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Real Exchange Rate Behavior: The Recent Float from the Perspective of the Past Two Centuries

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Using annual data spanning two centuries for dollar-sterling and franc-sterling real exchange rates, we find strong evidence of mean-reverting real exchange rate behavior. Using simple, stationary, autoregressive models estimated on prefloat data, we easily outperform nonstationary real exchange rate models in dynamic forecasting exercises over the recent float. Such stationary univariate equations explain 60–80 percent of the in-sample variation in real exchange rates, although the degree of short-run persistence may be high. The econometric estimates imply a half-life of shocks to the real exchange rate of about 6 years for dollar-sterling and a little under 3 years for franc-sterling.

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I. Introduction

In this paper we investigate the long-run, mean-reverting properties of real exchange rates and examine whether any additional insight into exchange rate behavior can be gained by considering the recent floating rate period from the perspective of data reaching much further back into history. To do so, we have assembled what to our knowledge is the longest currently available exchange rate and price-level data set for the United States, the United Kingdom, and France, a data set that continuously spans some two centuries in length, beginning in 1791 and ending in 1990.

The principal motivation for this investigation centers around two related issues: the concern that has recently been voiced in the literature over the low power of statistical tests of nonstationarity applied to real exchange rates during the current float (see, e.g., Frankel 1993; Johnson 1993), and the potential problems that arise in attempting to increase test power by incorporating prefloat observations in the data set.

These issues can perhaps be best understood in the context of the shifts in professional consensus over the past three decades on the subject of real exchange rate stability between the currencies of the major industrialized countries.[1] While most prefloat studies supported the existence of a fairly stable real exchange rate over the long run (e.g., Friedman and Schwartz 1963; Gailliot 1970),[2] the prevailing orthodoxy of the early 1970s, largely associated with the monetary approach to the exchange rate,[3] went even further by adopting the much stronger proposition of PPP on a continuous basis.[4] Then, how-

[1] See Froot and Rogoff (in press) for a recent survey of theoretical and empirical work on purchasing power parity (PPP) and long-run real exchange rates.

[2] According to Friedman and Schwartz, "One striking example of the stability of basic economic relations is the stability of relative prices in the United States and Great Britain adjusted for changes in the exchange rate between the dollar and the pound. We have a reasonably continuous series from 1871 on. . . . In the 79 years from 1871 to 1949, vast changes occurred in the economic structure and development of the United States, the place of Britain in the world economy, the internal monetary structures of both the United States and Great Britain, and the international monetary arrangements linking them. Yet despite these changes, despite two world wars and despite the statistical errors in the price-index numbers, the adjusted ratio on the base that makes 1929 = 100 was between 84 and 111 in all but one of the 79 years" (1963, pp. 678–79).

[3] See Taylor (1995) for a recent survey of the exchange rate economics literature, including PPP and the various exchange rate models that have been developed over the last 20 years.

[4] See, e.g., Frenkel (1976), McCloskey and Zecher (1976), and many of the other studies reprinted in Frenkel and Johnson (1978). Proponents of early monetary exchange rate models, moreover, argued that while the exchange rate may apparently diverge from PPP when conventional price indices are used, the condition would be seen to hold if one could observe the "true" price indices that are relevant for deflating national monies (see, e.g., Mussa 1976).

ever, in the mid to late 1970s, opinion shifted back in the earlier direction. The apparent "collapse" of PPP under the float (principally the observed high variance of real exchange rates) (Frenkel 1981) was a motivating force in the development of the sticky-price, overshooting exchange rate model due originally to Dornbusch (1976). Subsequently, largely as a result of studies published mostly in the 1980s that could not reject the hypothesis of random walk behavior in real exchange rates (e.g., Roll [1979], Adler and Lehmann [1983], and the later cointegration studies such as Taylor [1988] and Mark [1990]), sentiment shifted yet again, to a position broadly diametrically opposite to that of the belief in instantaneous PPP of a scant decade and a half before: The belief became prevalent that PPP was of little use empirically over any time horizon and that movements in real exchange rates, if not actually permanent, were so highly persistent as to be effectively so.[5] More recently, that view too has been called into question as a number of studies employing long-term, and hence largely prefloat, data (e.g., Abuaf and Jorion 1990; Kim 1990; Lothian 1990, 1991; Diebold, Husted, and Rush 1991; Grilli and Kaminsky 1991; Rogers 1994) have presented evidence of real exchange rate mean reversion.[6]

Because of the low power of tests for nonstationarity over short sample periods (Shiller and Perron 1985; Hakkio and Rush 1991; Lothian and Taylor 1995), some researchers have argued that the difference in the length of the data series used in the two types of studies is crucial.[7] Indeed, as we have pointed out, this is one of the principal motivations for this paper and our construction of the longest data set of any published study to date.

