, coupled with the introduction of improved methods of refining, led to a more than doubling of the world's gold stock from 1890 to 1914. (Friedman and Schwartz, 1963, p. 137). This in turn increased growth in money supplies and thus caused prices to rise. In Japan, the inflation exceeded that of the rest of the world. Given the fixed nominal exchange rate, the yen therefore depreciated against both the dollar and sterling in real terms. Government borrowing abroad and the drawing down of the gold balances received as an indemnity payment following the war with China in 1893 and 1894 are the likely reasons for this disparity in price behavior.[7] These enabled Japan to insulate itself from the operation of international gold-standard forces and thus to pursue inflationary policies domestically.

In 1914, with the outbreak of war in Europe, the worldwide gold standard broke down, most countries blocking its workings by placing embargoes on gold exports, some leaving gold completely. Japan took the former route until 1917, at which point it left gold officially. Unlike Britain and America, Japan remained off the gold standard throughout the 1920s, not returning until the beginning of 1930, and then only to leave a scant two years later.

The twenties were not, however, years of completely free floating yen exchange rates. An initial attempt to peg the yen against the dollar (1919 to 1920) was followed by controlled depreciation and then two planned, but aborted, moves to return to gold. The first attempt failed in the wake of the Great Kanto Earthquake of 1923 and the large trade deficits that resulted. The second, after a year of preliminary stabilization of the yen, was abandoned following the financial panic of March 1927 (Takagi, 1989). The years 1932 to 1934 were marked by a more or less free yen float, but the five years that followed by a peg of the yen to sterling.

What stands out during the 1915-1940 period is the volatility of real exchange rates. Judged in terms of both the subperiod-average rates of change shown in Table 1 and the yearly standard deviations shown below in Table 2, it was at record highs, far greater than under the gold standard and, in the main, even greater than under the post-Bretton Woods float. The only sense in which this is not the case is for the period viewed as a whole. The average annual rates of change of all three real rates over the years 1915 to 1940 were in fact less than the respective averages for the years prior to 1914. In each instance, protracted movements of the real exchange rate in one direction during WWI and the years immediately thereafter were very nearly offset by subsequent protracted movements in the opposite direction. Over the longest period, therefore, purchasing power parity again appears to have held, despite substantial departures for long periods in between.

With World War II came the disruption of international transactions, breaks in the official yen exchange-rate data and substantial increases in price levels around the world. In Japan, the inflation was severe. Between 1940 and 1949 Japanese wholesale prices increased by a multiple of 127, or at a continuously compounded average annual rate of increase of 53.8%. Relative to American and British wholesale prices, this translated into (continuously compounded) cumulative increases in excess of 400%.

In 1948, when official data for yen exchange rates become available, its value relative to the dollar had fallen from the 4.35 yen per dollar rate in place in 1940 to 160 yen per dollar. By 1950, in the face of continued strong inflation, it reached 361 yen per dollar, roughly the rate maintained for the remainder of the Bretton Woods era.

Then in 1971, in the face of monetary excesses in the United States, the reserve-currency country, the Bretton Woods system broke down and the current float began. Since then the yen has shown a trend-like nominal appreciation against the dollar and sterling, a similar real appreciation against the dollar, though somewhat surprisingly, not sterling, and a series of alternating sharp shorter term real appreciations and depreciations against both currencies.

The monetary part of the picture during the early years of the float can be divided into three episodes, all of which show evidence of links to U.S. policy. In the mid 1970s, Japan in part as a spillover from policy in the United States, experienced both high money growth and inflation (Darby and Lothian, 1983b). In its aftermath, however, Japanese policy became considerably tighter than policy in the United States and remained so longer. Despite renewed expansionary effects emanating from the United States via the balance of payments, Japan therefore escaped the double-digit inflation that plagued America and Britain at the start of the last decade.[8] In the latter part of the 1980s, Japan appears to have again been led into expansive policy as the Bank of Japan, along with the U.S. Federal Reserve, sought to halt the depreciation of the dollar.

Of particular interest in these episodes is the pattern of volatility of real exchange rates and of inflation. Over time, fluctuations in inflation have become more muted in Japan while fluctuations in the real yen- dollar rate have remained substantial. This, coupled with the longer term downward trend in the yen-dollar real exchange rate have been a source of increased skepticism about both purchasing power parity as an equilibrium condition and the functioning of the floating rate system.

