A Century Plus of Yen Exchange Rate Behavior

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Abstract

Examination of over a century's worth of annual data for Japan, the United States, the United Kingdom and France reveals a marked tendency for real exchange rates to return to their (measured) equilibrium values. The hypothesis that exchange-rate-adjusted price levels in these countries are not cointegrated is almost always rejected. Similar unit-root tests much more often than not reject the hypothesis of non-stationarity (or non-trend-stationarity) of real exchange rates. Analysis of earlier periods of floating yen rates -- particularly the latter decades of the nineteenth century -- points to an important link between monetary conditions and real exchange rate variability.

Since the advent of floating exchange rates in 1971, the yen has shown a trend-like real appreciation relative to virtually all of the world's other major currencies. Accompanying these longer term movements, moreover, have been marked fluctuations in both nominal and real yen exchange rates over shorter, but, nevertheless, still quite lengthy periods.

Against the dollar, this pattern has been both highly noticeable and much noticed. The longer term downward drift of the real yen-dollar rate has been of such a magnitude and so nearly continuous that at no point during the floating-rate era -- even during the period of the "strong" dollar in the first half of the 1980s -- did the level come close to matching the level that existed at the onset of floating.[1]

Interpreted according to one line of reasoning, the yen's behavior is simply a particularly glaring example of a more general phenomenon, the major characteristic of which is the failure of purchasing-power-parity relationships of any sort to hold over any time horizon.[2] Somewhat relatedly, it appears to provide yet additional evidence in favor of the hypothesis of non-neutrality of the exchange-rate system, the hypothesis that the system itself influences the behavior of real variables, in this case, the real exchange rate.[3]

My purpose in this paper is to consider both sets of issues, focusing explicitly on the yen, but comparing its behavior with the behavior of other major currencies relative to one another. To do so, I construct annual series for the real exchange rate of the yen relative to the U.S. dollar, the French franc and the pound sterling as well as the corresponding real cross rates for the period beginning in 1874 and ending in 1987.

The advantage of working with this long span of data, even though the observations are yearly, is that it expands degrees of freedom in a way that analysis of much higher frequency data for a shorter time period cannot. If, for example, there are exceedingly long lags in the adjustment of real exchange rates to equilibrium, as some have recently claimed, a long time series of this sort is a virtual necessity.[4] For the case of Japan, a country that has had two episodes of floating exchange rates in addition to the current one, episodes for the most part not shared by other major countries, it provides an added advantage. It allows us to better distinguish between the influence of the exchange-rate system per se and the historical period on exchange-rate behavior.

The results of this exercise are striking. Viewed from the perspective of more than a century of data, recent experience of the yen under floating is less anomalous than at first glance appears to be the case. Real exchange rates do not simply evolve in a random fashion with no tendency to come back to equilibrium. This is true for the yen as well as for the three other currencies vis-a-vis one another. By the same token the additional Japanese experience with floating exchange rates -- particularly experience during the last two decades of the nineteenth century -- suggests that the apparent non-neutrality of exchange-rate systems is a result of differences in underlying economic behavior rather than an inherent feature of the system itself.

2. Historical Background

Japan during most of the last third of the nineteenth century was not on the gold standard. From the Meiji restoration in 1867 until 1897, the Japanese monetary system was one of either fiat currency and floating exchange rates or a nominally bimetallic, but in effect silver, standard and thus floating rates relative to the gold-standard countries. [5]

As is apparent from a glance at Table 1, Japan experienced virtually no net movement in its price level during the earlier part of this period. Japanese wholesale prices in 1887, for example, stood only 3.6% below their level in 1874. Then the situation changed. Japanese prices began to rise and by 1896, the year before Japan went on gold, wholesale prices had increased by 35%. In the United States, in contrast, wholesale prices declined throughout this latter portion of the nineteenth century, by slightly over 40% between 1874 and 1887 and by another 21% between then and 1896. In Britain and France, the pattern was virtually identical to that in the United States, wholesale prices declining by 41% and 36% in the two countries, respectively, in the first of these subperiods and by 11% and 12%, respectively, in the second. Nominal exchange rates moved accordingly, with the yen depreciating relative to all three currencies over the period as a whole by somewhat over 50% in each instance.

This difference between price behavior in Japan and the other three countries to a very large extent appears attributable to developments in the international monetary sector as a whole, as opposed to domestic policies in Japan. Throughout the last quarter of the nineteenth century, countries were continually shifting from a silver to a gold standard. At the same time that this shift in the relative demand 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 shortly thereafter was an upward trend in prices in countries that remained on silver and a downward trend in prices of countries on gold.