Substantially increasing the length of the sample, however, results in the inclusion of data from the variety of nominal exchange rate

[5] See, e.g., Stockman (1987). A notable exception to this literature was Officer (1982).

[6] Several studies employing shorter-term data for episodes and countries other than the major industrial countries under the recent float (e.g., Taylor and McMahon 1988; McNown and Wallace 1989) have also uncovered evidence of mean reversion in real exchange rates. A feature of many of the series examined in these studies is that there are very large movements in the relative price series in such situations, including the interwar German hyperinflation and Latin American high-inflation episodes, although the finding of mean reversion of the real exchange rate for several country pairs in the 1920s in which this is not the case (Taylor and McMahon 1988) warrants further investigation. Flood and Taylor (1995) also find evidence of long-run reversion of real exchange rates toward PPP in a study employing time-series/cross-section data for 22 OECD countries over a 20-year period from 1974.

[7] This argument is made by Frankel (1986, 1993), Huizinga (1987), Abuaf and Jorion (1990), and Lothian (1990). It may be one reason why Grilli and Kaminsky (1991), e.g., are able to reject nonstationarity in the sterling-dollar real exchange rate over their full sample period, 1885–1986, but not in general over specific subperiods.

regimes that existed in the long historical period before the current float. The observations from that latter period therefore end up being a small proportion of the observations in the full sample. A significant innovation of the present study over the previous studies that have employed long-term real exchange rate data, therefore, is that we attempt to infer the information content of the prefloat data for the recent floating-rate period by, for example, estimating autoregressive real exchange rate equations using prefloat data and then testing and otherwise evaluating their stability and forecasting accuracy over the course of the recent float.

In Section II, we give a brief statement of the PPP hypothesis and discuss its relationship with mean reversion in the real exchange rate. Section III describes the data set, and Section IV presents our empirical results. Section V presents a summary of results and some brief conclusions.

II. Purchasing Power Parity

Under PPP, the nominal exchange rate is proportional to a ratio of foreign and domestic price levels:

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

where s_t is the logarithm of the nominal exchange rate (the foreign price of domestic currency) and p_t and p_t^* are the domestic and foreign price levels, respectively.[8] The nature of deviations from PPP can be examined through the real exchange rate since the logarithm of the real exchange rate, q_t, can be defined as the deviation from PPP:

$$q_t \equiv s_t + p_t - p_t^*. \tag{2}$$

If PPP held continuously, q_t would be a constant reflecting differences in units of measurement. However, the sample variance of major real exchange rates over the recent float is very large, providing strong and clear evidence against continuous PPP. As noted above, failure to reject the hypothesis of nonstationarity in the real exchange rate has often been taken as evidence against long-run PPP (although see Frankel [1993] for a critical discussion of this literature).[9]

[8] We are implicitly dealing with absolute rather than relative PPP (see Officer 1982).

[9] Note that it is theoretically possible for the real exchange rate to be in equilibrium at a level other than the PPP level. In equilibrium exchange rate models (e.g., Stockman 1980; Lucas 1982), the equilibrium real exchange rate is determined endogenously as the result of optimizing behavior by agents in clearing markets.

III. Two Centuries of Data on Real Exchange Rates

Our data set consists of annual observations of dollar-sterling and franc-sterling exchange rates and the wholesale price indexes of France, the United States, and the United Kingdom. In the case of the latter two countries, these data span the full two centuries 1791–1990 and, in the case of France, the 188 years 1803–1990. A full listing of data sources and methods is given in the Appendix. Deflating the nominal exchange rate series by relative prices, we obtain the dollar-sterling and franc-sterling real exchange rate series graphed in figures 1 and 2.