3. PPP, REAL EXCHANGE RATES AND EXCHANGE-RATE REGIMES

The historical overview highlights several sets of important issues. One has to do with the purchasing power parity relationship. The other centers around the links between exchange-rate regimes, exchange-rate variability and the behavior of other macroeconomic variables. The specific question that arises with regard to PPP is whether the tendency for nominal exchange rates to move in line with relative price levels that is apparent in the longer term comparisons presented in Table 1 is a behavioral phenomenon or simply a statistical quirk, the spurious correlation that can arise between two trended series.

The theoretical rationale for PPP and modified PPP relationships is as a macroeconomic equilibrium condition. In the simplest theoretical models, which ignore the effects of real variables like productivity and differences in relative prices of traded and non-traded goods, absolute PPP holds. It is the open-economy analogue of the classical closed-economy neutrality proposition as in in the monetary-approach models of the type developed in Frenkel and Johnson (1976). Expressed in log form, the absolute PPP relationship is

$$p_t - e_t = p_t^* , \tag{1}$$

where p, and p^* represent the logarithms of the price levels in the home country and the foreign country respectively, e represents the logarithm of the nominal exchange rate (the price in the home country's currency of a unit of the foreign country's currency), and t is an index of time.

There is now abundant empirical evidence suggesting that to the extent that purchasing power parity holds, it does so only over longer time periods, and that even then there may be disturbances to the relationship that are highly persistent in their effects. Two general classes of models have evolved to explain this phenomenon. In one, which is an extension of the monetary-approach model, such deviations are purely transient, the result of sluggish adjustment of prices to monetary shocks. (See, e.g., Dornbusch, 1976). In the other, which assumes instantaneous adjustment of goods prices and thus the price level, deviations from PPP can be permanent, the result of real shocks that affect the equilibrium real exchange rate (See Stockman, 1980). Models of this class preserve the long-run neutrality (or super-neutrality) of money but see absolute PPP as a highly special case that would only exist in the limit, in situations in which real influences were of no practical significance. Relative PPP does, however, potentially fare better in these models. Real shocks have one-time effects on levels. As the time period lengthens, the effect on rates of change therefore progressively diminishes.

Extending the concept of neutrality in another direction, Stockman (1983) demonstrated that within the context of an equilibrium model similar to the one developed in his earlier (1980) paper, and as intuition might suggest, the (nominal) exchange-rate regime should have no effect on the equilibrium behavior of real variables, including that of the real exchange rate.

Like continuous PPP, this insight does not appear to carry over to the actual data. Real exchange rates, as Stockman went on to show and as evidence in Mussa (1986) confirms, have been more variable under floating rates than fixed rates during the post-WWII period. The behavior of other real variables, however, appears to be invariant across the two regimes (Baxter and Stockman, 1989; Baxter, 1991).

The major difficulty that arises in interpreting these results is that the regime is essentially an endogenous variable. The choice of regime very likely is influenced by factors that, in turn, affect monetary and price-level behavior, and also by the behavior of real variables, including the real exchange rate itself.[9] How real exchange rates behave under different regimes, as well as the choice of the regime, may be two aspects of the same general question.

Below I examine these issues, the time-series behavior of PPP and the relationships between exchange-rate regimes and the variability of real exchange-rates. I begin with the analysis of real-exchange rate variability since it is more heavily descriptive and thus serves as useful introduction to the time-series analysis of PPP that follows.

3.1 REAL-EXCHANGE-RATE VARIABILITY AND EXCHANGE-RATE REGIMES

The data in Table 2 showing standard deviations of the log real exchange rates and their first differences for various subperiods appear fully consistent with the hypothesis of greater variability under floating than fixed exchange rates. Standard deviations for the current floating rate period, for the interwar period and the Japanese nineteenth century float are indeed greater than the standard deviations for the Bretton Woods and gold standard periods in most instances.[10]

This, however, does not appear to be the full story. One hint that more is involved than a simple fixed-floating dichotomy is provided by experience during the Japanese float in the latter decades of the nineteenth century. In this episode there is a marked difference in variability — particularly in the variability of the differenced data — between the subperiods 1875-1887 and 1888-1896. In the first of these subperiods, Japanese real exchange rates were noticeably less variable than in the second and not appreciably more variable than the real pound-dollar rate. Quite interestingly, this first subperiod saw much greater stability of Japanese inflation rates than the second.