When Japan made the switch to gold in 1897, price behavior in gold-standard countries started to undergo a reversal. Gold discoveries in Colorado, South Africa, Alaska and the Yukon, 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)]

Japan, however, appears to have partially insulated itself during these years from the operation of international forces working through the gold standard. Higher Japanese than restof-world inflation was accompanied by substantial government borrowing abroad and the drawing down of gold balances received as an indemnity payment following the war with China in 1893 and 1894.[6]

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 officially. Japan took the former route up until 1917 at which point it left gold completely. Unlike most other countries, however, 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.[7]

The years 1932 to 1934 were marked by a more or less free float of the yen and substantial fluctuations in its value relative to the U.S. dollar, the pound sterling and the French franc. After that, there followed a five-year period during which the yen was pegged to sterling. With World War II came the disruption of international transactions, breaks in the yen and franc exchange-rate data and substantial increases in price levels around the world. In Japan, these price increases were particularly dramatic. The ratios of Japanese to American and British wholesale prices rose at continuously compounded cumulative rates in excess of 400% between 1940 and 1949; the ratio of Japanese to French wholesale prices, at a continuously compounded cumulative rate of 233%.

In 1949, when the foreign exchange market for the yen reopened, its value was pegged at 360 to the dollar versus 4.35 yen nine years earlier.

And it remained at roughly that same nominal value until 1971, when the Bretton Woods system broke down and the current float began.

3. Purchasing Power Parity and the Real Exchange Rate

In equilibrium, according to the purchasing power parity theorem, the exchange rate between two countries' currencies will equal the ratio of their respective price levels. The motivation for positing such a relationship has generally taken either of two forms. One is the law of one price, the condition that, in the absence of transactions costs, the price of an identical good must be the same in two countries when expressed in a common currency. The alternative views purchasing power parity as a condition of equilibrium in a macroeconomic model in which either exchange rates and price levels, in the case of a floating exchange rate, or price levels and money supplies in the case of fixed exchange rates are determined simultaneously.

One objection to purchasing power parity centers around the possibility that real factors -- cross-country differences in productivity behavior, or changes in the terms of trade, for example -- will affect the relationship, causing the ratio of the overall price levels in the two countries to permanently diverge from the exchange rate. A second set of objections focuses on the influence of transitory factors, most prominently monetary shocks in the presence of price "stickiness."[8] A third centers around a series of factors that can be lumped together under the general heading of "measurement errors". These include actual recording errors in prices as well as divergences in movements of measured and true price levels due to things such as relative price changes, incorrect weights and the like.

Studies of purchasing power parity conducted prior to the breakdown of Bretton Woods generally took the view that PPP, though not likely to obtain very closely in the shorter run, did indeed provide a useful first approximation over longer periods -- if not years, quinquennia, and certainly decades. [See, for example, Galliot (1970); Friedman and Schwartz (1963)].

Then, in the years immediately surrounding the onset of floating, a stronger version of the theorem, one positing continuous short-run PPP, gained adherents. The often sizeable deviations of exchange rates from purchasing power parity thereafter, coupled with the empirical failure of models embodying the PPP assumption and the widespread finding that real exchange rates could be described as a random walk, led to a near-total reversal in thinking.[9] Purchasing power parity came to be viewed as a special case and the concept of an equilibrium real exchange rate as largely devoid of empirical content.

More recently, however, opinion has begun to swing back in the opposite direction. Several researchers have pointed to a long, drawn-out process of reversion of real exchange rates to equilibrium [e.g., Frankel and Meese (1986); Huizinga (1987)] ; others,to the long-run equality between exchange-rate-adjusted price levels under a wide variety of conditions [e.g. Enders (1988, 1989); Mc Nown and Wallace (1989, forthcoming)]. The empirical examination of these issues for Japan begins immediately below.

3.1 An Overview of the Data

The real exchange rate for each country pair was constructed as:

$$Q_{ijt} = E_{ijt}/(P_{it}/P_{jt}), \tag{1}$$

where E_{ijt} is the price of in country i's currency of a unit of country j's currency and the term in the denominator is the ratio of the respective countries' wholesale price indexes.[10]

Dropping the subscripts other than the time subscript to simplify the exposition, letting the lower case letters q, e, p and p^* represent the logarithms of the real exchange rate, the nominal exchange rate and the two wholesale price indexes, respectively, we can rewrite this expression as

$$q_t = e_t - (p_t - p_t^*). \tag{2}$$

Figures 1 through 6 contain plots of the six log real exchange rates, in each instance, converted to an index by dividing the yearly value of the nominal exchange rate by its value in 1980. Table 2 reports corresponding summary statistics -- standard deviations of the levels and first differences of the logs of the real exchange rates and of their nominal-exchange-rate and price-ratio components along with the squares of the correlation coefficients between the components. These correlations were computed under the assumption that the ratio constraint of a unit elasticity of the nominal exchange rate with respect to the price ratio holds.[11]

Several things in the charts stand out. One is an apparent downward drift in the three yen real exchange rates over the full period, the absence of any such noticeable drift in the derived real sterling-dollar rate and the possibility of a shift of some sort in the real franc-dollar and real franc-sterling rates. This drift in the yen rates, appears particularly to characterize behavior prior to 1914 and after 1970.[12]

A second feature of interest is the relative turbulence of all of the series after 1914. The only respite from this turbulence that is visible in the charts occurs during the Bretton Woods period, and even that does not appear to last for the full period in most instances. Another is the form that this variability takes. In the neighborhood of the world wars, in particular, there is the appearance of sharp step-like movements in a number of instances. Given the magnitude of the changes in price levels during the wars, particularly in France and Japan, movements of this sort appear suspicious. Even small percentage errors in the price level data during such episodes could produce fairly sizeable absolute errors in the computed real exchange rates.