This sample offers a uniquely rich body of data for studying exchange rate behavior. For the three countries we study, exchange rate arrangements varied considerably over these two centuries, ranging from the pure gold standard, including its heyday period of 1880–1914, to wartime controls of varying intensity, to episodes of floating rates and fiat money. The number of separate exchange rate regimes during this 200-year span varied from nine for the United Kingdom to 12 each for France and the United States, when the periods in which the two were on a bimetallic standard are subdivided into subperiods of gold or silver dominance (see Lothian and Taylor 1995).

Confrontation with data spanning several nominal exchange rate regimes is the inevitable cost of increasing the length of the data sample size, but at the same time, it provides the basis for a more stringent test of mean reversion in the real exchange rate than would be possible with shorter though still lengthy samples. A number of studies have documented the increased short-term volatility of real exchange rates during floating-rate regimes.[10] In this paper, however, we are concerned with the longer-run properties of real exchange rates. Although we believe it is quite likely that the time-series properties of real exchange rates will have altered in some respects between regimes, we are in effect examining whether there are significant similarities that carry over.[11] It also seems likely that, over a period

[10] See, e.g., Stockman (1983), Mussa (1986), Frankel and Meese (1987), Dornbusch and Frankel (1988), Baxter and Stockman (1989), and Becketti and Hakkio (1992). In the empirical work reported in the next section, we allow for variations in the short-run volatility of real exchange rates across regimes by employing heteroskedasticity-robust econometric techniques.

[11] Moreover, in some equilibrium exchange rate models (e.g., Stockman 1980), the real exchange rate is invariant to the choice of nominal exchange rate regime. While it is known that the volatility of the real exchange rate is not regime neutral, Becketti and Hakkio argue that regime neutrality is more likely to hold for the long-run properties of the real exchange rate; see Becketti and Hakkio (1992, pp. 5–7) for further discussion of this issue in relation to testing for mean reversion in real exchange rates across regimes. See also Rogers (1994) on this issue.

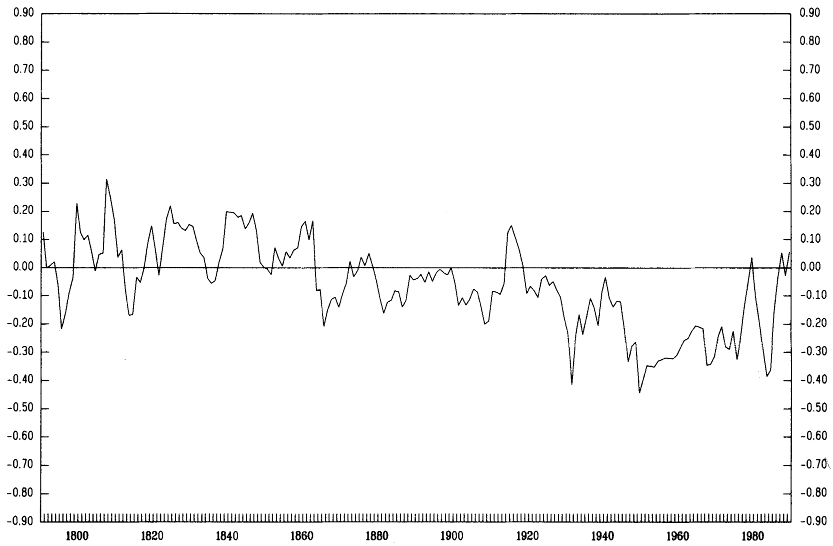

FIG. 1.—Logarithm of dollar-sterling real exchange rate, 1791–1990 (1900 = 0; increase = sterling appreciation).