Table 2
Standard deviations of real exchange rates, 1875-1989

Period	Countries					
	Levels of logs			Differences in logs		
	JA/US	JA/UK	UK/US	JA/US	JA/UK	UK/US
1875-1896	8.80	7.71	4.95	8.77	6.95	4.77
1875-1887	6.29	5.89	7.90	5.26	5.28	8.31
1888-1896	8.22	7.74	3.47	10.38	9.24	4.15
1897-1914	5.50	7.93	6.31	5.52	3.82	3.95
1915-1940	17.67	18.03	12.46	9.14	11.88	10.53
1921-1928	8.72	8.83	4.07	8.83	9.62	5.57
1929-1940	14.38	16.69	13.39	9.31	13.07	14.20
1954-1973	5.43	5.03	3.89	4.37	4.45	3.23
1974-1989	13.64	9.12	13.71	10.15	10.00	10.82

Note: Figures are multiplied by 100 to convert to per cent terms.

A more serious problem is posed by the interwar years. This was a period of managed floats alternating with pegs of various sorts, over various time spans, depending upon the currency. Real exchange rates, however, were even less stable during the interwar years than under the current float. Hence, if there is a behavioral-type relationship between the degree of exchange rate flexibility and the variability of real exchange rates it is certainly not monotonic. Alternatively, it may be that the relationship is largely statistical, economic conditions that give rise to variability in real exchange rates also strongly influencing the choice of regime.

To investigate these issues further, I computed standard deviations of the changes in the log real exchange rates and of the three countries' inflation rates for five-year periods. I then used these as the observations in a series of dummy-variable regressions. These regressions took the general form:

$$\sigma_{x_j} = \gamma_0 + \gamma_1 \text{ DFIX} + \gamma_2 \text{ DIW} + \gamma_3 \text{ DWW} + \epsilon_j , \qquad (2)$$

where σ_x is the standard deviation of variable x, DFIX is a dummy taking the value 1 for fixed-rate periods (the gold-standard years and the years of greatest stability under Bretton Woods) and 0 otherwise, DIW is a dummy taking the value 1 for the interwar period and 0 otherwise, DWW is a dummy taking the value 1 for the two world wars and 0 otherwise, the γs are coefficients to be estimated, ϵ is the error term, and j is an index for the period. Table 3 contains the results of these regressions.

Under the hypothesis that the regime *per se* is the determinant of real-exchange-rate variability, γ_1, γ_2 and γ_3 should all be negative, and γ_2 and γ_3 should each be less in absolute value than γ_1. The data, in general, do not support these predictions.

Table 3
Regressions to analyze the variability of real exchange rates and inflation rates across regimes

$$\sigma_{x_j} = \gamma_0 + \gamma_1 \text{ DFIX} + \gamma_2 \text{ DIW} + \gamma_3 \text{ DWW} + \epsilon_j,$$

Countries	γ_0	γ_1	γ_2	γ_3	R^2	SEE
ΔLog real exchange rate						
JA/US	.081	-.042	.002	.086	.294	.068
	(3.517)	(-1.311)	(0.048)	(2.216)		
JA/UK	.086	-.060	.032	.134	.413	.081
	(3.152)	(-1.577)	(0.665)	(2.899)		
UK/US	.087	-.051	.031	.015	.490	.036
	(4.534)	(-2.145)	(0.886)	(.778)		
Inflation rate						
JA	.051	-.018	.062	.182	.386	.098
	(1.554)	(-.395)	(1.056)	(3.256)		
US	.052	-.023	.054	.040	.395	.039
	(3.917)	(1.264)	(2.279)	(1.798)		
UK	.043	-.010	.069	.048	.378	.045
	(1.840)	(-.402)	(2.113)	(1.631)		

Source: Observations are standard deviations of annual data for non-overlapping five-year periods.
Note: σ_x is the standard deviation of the variable x, DFIX is a dummy for fixed-rate periods, DIW is a dummy for the interwar period, DWW is a dummy taking the value 1 for the two world wars and 0 otherwise. Figures in parentheses are t statistics.

In all three instances, DFIX has a negative sign, which is consistent with the view that the variability of real exchange rates is low under fixed rates. But only in the case of the pound-dollar rate is the difference statistically significant. For the two yen rates only DWW is significant. Much more important, in all three cases there appears to be little difference statistically between the interwar period and periods of relatively free float: DIW is insignificant and slightly positive in all three instances. Certainly, there is no evidence of lower variability then as would be the case if the degree of variability of real exchange rates were directly related to the degree of flexibility of nominal exchange rates.