A final item to note is the greater shorter term variability of the yen real exchange rates than the three real cross rates during much, though again not all, of the period prior to 1914. Since most of this period in Japan was one of floating exchange rates, this is suggestive of their being a systematic difference across regimes. I return to this issue in section 3.3 below.

The summary statistics presented in Table 2 add to the story told by the charts in several important ways. Consider first of all the standard deviations of the log real exchange rates. These are estimators of the coefficients of variation of the levels of the real exchange rates. One way to interpret these figures is as measures of prediction error, the percentage error that would result from predicting one component (either the price ratio or the nominal exchange rate) using knowledge of the other and assuming a constant geometric mean for the real exchange rate. For the full period, these errors range from 10.5% to 26%; for the two subperiods they range from 9.7% to 23.6% and 7.9 to 17.2%, respectively. These are substantial in absolute terms.[13] Nevertheless, they are in almost all instances a small fraction of the standard deviations of the logs of the corresponding component series. The fraction of the variation in the one component or the other accounted for by this naive predictive model is, therefore, generally very high. We can see this in the last two columns of the table, which list the squared correlation coefficients. As a first approximation, therefore, purchasing power parity has much to recommend it, working tolerably well as a long-term predictive device over more than a century for a diverse group of countries, under exceedingly varied circumstances.

3.2. Cointegration, Unit Roots and Error Correction

To investigate the performance of the purchasing-power-parity relationship further, I conducted a series of tests for cointegration between the exchange-rate-adjusted PPIs making up each of the real exchange rate series. I then estimated two sets of error correction models for real exchange rates that I used to conduct additional, related tests of hypotheses.

First, let us turn to the cointegration tests. Two variables, which themselves have to be differenced to be stationary, are said to be cointegrated if there is some linear combination of their levels that is stationary.[14] Cointegrated variables, therefore, have the property that even though both may be subject to upward or downward shifts over time, there is a linear combination of the two that is not. In the case of exchange rates, cointegration of the price ratio and the nominal exchange rate, or what amounts to the same thing, cointegration of the exchange-rate-adjusted price level in one country (defined as the difference between the log of its price level and the log of the nominal exchange rate) and the price level in the other, translates into stability of the real exchange rate over time.

To test for cointegration, I followed the two-step procedure outlined in Engle and Granger (1987), first estimating the equilibrium regression

$$p_t^a = a + b\, p_t^* + u_t, \tag{3}$$

and then using variants of the Dickey-Fuller (1979) test for unit roots and thus the stationarity of the u_t. The equations underlying these tests took the general forms

$$u_t - u_{t-1} = a_1 + b_1 u_{t-1} + v_t \tag{4}$$

and

$$u_t - u_{t-1} = a_1 + b_1 u_{t-1} + \sum_{k=1}^{K} b_{k-1} (u_{t-k} - u_{t-k-1}) + v_t \tag{5}$$

Of interest in each instance is b_1, the coefficient on the level of the lagged error term. A negative and statistically significant value of b_1 is a rejection of the hypothesis of a unit root and, hence, of non-stationarity, which in turn implies that p^a and p^* are cointegrated. The first variant of the test, based on equation (4), is referred to below as the DF (Dickey-Fuller) test; the second variant, based on equation (5), is referred to as the ADF (augmented Dickey-Fuller) test.[15]

Table 3 contains the results of these tests. In each instance, the tests were run using data for the period 1874 to 1987, with the years 1940-1949 omitted due to missing exchange-rate observations. In all but two cases, the coefficient on the lagged u term is negative and significantly different from zero at the .95 level or better. The exceptions are the DF tests for both the yen-sterling and yen-franc rates. For the former we can reject at the .90 level; for the latter, we cannot reject at any conventional level.[16] In general, therefore, both sets of tests support the notion of a fairly stable long-run real exchange rate.

Even this long-run stability, however, does not appear to have been absolute. The slope coefficients in many of the first-stage regressions are far enough removed from the theoretical value of unity to suggest that equilibrium real exchange rates have indeed changed somewhat over the sample period. This, of course, is consistent with our earlier visual inspection of the data, which showed some downward drift in the yen real exchange rates and perhaps also some upward drift in the franc-dollar and franc-sterling real exchange rates. Given the more or less steady increases in price levels over much of this period, failure to allow for changes in real exchange rates is likely to result in specification bias, with the estimated coefficient of p^* differing from unity as a result.