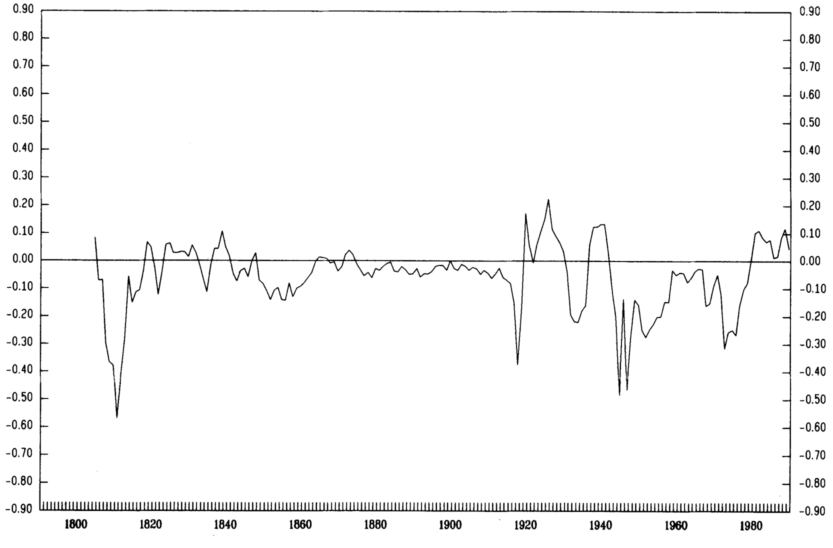

FIG. 2.—Logarithm of franc-sterling real exchange rate, 1805–1990 (1900 = 0; increase = sterling appreciation).

of 200 years, there will have been important real shocks to the real exchange rate, some of which may have had permanent components.[12] Our aim is to examine whether the hypothesis of a stationary real exchange rate is a good first approximation that describes the salient characteristics of real exchange rate behavior even over such a diverse period as the last two centuries.

IV. Empirical Results

A. *Unit Root Tests*

We applied two sets of unit root tests to the data, both standard Dickey-Fuller tests and the seminonparametric Phillips-Perron modifications of those tests as cataloged in Perron (1988). Perron demonstrates that if a series is stationary about a linear trend but no allowance for the trend is made in the construction of the unit root test, then the probability of a type II error (failure to reject the unit root hypothesis when it is false) may be high.[13] Perron suggests the following strategy for testing for unit root behavior in a series q_t. First, estimate the following regression by ordinary least squares:

$$q_t = \kappa + \lambda\left(t - \frac{T}{2}\right) + \delta q_{t-1} + u_t, \tag{3}$$

where $T + 1$ is the sample size and u_t is an error that may be serially correlated and heterogeneously distributed.[14] Then use the seminonparametric test statistics developed by Phillips (1987*a*, 1987*b*) and Phillips and Perron (1988) to test the following hypotheses:

$$H_A\colon \delta = 1; \quad H_B\colon (\kappa, \lambda, \delta) = (0, 0, 1); \quad H_C\colon (\lambda, \delta) = (0, 1). \tag{4}$$

The appropriate test statistics are, in fact, transforms of the standard t-statistic for H_A and of the standard F-statistics for H_B and H_C (we denote them $Z(\tau_\tau)$, $Z(\Phi_2)$, and $Z(\Phi_3)$, respectively). If the unit root hypothesis can be rejected at this juncture, there is no need to pro-

[12] Grilli and Kaminsky (1991) argue that the persistence of real exchange rate shocks is more likely to be a function of the specific historical period rather than the particular nominal exchange rate regime.

[13] In other words, the test will lack power. The intuition behind Perron's formal proof can be seen as follows. Suppose that the true data-generating process is $q_t = \alpha + \beta t + u_t$, where u_t is stationary white noise; i.e., q_t is stationary about a linear trend. If we estimate the AR(1) model $q_t = \tau + \rho q_{t-1} + \epsilon_t$, then ρ will be forced to unity, so that the AR(1) model is equivalent to $q_t = q_0 + \tau t + \tilde{\epsilon}_t$, where $\tilde{\epsilon}_t = \Sigma_0^t \epsilon_t$, which approximates a linear trend.

[14] See Perron (1988) for the precise set of assumptions concerning the error term. The assumptions are sufficiently weak to allow q_t to follow a general autoregressive moving average or (subject to the stationarity of the exogenous variables) ARMAX process.

ceed. If not, then greater test power may be obtained by estimating the regression

$$q_t = \kappa^* + \delta^* q_{t-1} + u_t^* \tag{5}$$

and testing the hypotheses

$$H_D\colon \delta^* = 1; \quad H_E\colon (\kappa^*, \delta^*) = (0, 1) \tag{6}$$

using the Phillips-Perron transforms of the relevant t-statistic and F-statistic ($Z(\tau_\mu)$ and $Z(\Phi_1)$). This procedure is valid, however, only if the drift term in (3), κ, is zero since $Z(\tau_\mu)$ and $Z(\Phi_1)$ are not invariant with respect to κ. Thus the statistics $Z(\tau_\mu)$ and $Z(\Phi_1)$ should be used to provide additional evidence on the unit root hypothesis only if the value of $Z(\Phi_2)$ suggests that H_B cannot be rejected (Perron 1988).[15]