The inflation-rate regressions provide a partial clue to what underlies these results. For all three countries, DWW is significantly positive and for Japan especially so. For the United States and the United Kingdom, so also is DIW. DFIX is negative in all three instances but in none of the regressions is it significant.

Both bodies of data, therefore, show somewhat similar temporal patterns. and, in the case of Japan, a similarity that is particularly pronounced. The close association observed between movements in nominal and real exchange rates since the advent of floating exchange rates in the early 1970s is, therefore, clearly not a general phenomenon. Over the long span of years covered by these data, variability in inflation rates very often has accompanied variability in real exchange rates. This continued association between the two suggests the need for a common explanation.

3.2 PPP: Evidence from tests of cointegration

The implications of the theoretical models of exchange rate determination reviewed above translate into competing hypotheses about the nature of the disturbances that affect the PPP relationship.

To illustrate, let us first amend equation (1) to include a disturbance term and also, since it will be of use empirically, consider an alternate version written in terms of the real exchange rate.

As the empirical counterpart of equation (1), we get:

$$p_t^a = a + p_t^* + u_t \ , \qquad (3)$$

and as the real-exchange-rate equation,

$$q_t = a' + u_t' \ , \qquad (4)$$

where $p_t^a \equiv p_t - e_t$, $q_t \equiv (e_t - p_t + p_t^*)$, p and p^* now represent logarithms of price indexes rather than price levels, a and a′ are normalizing constants, and u and u′ are error terms.

Particularly well suited to analyzing the processes governing these errors are the tests of cointegration developed by Engle and Granger (1987). According to Engle and Granger, two series which themselves have to be differenced n times to be stationary, are said to be cointegrated of order n-1 if some linear combination of their nth differences is stationary.[11] Cointegrated variables have the property that even though, for example, the levels of both may be subject to drift, there is some linear combination of the two that is not. Tests for cointegration are therefore essentially unit-root tests applied to the errors in these equations, or to suitably differenced versions thereof.

To see the connection between the tests and the hypotheses about exchange rate behavior suggested by theory, let us first consider the (instantaneous) equilibrium model. Since in this model both goods prices and the nominal exchange rate adjust fully within the period to monetary shocks, deviations from PPP are solely the result of real shocks. These real shocks both have permanent effects and provoke full within-period adjustment. Accordingly, the equilibrium model predicts: non-stationary of the u_ts (or u_t's) and hence non-cointegration of p_t^a and p_t^*; the necessity of differencing to achieve stationarity; and an extremely rapid pattern of adjustment.

In the monetary overshooting model, real shocks play no role. Deviations from PPP are solely the result of lagged adjustment to monetary shocks. In the long run, the adjustment of nominal exchange rates and the price level to such shocks is complete, but in the short run the exchange rate overshoots to maintain covered interest rate parity, while the price level adjusts slowly. The overshooting model, therefore, predicts: stationarity of the u_ts and, hence, cointegration of the levels of p_t^a and p_t^*; and a pattern of adjustment that corresponds to that of the price level.

A third more general class of models admits the possibilities of both real shocks influencing the equilibrium exchange rate and sluggish adjustments of prices (see e.g. Mussa, 1982). The predictions of these models are, therefore, a mixture of those of the other two: stationarity of the errors, at least after differencing or adjustment for a deterministic trend in the real exchange rate; and a pattern of adjustment to residual errors that again mimics that of the price level following a monetary shock.

To test these hypotheses, I followed two related procedures. One was the two-step method outlined by Engle and Granger (1987); the other was simply to apply unit-root tests in the context of simple univariate models of the real exchange rate.