The two error-correction models described below are alternative approaches to this problem. The first is used to test the stationarity of the real exchange rate itself. We can view it as a test for cointegration, given the constraint of a coefficient of unity in the equilibrium regression. The second model allows for a deterministic trend in the real exchange rate. The corresponding test is, therefore, a test of trend-stationarity.

To understand the logic underlying these models, consider a partial adjustment equation in which the actual change in the (log) real exchange rate is the result of two forces, the change in the equilibrium log real exchange rate and the deviation of the actual from the equilibrium log real exchange rate in the last period:

$$q_t - q_{t-1} = q_t^e - q_{t-1}^e - d(q_{t-1} - q_{t-1}^e), \qquad (6)$$

where q^e_t is the equilibrium value of q_t and d is the adjustment coefficient.

Rearranging terms and letting $c_1 = 1\text{-}d$, we can rewrite this as an equation that relates the difference between the actual and the equilibrium values of q to the corresponding difference last period:

$$q_t - q_t^e = c_1 (q_{t-1} - q_{t-1}^e). \qquad (7)$$

Under the assumptions that the equilibrium real exchange rate is constant and that it can be estimated by the sample mean of the actual real exchange rate, we can obtain estimates of c_1 and hence d from the simple regression

$$q_t = c_0 + c_1\, q_{t-1} + v_t, \tag{8}$$

which, when written in the alternative form common to unit-root tests,

becomes

$$q_t - q_{t-1} = c_0 + c_2\, q_{t-1} + v_t, \tag{9}$$

where the constant term c_0 is an estimator of the (unchanged) equilibrium value of q_t, v_t again denotes an error term, and $c_2 = c_1 - 1$.[17]

Under the alternative assumption that the equilibrium log real exchange rate follows a (deterministic) trend, we can use (7) to derive the second regression equation:

$$q_t = c_0 + c_1\, q_{t-1} + c_3\, t + v_t\,, \tag{10}$$

where c_3 is the trend coefficient.

In all instances, the focal point again is the coefficient of q_{t-1}. A value of c_1 of unity (or of c_2 of zero) would imply that d is identically zero and, hence, that there is no tendency whatsoever for actual q to return to equilibrium. Correspondingly, a value of c_1 significantly less than unity would imply that d is positive, that the actual value of q reverts to the equilibrium at the rate of d per year and, hence, that the v_t are stationary or trend-stationary, as the case may be.

Table 4 contains the important summary and test statistics for the equations estimated for the full sample period, again with the years 1941-1949 omitted. For Japan, the coefficient on the time trend variable in each instance is negative and over two times its standard error. Equilibrium appears to be somewhat better approximated by the fitted trend value than by the mean, as the charts suggested. The estimates of c_1, the autoregressive coefficients, for these three regressions fall in the general area of .80. The estimated speed of adjustment, therefore, is roughly 20% per year.

The t ratios shown in the table are for tests of the hypothesis that c_1 is equal to unity. The first two sets are for the DF and ADF tests based on equation (8); the last is for the DF test based on equation (10). These are compared with the values in Fuller (1976). For both the yen-dollar and yen-sterling rates, we are able to reject the hypothesis of a unit root using at least one form of the ADF test at the .90 level or better, but are unable to do so using the DF test. For the yen-franc rate, we are unable to reject using any of these tests. Turning to the results based upon the regressions that include the trend, we see roughly the same pattern -- rejection at approximately the .90 level for the dollar-yen and at the .95 level for the yen-pound, but a failure to reject for the yen-franc.

The tests for the cross rates almost all reject the hypothesis of a unit root. For these three rates, moreover, this is the case regardless of whether "equilibrium" is defined as the mean or as the trend value. The estimated c_1's range from .68 for the dollar-pound in the regression with the trend, to .83 for the franc-pound rate in the regression without the trend. All six are significantly different from unity at the .95 level or better. The estimated speeds of adjustment to the mean range from 17% to 31% per year, and the estimated speeds of adjustment to trend from 22% to 32% per year.

In all instances, therefore, adjustment apparently follows an extremely slow process. As Frankel (1986) and Huizinga (1987) have both pointed out, this well may account for the typical finding in studies using post-Bretton-Woods data alone of an inability to reject the hypothesis of a random walk. For Japan, in particular, it appears further that this adjustment has not been to some relatively constant equilibrium value, but to an equilibrium real exchange rate that has shifted through time. Perhaps, these shifts have followed a trend-like pattern, as assumed in the last set of tests. Perhaps, and I believe this to be more likely, the process has been discontinuous. I return to this issue in the concluding section.

3.3. Exchange-Rate Variability and the Exchange-Rate Regime

Tables 5 and 6 list standard deviations of the log real exchange rates and of their first differences by subperiods. The pattern of greater variability under fixed than under floating exchange rates documented for the period after World War II is visible in this sample also [See Mussa (1986); Stockman (1983)]. In addition, however, there appear to be factors other than the exchange-rate regime per se that account for such differences.