For the full sample periods (1791–1900 for dollar-sterling and 1803–1990 for franc-sterling), the unit root hypothesis is rejected at standard significance levels (table 1). This is also true when the sample period is truncated at 1945. For the subperiod following World War II (1946–90), however, and for the floating exchange rate period (1974–90), we are unable to reject the unit root hypothesis at even the 10 percent level for either exchange rate. Our inability to reject the unit root hypothesis for the post–World War II period and the floating-rate period may, however, be due to a loss of power in moving to a smaller sample size. This point is underscored by considering the unit root tests applied to other subsamples of approximately 45

[15] Phillips and Perron (1988) and Schwert (1989) demonstrate that the Phillips-Perron statistics may be subject to considerable distortion in the presence of moving average components in the time series (see also Hamilton 1994, pp. 515–16). Estimates of ARIMA(1, 0, 1) and ARIMA(1, 1, 1) models for the various subsamples, however, indicated the presence of small and insignificant moving average components. For the full sample, e.g., we estimated the following ARIMA(1, 0, 1) models:

dollar-sterling:

$$\underset{(38.110)}{q_t = 1.589} + \underset{(21.275)}{.863} q_{t-1} + u_t + \underset{(1.171)}{.137} u_{t-1},$$

$$Q(42) = \underset{(.57)}{39.56}, \text{ sample} = 1792\text{–}1990,$$

franc-sterling:

$$q_t = \underset{(-56.167)}{-1.382} + \underset{(12.120)}{.757} q_{t-1} + u_t + \underset{(.431)}{.041} u_{t-1},$$

$$Q(39) = \underset{(.86)}{29.59}, \text{ sample} = 1804\text{–}1990,$$

where Q is the Ljung-Box statistic, figures in parentheses below coefficient estimates are asymptotic t-ratios, and those below the values of the Ljung-Box statistic are marginal significance levels.

TABLE 1

UNIT ROOT TESTS FOR REAL EXCHANGE RATES

	τ_μ	τ_τ	$Z(\tau_\mu)$	$Z(\Phi_1)$	$Z(\tau_\tau)$	$Z(\Phi_2)$	$Z(\Phi_3)$
				Dollar-Sterling			
1791–1990:							
Log level	−3.47*	−4.36*	−3.52*	6.20*	−4.61*	7.17*	10.76*
First difference	−13.24	−13.21	−13.31	88.36	−13.27	58.56	87.81
Second difference	−21.92	−21.86	−31.47	491.55	−13.15	322.66	483.99
1791–1945:							
Log level	−3.85*	−4.58*	−4.01*	8.08*	−4.79*	7.68*	11.49*
First difference	−12.29	−12.25	−12.45	77.37	−12.40	51.17	76.73
Second difference	−20.22	−20.15	29.76	441.07	−29.44	287.86	431.76
1946–90:							
Log level	−1.47	−2.85	−1.52	1.31	−2.71	3.12	4.48
First difference	−5.52	−5.50	−5.53	14.93	−5.47	9.84	14.62
Second difference	−8.71	−8.56	−12.10	69.71	−11.44	43.61	65.41
1974–90:							
Log level	−1.21	−1.42	−1.18	1.05	−1.37	.91	1.01
First difference	−2.62	−2.57	−2.43	2.59	−2.28	1.64	2.45
Second difference	−4.47	−4.30	−5.36	13.37	−4.71	7.31	10.51

	Franc-Sterling						
1803–1990:							
Log level	−4.85*	−4.83*	−5.17*	13.41*	−5.16*	8.94*	13.40*
First difference	−14.77	−14.73	−14.97	111.85	−14.91	74.08	111.12
Second difference	−24.35	−24.28	−37.62	705.41	−37.31	462.86	694.23
1803–1945:							
Log level	−3.27*	−3.21	−3.93*	8.06*	−3.97*	5.46*	8.03*
First difference	−9.44	−9.44	−9.30	42.66	−9.23	78.65	47.96
Second difference	−16.60	−16.57	−22.07	240.18	−22.05	161.38	241.93
1946–90:							
Log level	−2.05	−3.15	−2.00	2.05	−3.34	3.82	5.69
First difference	−8.64	−8.49	−8.65	37.55	−8.48	24.95	37.27
Second difference	−10.61	−10.40	−16.10	130.07	−15.35	81.04	119.44
1974–90:							
Log level	−1.78	−.87	−1.86	3.22	−.62	2.03	1.62
First difference	−2.47	−2.87	−2.43	2.95	−2.57	2.61	3.73
Second difference	−3.69	−4.17	−3.98	6.42	−3.72	4.83	7.16