In the two-step procedure, the first step was to estimate the cointegrating regression based on equation (3):

$$p_t^a = a + b\ p_t^* + u_t\ , \tag{5}$$

where a and b are the coefficients to be estimated and where the slope coefficient b, which in theory should be unity, is included as an allowance for measurement error (Taylor, 1988).[12]

The second step uses variants of the Dickey-Fuller (1979) test to examine the stationarity of the u_ts.[13] The equations underlying these tests took the general form:

$$\Delta u_t = \beta_1\ u_{t-1} + \sum_{k=1}^{K} \beta_{k-1}\ \Delta u_{t-k} + v_t. \tag{6}$$

Here the parameter of interest is β_1, the coefficient on the level of the lagged error term from the cointegrating regression. A negative and statistically significant value of β_1 leads to rejection of the hypothesis of non-stationarity. This, in turn, implies that p^a and p^* are cointegrated and hence is evidence in favor of long-run PPP. In one variant of the test, the coefficients on the lagged differences of the errors were constrained to zero. This is referred to as the DF (Dickey-Fuller) test. In the other, no such constraint was imposed. This variant of the test is referred to as ADF (augmented Dickey-Fuller) test.[14]

The alternative procedure, in which I examined the stationarity of the real exchange rate directly, is essentially a test of cointegration subject to the constraint that b, the slope coefficient in the cointegrating regression, is unity. Given this constraint, the two steps collapse into one and the following general equation serves as the basis for our tests:

$$\Delta q_t = \mu_0 + \mu_1 q_{t-1} + \sum_{k=1}^{K} \lambda_k \Delta q_{t-k} + v_t . \qquad (7)$$

Again the focus of the tests is on the coefficient of the lagged level, a value of μ_1 significantly less than zero providing evidence in favor of the hypothesis of stationarity of the real exchange rate. In the DF tests, the λ_k again were assumed to be zero; in the ADF tests, the number of such coefficients to be included in the regression was chosen empirically.

To investigate the influence of real variables and other factors that might cause the real exchange rate to undergo permanent shifts, I conducted two further series of tests. In the first, I estimated a variant of (7) that included a deterministic time trend as an additional regressor. In the second, I allowed for a stochastic trend by substituting log differences of the real exchange rate data in place of the log levels used initially. In both instances, I conducted unit-root tests similar to those used above.

The equations underlying these additional tests took the respective forms:

$$\Delta q_t = \mu_0 + \mu_1 q_{t-1} + \mu_2 t + \sum_{k=1}^{K} \lambda_k \Delta q_{t-k} + v_t , \qquad (8)$$

and

$$\Delta q_t - \Delta q_{t-1} = \mu_0 + \mu_1 \Delta q_{t-1} + \sum_{k=1}^{K} \lambda_k (\Delta q_{t-k} - \Delta q_{t-k-1}) + v_t . \qquad (9)$$

Table 4 contains the results of the cointegration tests based on the two-step procedure, both the DF and ADF t-like statistics and the Durbin-Watson statistic from the cointegrating regression. Table 5 contains the statistics for the analogous unit root tests for the real exchange rates. In each instance in Table 4, we are able to reject the hypothesis of no cointegration between p_t^a and p_t^*. The same is true for the third test proposed by Engle and Granger based upon the Durbin-Watson statistic. Correspondingly, we are able to reject the hypothesis of non-stationarity of the real exchange rate, or put another way, of no cointegration given the constraint of a unit coefficient in the cointegrating regression linking p_t^a and p_t^*.

Estimated speeds of adjustments to equilibrium are rather lengthy in both instances.[15] For the pound-dollar the estimated half lives range from 2.1

to 2.3 years based on the results reported in Table 4 and from 2.2 to 2.9 years based on those reported in Table 5. These are not the rapid speeds of adjustment envisioned in the equilibrium models, but they are not out of line with the estimated speeds of adjustment of price levels to monetary shocks in the United States and the United Kingdom.[16]

Table 4
Tests for cointegration between the logarithms of exchange-rate-adjusted price levels: 1875-1989

Countries	$\frac{b}{sb}$	DW	$\frac{1-\beta_1}{s\beta_1}$	DF	$\frac{1-\beta_1}{s\beta_1}$	ADF(K)	K
JA/US	1.164 (.019)	.540*	.714 (.064)	-4.486*	.741 (.077)	-4.663*	2
JA/UK	1.091 (.014)	.553*	.715 (.065)	-4.421*	.747 (.075)	-3.392**	2
US/UK	1.016 (.014)	.474**	.779 (.063)	-3.495**	.723 (.077)	-3.583**	3

Notes: The slope coefficient in the cointegrating regression is denoted by b and its standard error by sb. The coefficient in the test regression of the lagged residual from the cointegrating regression, u_{t-1}, is denoted by β_1 and its standard error by $s\beta_1$. DW is the Durbin-Watson statistic from the cointegrating regression, DF is the Dickey-Fuller test statistic and ADF(K) is the augmented Dickey-Fuller test statistic from a regression with K lagged values of the differenced residuals. One, two, and three asterisks denote significance at the .01, .05 and .10 levels, respectively in this and the next table.