The difference in variability across the two regimes is brought out by three sets of comparisons: Japanese versus other-country exchange rates during the years 1875-1896, the years in which the yen was floating; Japanese and other-country exchange rates in that subperiod versus the subperiod 1897-1914; and Japanese and other-country experience in all of the floating-rate periods combined versus the two classic periods of fixed rates combined.

During Japan's nineteenth century episode of floating rates, yen real exchange rates were clearly more variable than the cross rates in both log level and log difference form. For the years 1875 to 1896, the standard deviations of the log levels of the yen rates ranged from .071 to .088 as opposed to a range of .033 to .062 for the logs of the cross rates. The standard deviations of the first differences of the logs of the yen rates ranged from .066 to .079 and from .036 to .065 for the first differences of the logs of the cross rates.

After Japan went on gold, the variability of yen exchange rates declined and the dichotomy between the yen rates and the cross rates became much less apparent. The standard deviations of the yen levels ranged from .055 to .079 and of the yen first differences from .038 to .055. Comparable figures for the cross rates, which interestingly also show some decline in variability, were .032 to .063 for the levels and .032 to .046. for the first differences.

Finally, when we aggregate the data temporally, we see the same sort of pattern emerging. We see less variability in exchange rates during the combined gold-standard and Bretton-Woods periods than during the combined floating-rate periods. This is the case for both the yen rates and the cross rates, for both levels and first differences and regardless of exactly how the gold-standard period is defined.

This simple fixed versus flexible rates dichotomy is not, however, the whole story. Consider the figures presented in Table 7 for the breakdown of the nineteenth-century Japanese floating-rate period into the shorter subperiods 1875-1887 and 1888-1896. As described above, the two differed substantially with regard to price experience, the first being a period of almost total stability in the Japanese price level, and the second, one of moderate, but continual inflation. Yen real exchange rates during this first subperiod were less variable than during the second subperiod, particularly when viewed in first-difference form, and not appreciably more variable than the cross rates in the first subperiod. Similarly, the variability of yen rates during this first subperiod is not at all out of line with the variability of either the yen or the cross rates in the Bretton-Woods period.

What makes these last comparisons so interesting is the nature of the Japanese exchange-rate regime in 1875-1888. This was for all practical purposes a de novo experiment. Japan had only recently opened up contact with the West. Prior to 1868, there was virtually no foreign trade and, hence, no meaningful exchange rates. Japan, therefore, came to floating rates without the excess baggage in the form of high and variable inflation, wartime disruptions or both that have generally accompanied a country's adopting floating rates. At the same time, as foreign trade developed, real factors that in principle could have substantial effects on equilibrium real exchange rates began to play an important role. Nevertheless, it was not until well into this period, when the Japanese price level began to increase noticeably that the variability of yen real exchange rates increased.

In this regard, the juxtaposition between the 1920s and the current floating-rate period, on the one hand, and the late nineteenth century period of floating yen rates, on the other, is instructive. Of the three periods, the 1920s was subject to the most in the way of economic disruptions. Price level variability was extreme. The decade began and ended with severe business cycle contractions. And, perhaps equally important, the Japanese float was a tenuous matter throughout, and thus very likely a source of considerable uncertainty, with two attempts to return to gold prior to the actual return in 1929 having been aborted by outside forces.

III. Conclusions

Two empirical propositions about exchange rates have gained widespread acceptance over the past decade: Purchasing power parity has broken down; real exchange rates follow random walks. Given the pattern of movements in the yen-dollar rate under the current float, Japanese experience -- perhaps more than that of any other country -- has appeared to be a major case in point supporting both propositions.

Unless greatly qualified, however, neither proposition is correct. My examination of over a century's worth of annual data for Japan, the United States, the United Kingdom and France from the last quarter of the nineteenth century until the late 1980s, reveals a marked tendency for real exchange rates to return to their (measured) equilibrium values. The test that I have conducted, almost always result in rejection of the hypothesis that the exchange-rate-adjusted price levels in these countries are not cointegrated. Similar tests applied to real exchange rates much more often than not reject the hypothesis of non-stationarity (or non-trend-stationarity) of real exchange rates.

The reversion of real exchange rates to their mean or trend values, however, is generally quite slow. Purchasing power parity is, therefore, often a poor approximation over periods of even as much as several years in length; nevertheless, it gains greatly in predictive power when viewed over longer periods still.

The notion of a breakdown in purchasing power parity, in the sense of substantially greater instability of real exchange rates under the current float than in earlier floating-rate periods, also fails to be corroborated by the data. The variability of real exchange rates in our own era of floating rates has not been greater than in the nineteenth century episode of Japanese floating rates; at the same time, it has been much less than in the briefer Japanese episode in the 1920s.

We do see a dichotomy with regard to variability of real exchange rates between floating-rate periods as a whole and the combined Bretton-Woods and gold-standard periods, and likewise between the current floating-rate period and the Bretton-Woods periods viewed separately. This is consistent with past empirical observation, but other evidence, principally the relative stability of real exchange rates during the decade of stable prices at the outset of the Japanese float in the nineteenth century and their greater variability in the inflationary years that followed, suggests that the observed differences in the variability of real exchanges rates across the two types of exchange-rate regimes may very well be due to systematic differences in monetary behavior.