NOTE.—The null hypothesis and test statistics are discussed in the text and defined in Perron (1988). Allowance was made for up to fifth-order serial correlation using the lag window recommended by Newey and West (1987). The asymptotic critical values are taken from Fuller (1976) and Dickey and Fuller (1981) and are as follows:

Significance Levels	Critical Values 10%	5%	2.5%	1%
$Z(\tau_\mu)$, τ_μ	−2.57	−2.86	−3.12	−3.43
$Z(\Phi_1)$	3.78	4.59	5.38	6.43
$Z(\tau_\tau)$, τ_τ	−3.12	−3.41	−3.66	−3.96
$Z(\Phi_2)$	4.03	4.68	5.31	6.09
$Z(\Phi_3)$	5.34	6.25	7.16	8.27

* Significant at the 5 percent level or less (log levels only).

TABLE 2

UNIT ROOT TESTS FOR SELECTED SUBPERIODS: LOG LEVELS

	τ_μ	τ_τ	$Z(\tau_\mu)$	$Z(\Phi_1)$	$Z(\tau_\tau)$	$Z(\Phi_2)$	$Z(\Phi_3)$
			Dollar-Sterling				
1805–50	−2.54	−2.43	−2.77	3.92	−2.71	2.57	3.86
1870–1913	−2.65	−3.17	−2.72	4.03	−3.24	3.66	5.47
			Franc-Sterling				
1805–50	−2.15	−2.74	−2.48	3.14	−3.07	3.23	4.82
1870–1913	−3.23*	−3.47*	−3.27*	5.36*	−3.54*	4.21*	6.31*

NOTE.—The null hypothesis and test statistics are discussed in the text and defined in Perron (1988). Allowance was made for up to fifth-order serial correlation using the lag window recommended by Newey and West (1987). Critical values are defined in table 1.

* Significant at the 5 percent level.

years (table 2): only once in four cases is the unit root hypothesis rejected at the 5 percent level.[16]

B. *Univariate Autoregressions*

In figures 3, 4, 5, and 6, we have plotted the sample correlogram and partial correlogram of the two real exchange rate series for the full sample period. In each case, the correlogram shows exponential decay, and the partial correlogram has a single significant spike at the first partial autocorrelation. Thus, in both cases, a simple first-order autoregressive model is indicated. Note that the sample correlograms, while suggesting the stationarity of both series, do, however, indicate a higher degree of persistence in the dollar-sterling real rate.

In table 3, we report AR(1) equations estimated for the two exchange rates both over the full sample period and excluding the recent float. In each case the estimated slope coefficients are close to but less than unity.[17] The equations provide good fits, explaining some 80 percent of the variation in the dollar-sterling real exchange rate over the past 200 years and some 60 percent of the variation in the franc-sterling real rate. The slope coefficients are extremely well determined, and each equation supplies satisfactory residual diagnostics. Moreover, the coefficients alter only very slightly when the floating-rate period data are included, and indeed there is no sign of a

[16] It is interesting to note that the subperiod in which the unit root hypothesis is rejected for the franc-sterling real exchange rate corresponds broadly to the classical gold standard period.

[17] Note that we use heteroskedasticity-robust estimation techniques, so that the variance of shocks to the real exchange rate is allowed to vary over time.