For the yen rates, the situation is similar when we confine our attention to Table 4. The estimated half lives range from 2.1 to 2.4 years for the yen-pound and from 2.1 to 2.3 years for the yen-dollar. The picture changes, however, when we look at the results reported in the top panel of Table 5. For the yen-dollar the estimates range from 3.7 to 4.2 years, and for the yen-pound from 3.0 to 3.7 years.

The difference in the two sets of estimates for the yen exchange rates, I believe, reflects the imposition of the constraint b=1 that is implicit in the real-rate formulation. For the pound-dollar the constraint appears to be reasonable. The estimate of b reported in Table 4 is virtually unity and reversing the order of the variables in the cointegrating regression does not alter this result. In the cointegrating regressions for the two yen rates, in contrast, the estimates of b are both somewhat removed from unity, 1.16 and 1.09 for the yen-dollar and yen-pound, respectively. This, coupled with the visual impression of a long-term drift in the yen-dollar rate that one gets from Figure 1, raise questions about the importance of other than transient shocks.

One possibility is outright measurement error, particularly for the price series, but perhaps also for the early exchange rate data since these were derived as midpoints of the yearly highs and lows published by the Bank of Japan. The other obvious possibility is that real variables are affecting these real exchange rates. As already noted, a number of researchers have used differences in productivity growth in the United States and Japan to account for the drift in the yen dollar rate over the post-WWII period (see

Table 5

Unit root tests of real exchange rates: 1875-1989

Countries	$\frac{1-\mu_1}{s\mu_1}$	DF	$\frac{1-\mu_1}{s\mu_1}$	ADF(K)	K
Levels					

$$+ \mu_1 q_{t-1} + \sum_{k=1}^{K} \lambda_k \Delta q_{t-k} + v_t$$

Countries	$\frac{1-\mu_1}{s\mu_1}$	DF	$\frac{1-\mu_1}{s\mu_1}$	ADF(K)	K
JA/US	.847 (.051)	-2.987**	.829 (.059)	-2.887**	2
JA/UK	.792 (.056)	-3.727*	.828 (.062)	-2.789**	2
UK/US	.786 (.064)	-3.364*	.729 (.073)	-3.443*	3

Levels with trend

$$\Delta q_t = \mu_0 + \mu_1 q_{t-1} + \mu_2 t + \sum_{k=1}^{K} \lambda_k \Delta q_{t-k} + v_t$$

Countries	$\frac{1-\mu_1}{s\mu_1}$	$\frac{\mu_3}{s\mu_3}$	DF	$\frac{1-\mu_1}{s\mu_1}$	$\frac{\mu_3}{s\mu_3}$	ADF(K)	K
JA/US	.741 (.064)	-.0009 (.0003)	-4.040*	.668 (.077)	-.0012 (.0004)	-4.308*	2
JA/UK	.646 (.072)	-.0013 (.0004)	-4.903*	.663 (.088)	-.0012 (.0005)	3.847**	2
UK/US	.788 (.065)	.0000 (.0002)	-3.291***	.733 (.082)	.0000 (.0002)	3.277***	3

Differences

$$\Delta q_t - \Delta q_{t-1} = \mu_0 + \mu_1 \Delta q_{t-1} + \sum_{k=1}^{K} \lambda_k (\Delta q_{t-k} - \Delta q_{t-k-1}) + v_t$$

Countries	DF	ADF(K)	K

JA/US	-9.808*	-7.704*	3
JA/UK	-10.750*	-7.586*	2
UK/US	-9.394*	-6.026*	3

Notes: The symbols $s\mu_1$ and $s\mu_3$ represent the standard errors of the regression coefficients μ_1 and μ_3. DF is the Dickey-Fuller test; ADF(K) is the augmented Dickey-Fuller test based on a regression using n lagged differences of the dependent variable.

Marston, 1986; and Yoshikawa, 1990). In light of the rapid growth of the Japanese traded goods sector prior to WWII, it is plausible to believe that productivity differences may have been important then also. Given the somewhat low power of unit-root tests, we may therefore be incorrectly rejecting the hypothesis of non-stationarity.