This is clearly an important area for further research. With the exception of Canada for a time in the 1950s and early 1960s, floating exchange rates have generally been associated with either situations of very high inflation -- often hyperinflation -- major wartime periods and a few years immediately thereafter, or both. The nineteenth-century Japanese episode, in contrast, was one of more stable economic conditions. It thus facilitates the separation of any regime effects from underlying economic effects on exchange-rate behavior.

A related set of questions for future research concerns the nature and magnitude of the variability in the long-term equilibrium real exchange rate. The results I have presented, I believe, allow us to rule out the idea that all, and perhaps even most, of the variations in measured real exchange rates are shock-induced shifts in long-run equilibrium levels. At the same time, several pieces of evidence suggest that the assumption of a constant equilibrium value implicit in the cointegration tests, to some extent, is violated. Obtaining useful bounds for the degree of variability of the equilibrium real exchange rate, estimating the size of such variability relative to the variability in the actual measured real exchange rate and investigating further the time-series properties of the changes in the equilibrium real rate are particular issues of interest.[18]

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Table 1

Average Annual Rates of Inflation

1875-1896

Period	Japan	U.S.	U.K.	France
1875-1896	1.43	-2.77	-2.30	-2.16
1875-1887	-0.27	-3.10	-3.03	-2.78
1888-1896	3.91	-2.30	-1.24	-1.28
1897-1914	2.67	2.15	1.58	2.02
1915-1940	3.76	0.54	1.96	1.92
1915-1921	16.65	13.60	18.99	26.43
1921-1928	-5.21	-5.81	-9.77	2.58
1929-1940	3.29	-1.76	1.27	2.76
1941-1953	40.24	5.92	6.74	22.41
1954-1973	1.37	2.16	3.24	4.05
1974-1986	3.68	6.15	10.98	7.45

Source: See text.

Note: Figures are continuously compounded rates of change of wholesale price indexes expressed in per cent per annum terms.

Table 2

Variability of Price Ratios and Nominal Exchange Rates Accounted for under Assumption of Constant Real Exchange Rate

Period	Variation in		Fraction Accounted for in		
Countries	$p - p^*$	e	q	$p - p^*$	e
1875-1987					
JA/US	256.7	248.7	16.8	99.6	99.5
JA/UK	227.2	216.7	18.0	99.3	99.3
JA/FR	75.0	69.8	26.0	88.0	86.1
UK/US	37.4	37.3	10.5	92.1	92.1
FR/US	196.1	205.0	15.6	99.4	99.4
FR/UK	165.9	171.9	14.7	99.2	99.3
1875-1940					
JA/US	45.6	37.1	16.1	87.5	81.1
JA/UK	46.0	34.9	18.5	83.8	71.9
JA/FR	42.8	52.7	23.6	69.6	79.9
UK/US	10.1	8.6	9.7	7.8	-27.2
FR/US	63.1	71.0	13.8	95.2	89.0
FR/UK	61.5	66.9	12.1	96.1	96.7
1949-1987					
JA/US	17.5	24.7	13.2	43.1	71.4
JA/UK	42.4	45.6	7.9	81.4	97.0
JA/FR	27.9	41.9	17.2	62.0	83.1
UK/US	31.6	25.9	11.3	87.2	81.0
FR/US	20.3	25.3	14.0	52.4	69.4
FR/UK	22.4	15.6	16.8	44.0	-16.0

Source: See text.

Notes: Figures in the first three columns are (logarithmic) standard deviations of the components of q and of q itself, each multiplied by 100. Figures in the last two columns are computed as one minus the ratio of the squared standard deviation of q to the squared standard deviation of the respective component, again multiplied by 100.

Table 3

Tests for Cointegration between the Logarithms of Exchange-Rate-Adjusted Price Levels: 1875-1987

$$p^{a}_{t} = a + b\, p^{*}_{t} + u_{t}$$

Countries	b /(sb)	DF	ADF(2)
JA/US	1.149 (.0172)	-3.740	-3.924
JA/UK	1.095 (.0139)	-3.350	-3.232
JA/FR	1.069 (.0069)	-2.614	-3.957
UK/US	.998 (.0149)	-4.199	-3.800
FR/US	.887 (.0179)	-3.745	-4.691
FR/UK	.924 (.0109)	-3.871	-3.479

Source: See text.

Notes: b is the slope coefficient in the cointegrating regression and sb its standard error, DF is the Dickey-Fuller test and ADF(2) the augmented Dickey-Fuller test, based on a regression using two lagged values of the differenced residuals from the cointegrating regression.