To investigate this possibility, I ran the additional tests based on equations (8) and (9). In the middle panel of Table 5, I show the results of the tests in which a deterministic trend is included in the regression. In the bottom panel, I show the results for the first differences in q. In both cases, we can reject non-stationarity, and generally at high levels of significance. Real yen rates may be subject to permanent influences — either stochastic shocks or forces that follow a trend-like pattern — but there is a decided tendency to return to equilibrium otherwise. Over long periods PPP appears to hold at least for rates of change, and perhaps also for levels, albeit with the possible need for adjustment for a dterministic trend in the real exchange rate.[17]

4. CONCLUSIONS

For the study of exchange-rate behavior, Japanese historical experience offers a nearly ideal laboratory. Over the 115 years for which data are available, the yen has floated with much greater frequency than either sterling or the dollar, while the Japanese price level has been subject to considerably greater variability than either the British or the American price level.

Despite this volatility, however, purchasing power parity — at least in relative form — has held remarkably well for the yen over the longer run. Using an expanded body of data relative to that in my earlier (1990) study, I can always reject the hypotheses of non-trend stationarity and non-difference-stationarity of real yen exchange rates at high levels of significance. Relaxing the constraint of a unit cointegrating factor between the exchange-rate-adjusted Japanese price level and the foreign price level, I can do the same for the hypothesis of non-stationarity of the absolute levels.

These results stand in sharp contrast both to casual impressions gained from experience under the current float and to much scholarly evidence derived from it. The difference, I believe, is due in the main to the difference in the spans of data. Given the existence of long-lived deviations of exchange rates from PPP, a long historical series is a virtual necessity if we are to distinguish persistent, but transient, deviations from permanent ones.

Viewed from the perspective of this study, the continued emphasis by the

Bank of Japan and by business economists on PPP as a macroeconomic equilibrium condition no longer appears anomalous.[18] The fluctuations in the real yen-dollar rate over the past decade that made it seem such turn out to not differ much from the often substantial and largely self-reversing movements observed historically. Relative to the fluctuations in the years surrounding World War II they are, in fact, rather small.

Not directly identifiable are the factors producing such fluctuations. For the sterling-dollar rate they appear to have been largely transitory in their impact. For the two yen rates, both permanent and transitory factors appear to have mattered. Productivity-related influences may well have been important over much of the sample period. In addition, the close association between variability in yen real exchange rates and variability in the Japanese inflation rate suggests a major role for monetary influences.[19]

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NOTES

1. Data for Japanese nominal exports and imports came from Ohkawa and Rosovsky (1973). I divided these figures by the estimates of nominal GDP in Nakamura (1983) to convert them to ratio form.

2. The silver yen became legal tender in May of 1878. See the discussions of this period in Moulton (1931) and Shinjo (1962) and the references cited therein.

3. The exchange rate data for the period ending in 1965 are annual series for the yen relative to the currencies of the other three countries as reported in the Bank of Japan's <u>Hundred Year Statistics of the Japanese Economy</u>. For the years 1880 to 1914, these are midpoints of the range between the reported yearly high and low exchange rates for each currency; for 1874 to 1879 and for the years after 1914, they are yearly averaged data. These series were used directly to compute yen-other country real exchange rates and to derive the sterling-dollar real exchange rate.

The published figures for 1894 contained what appears to be two errors. I corrected the yen-dollar rate using the alternative estimate of Nakamura (1983, p. 34) and derived the yen-sterling rate using that corrected figure and the estimate of the dollar-pound exchange rate for 1894 in Friedman and Schwartz (1982).

Observations for yen exchange rates for the years 1941 to 1947 were not reported by the Bank of Japan. For these years, I used Swiss quotes of yen-dollar rates from Abuaf and Jorion (1990) that Phillipe Jorion graciously provided me, and the dollar-sterling figures reported in Friedman and Schwartz (1982) to fill in the missing observations for the yen-sterling and pound-dollar rates and to derive the yen-pound rate.

I updated the nominal exchange rate series for the years after 1965 using the basis of the annual average yen-dollar and dollar-pound rates reported in the <u>International Financial Statistics</u> (<u>IFS</u>) and derived the yen-pound rate from these figures.