Critical values for the tests of the hypothesis of no cointegration are as follows:

	.01	.05	.10
DF	-4.07,	-3.37	-3.03
ADF	-3.73,	-3.17	-2.91

Table 4

Error-Correction Models for and Unit Root Tests of Logarithms of Real Exchange Rates: 1875-1987

$$q_t = c_0 + c_1 q_{t-1} + v_t$$

Countries	c_1 /(sc_1)	DF	ADF(2)	ADF(4)
JA/US	.905 (.0455)	-2.090	-2.903	-3.734
JA/UK	.895 (.0424)	-2.481	-2.176	-2.613
JA/FR	.940 (.0366)	-1.653	-1.463	-2.364
UK/US	.756 (.0678)	-3.600	-4.607	-5.421
FR/US	.809 (.0567)	-3.363	-3.524	-4.868
FR/UK	.842 (.0551)	-2.855	-4.073	-3.928

$$q_t = c_0 + c_1 q_{t-1} + c_3 t + v_t$$

Countries	c_1 /(sc_1)	c_3 /(sc_3)	DF
JA/US	.819 (.0575)	-.0007 (.0003)	-3.141
JA/UK	.793 (.0588)	-.0008 (.0003)	-2.176
JA/FR	.848 (.0536)	-.0009 (.0004)	-1.463
UK/US	.751 (.0701)	.0001 (.0002)	-4.607
FR/US	.725 (.0673)	.0007 (.0003)	-3.524
FR/UK	.794 (.0606)	.0005 (.0003)	-4.073

Source: See text.
Notes: The symbols sc_1 and sc_3 represent the standard errors of the regression coefficients c_1 and c_3. DF is the Dickey-Fuller test; ADF(2) and ADF(4) are the augmented Dickey-Fuller tests, based on regressions using two and four lagged differences of the deviations of actual q from the estimated equilibrium value of q, respectively. In each case, these are tests of the null hypothesis of $c_1 = 1$.

The .01, .05 and .10 critical values for the tests reported in the top half of the table are -3.51, -2.89 and -2.58, respectively; for those reported in the bottom half of the table, yhey are -4.04, -3.45 and -3.14, respectively.

Table 5

Standard Deviations of Logarithms of Real Exchange Rates

1875-1896

Period	Countries					
	JA/US	JA/UK	JA/FR	UK/US	FR/US	FR/UK
1875-1896	8.80	7.71	7.07	4.95	6.24	3.33
1897-1914	5.50	7.93	6.46	6.31	5.30	3.23
1915-1940	17.67	18.03	29.95	12.46	20.22	18.4
1921-1928	8.72	8.83	9.63	4.07	10.92	11.67
1929-1940	14.38	16.69	23.39	13.69	11.15	17.08
1954-1973	5.43	5.03	3.41	3.89	6.89	5.94
1974-1986	9.64	9.06	16.47	12.37	20.52	16.61

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

Table 6

Standard Deviations of Changes in Logarithms of Real Exchange Rates

1875-1896

Period	Countries					
	JA/US	JA/UK	JA/FR	UK/US	FR/US	FR/UK
1875-1896	8.77	6.95	6.59	4.77	6.51	3.62
1897-1914	5.52	3.82	4.21	3.95	4.61	3.24
1915-1940	9.14	11.88	16.34	10.53	13.81	14.56
1921-1928	8.83	9.62	15.29	5.57	13.96	14.35
1929-1940	9.31	13.07	13.36	14.20	8.89	12.86
1954-1973	4.37	4.45	3.46	3.23	4.99	4.91
1974-1986	10.55	9.65	10.86	11.58	13.69	8.20

Source: See text.

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

Table 7

Comparisons of the Variability of Real Exchange Rates
During the Japanese Floating-Rate Period of 1875 to 1896

Period	Countries					
	JA/US	JA/UK	JA/FR	UK/US	FR/US	FR/UK
	Standard Deviations of Log Levels					
1875-1887	8.31	6.29	5.71	5.89	6.87	2.79
1888-1896	8.22	7.74	8.50	3.47	4.98	2.95
	Standard Deviations of First Differences of Logs					
1875-1887	7.90	5.26	4.72	5.28	6.13	3.09
1888-1896	10.38	9.24	8.98	4.15	7.36	4.48

Source: See text.

Note: All figures are multiplied by 100.

Notes

1. During the post World War II era, the only currency that shows a similar downward drift against the dollar is the Swiss franc. In this regard, see the graphical evidence contained in my 1986 paper and the statistical evidence derived from a principal-components analysis of the major currencies in Koedijk and Schotman (1989, forthcoming).

2. See the papers cited below in connection with the discussion of purchasing power parity. Note that this description of exchange-rate behavior under the current float, though perhaps a majority opinion, is not universally shared. Cross-country evidence presented in Lothian (1985) indicates that dollar exchange rates for a sample of 19 developed countries exhibited a pattern of changes roughly in line with the changes in inflation differentials between the Bretton-Woods and floating-rate periods. Suzuki (1988) reaches similar conclusions on the basis of his overview of four real dollar exchange rates under floating.

3. Mussa (1986) provides copious evidence with regard to the greater variability of real exchange rates under floating than under fixed rates. The bulk of this evidence comes from comparisons of behavior of various dollar exchange rates during the current float with that under Bretton Woods. Also see Stockman's (1983) study using two-way analysis of variance to compare the annual variances of monthly real dollar exchanges across a sample of 38 countries during the Bretton-Woods and early floating-rate years. Baxter and Stockman (1988), however, find little evidence of differences between exchange-rate regimes in the relationships among other real economic variables either across countries or within countries over time.present conflicting evidence.

4. One paper advancing this view is Frankel's (1986) examination of long term behavior of the dollar-sterling exchange rate. Also see my analyses (1986, 1987) of real exchange rates of 12 major industrial countries in the Bretton-Woods and current floating-rate periods, a major conclusion of which was that the variations in real dollar exchange rates were dominated by two large shifts in the average levels and that the data, therefore, contained relatively few effective degrees of freedom.

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

6. See the discussion in Lockwood (1954, pp. 36-37) and the references contained therein.

7. The period was not, however, one of a completely free float. 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, was abandoned after a year of preliminary stabilization of the yen
due to the financial panic of March 1927 (Takagi, 1989).

8. Dornbusch (1976)contains the classic statement of the "sticky-price"
monetary model of exchange-rate determination that underlies this result. Also see Muss (1982).

Friedman and Schwartz (1963), citing Jacob Viner, assign an important role to capital flows during many periods in U.S. history in which nominal exchange rates exhibited marked shorter term divergences from purchasing power parity.

9. These studies of the time series properties of exchange rates include Roll(1979) and Darby (1983). Meese and Rogoff (1983) present evidence of the inability of reduced-form forecasting equations to outperform the random-walk model in predicting exchange rates.

10. The data span four countries -- Japan, France, the United States and the United Kingdom -- and, with an interruption for World War II, the years 1874 to 1986. 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 Hundred Year Statistics of the Japanese Economy. 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 three sterling-dollar, franc-dollar and franc-sterling real cross rates. They were updated on the basis of the annual average (dollar) exchange rates reported in the International Financial Statistics (IFS).

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

11. For the levels, the correlation is computed as one minus the ratio of the variance of the log of the real exchange rate to the variance of the log of the component; for the first differences, it is computed as one minus the ratio of sum of the variance of the first differences of the log of the real exchange rate and the square of the mean of those first differences to the variance of the first differences of the log of the component.

12. Marston (1986) presents evidence linking the trend in the post-WWII period to rapid technological change in the manufacturing sector. Also in this regard see the discussion of yen real exchange rates in Harberger (1989).

13. One standard of comparison is the variability of velocity over similarly long periods, or across a broad sample of countries. Friedman and Schwartz, using data averaged over cycle phases, provide estimates of the coefficient of M2 velocity of .34 for the United States and .16 for the United Kingdom over the period 1870 to 1975. I derive an estimate of the coefficient of variation of high-powered money velocity of .32 across 47 countries and the years 1952 to 1967 (Lothian, 1976).

14. See the discussion of cointegration in Engle and Granger, 1987. Applications to exchange rate data are contained in Baillie and Bollerslev (1989), Enders (1988, 1989), Hakkio and Rush

(1989) and McNown and Wallace (1989 forthcoming).

15. Note that the significance levels for the t-statistics used in these tests are those of Engle and Yoo (1987).

16. It is interesting to note that these results are contradicted by the indirect evidence provided by the test for the exchange-rate pairs that are components of these two exchange rates (the yen-dollar and sterling-dollar rates in the case of the yen-sterling rate; the yen-dollar and franc-dollar rates in the case of the yen-franc rate). In each instance, these tests support the hypothesis of cointegration.

17. If we write equations (8) and (9) in their equivalent forms with the q terms expressed as deviations from the mean and the constants omitted, the correspondence to the cointegration test becomes clearer: These are simply one-equation analogues of the two-step procedure used in the tests of cointegration reported above, the one substantive change being that the cointegration factor, the slope term in the earlier equilibrium equation, has now been constrained to unity. A test of the hypothesis that c_1 is equal to unity (or equivalently, that c_2 is equal to zero) is, therefore, a test of cointegration, given this constraint. Correspondingly, we can write an expanded version of (10), that includes lagged first differences of q, to conduct the ADF test analogous to those conducted with equation (4) above.

18. One possibility is that measured real exchange rates are subject to two types of effects -- periodic permanent shifts in levels due to real factors and measurement errors of various sorts and transitory movements due to shifts in monetary policy, actual or anticipated. Gandolfi and I (1983), using much the same data as Darby (1983) uses in his analysis of real exchange rates, find that this characterization describes the error structure of the price equations that we estimate.

Cochrane (1988) contains a discussion of the statistical difficulty of distinguishing this type of stochastic trend model from one in which permanent shifts follow a deterministic trend, which is the simplifying assumption employed here.