The data for wholesale prices came from a variety of sources: for the United States,the U.S. Department of Commerce's <u>Long Term Trends</u> for the years 1873 to 1970, and the <u>IFS</u> thereafter; for the United Kingdom, <u>European Historical Statistics</u> for the years 1873 to 1975 and <u>IFS</u> thereafter; and for Japan, the Bank of Japan's <u>Hundred Year Statistics</u> for the years 1873 to 1965 and the <u>IFS</u> thereafter. These subseries were linked either by regression or by multiplying the earlier series by the ratio of the overlapping observations. The resultant series were then rebased to 1980.

4. I define the real exchange rate as the ratio of the nominal exchange rate (the price of a unit of the foreign currency) divided by the ratio of the home-country price index to the foreign-country price index.

5. This explanation has been widely applied to explain the behavior of the yen-dollar rate in the post-WWII period. See, for example, Marston (1986) and Yoshikawa (1990).

6. Japanese real income (GDP) and industrial production data came from Nakamura (1983); U.S. and U.K. real income (NNP) data from Friedman and

Schwartz, (1982); U.S. industrial production from U.S. Department of Commerce (1973); and U.K. industrial production from Feinstein (1972).

7. See the discussion of this episode in Lockwood (1954, pp. 36-37) and the references cited therein.

8. This short-run spillover of expansive U.S. policies to Japan is evident in data for Japanese balance of payments and high-powered money growth. Japan's official settlements surplus increased sharply in 1977 and remained high in 1978 in the face of substantial U.S. official settlements deficits in these years. Japanese high-powered money growth in this environment rose from 8.1% per year on average in 1976 and 1977 to 13.9% per year in 1978.

See Darby and Lothian (1989) on the difference between long-run and short-run price behavior among OECD countries since the advent of floating rates and Ohta (1983) for a discussion of Japanese policy during the late 1970s and early 1980s.

9. Stockman (1988) attributes the greater stability of real exchange rates under fixed rates to government actions in the goods and capital markets that affect both the price level and the nominal exchange rate. Mussa (1986), in contrast, attributes the variability under floating exchange rates to the non-instantaneous adjustment of goods prices.

Savvides (1991) using a simultaneous model estimated for a group of 39 developing countries over the period 1976 to 1984 studies the relationship between the exchange-rate regime and the behavior of real exchange rates. He finds no independent effect of the regime on the variability of real exchange rates.

10. The definition of the gold-standard period varies with the countries being compared. For Japan it begins in 1897 and for the United States in 1879.

11. See the discussion of cointegration in Engle and Granger, 1987. I apply this technique to long-term time series data for Japan, the United States, the United Kingdom and France in my earlier (1990) paper. Unlike the data used here those data excluded the WWII and immediate postwar years.

Other applications to exchange rate data are contained in Abuaf and Jorion (1990), Baillie and Bollerslev (1989), Diebold, Husted and Rush (1990), Enders (1988, 1989), Hakkio and Rush (1989), McNown and Wallace (1989), Taylor (1988) and Taylor and McMahon (1988).

12. As I point out below, an estimate different from unity may also be an indication of omitted variables that affect the equilibrium real exchange rate.

13. Since there is no way *a priori* to choose the ordering of the variables, I also ran the reverse set of regressions and conducted the corresponding tests for cointegration. These resulted in no appreciable change in the results reported below.

14. Significance levels for the t-statistics used in these tests are those of Engle and Yoo (1987).

15. These estimated adjustment speeds are derived from the coefficients on the lagged level terms in equations (6) and (7). The estimated half lives of adjustment are $\ln(.5)/\ln(1-\beta_1)$ and $\ln(.5)/\ln(1-\mu_1)$ for the two equations respectively.

16. For the United States and the United Kingdom, the lag before the effects of a monetary shock become apparent in prices is often described as being on the order of two years. Full adjustment — including overshooting — appears to take longer, however. See Darby and Lothian (1983a) for a discussion of this issue and for estimates of the adjustment process for the United Kingdom that takes overshooting into account.

17. A similar phenomenon appears to characterize money-price relationships. (See Gandolfi and Lothian, 1983; and Lothian, Darby and Tindall, 1990).

18. See Yoshio Suzuki (1988) of the Bank of Japan's research department for an analysis based on long-run purchasing power parity of movements in the yen exchange rates under the current float. Frederick W. Sturm (1989) of Fuji Securities presents a similar analysis of recent movements in the yen-dollar, DM-dollar, and dollar-pound exchange rates.

19. Evidence suggesting that this is also the case under the current float is presented in my (1986) study of the real dollar exchange rates of 11 OECD countries.