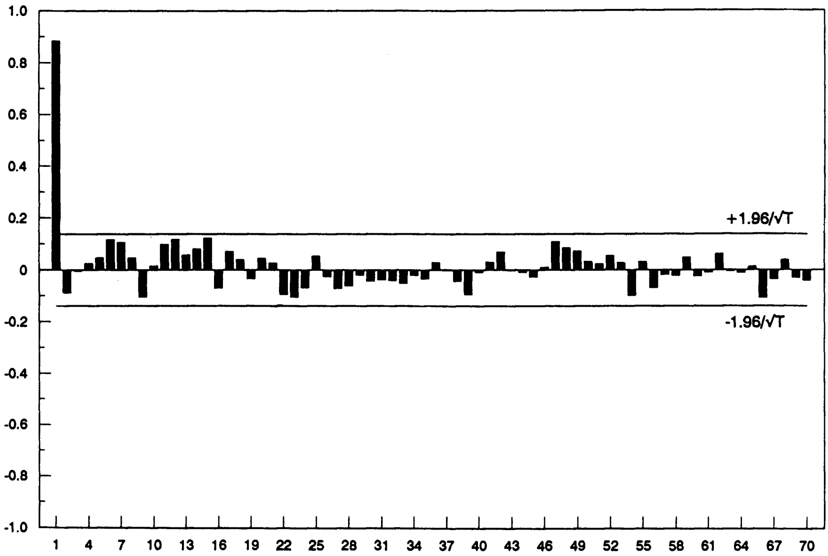

FIG. 3.—Sample partial autocorrelation function for dollar-sterling real exchange rate.

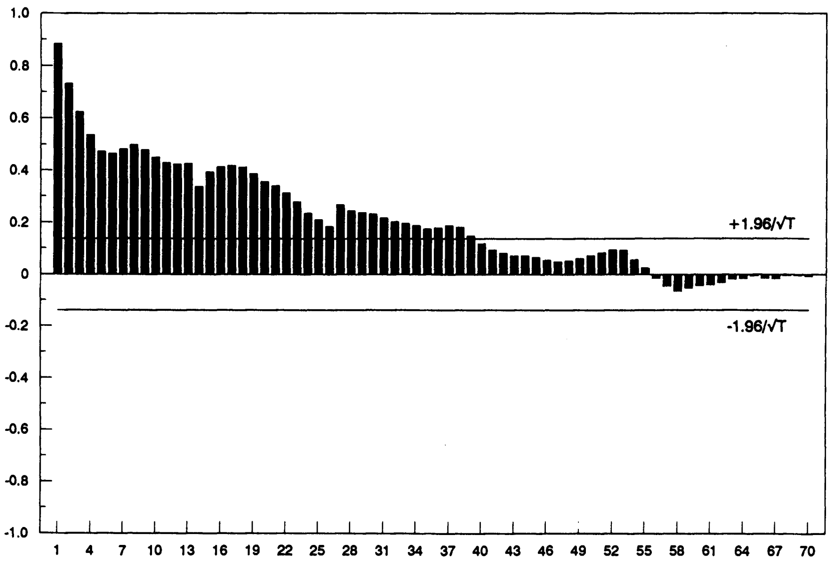

FIG. 4.—Sample autocorrelation function for dollar-sterling real exchange rate

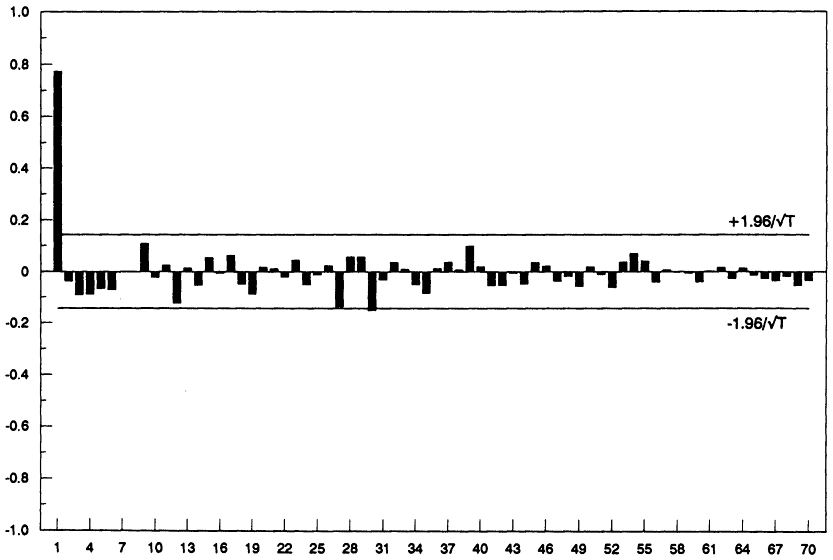

FIG. 5.—Sample partial autocorrelation function for franc-sterling real exchange rate.

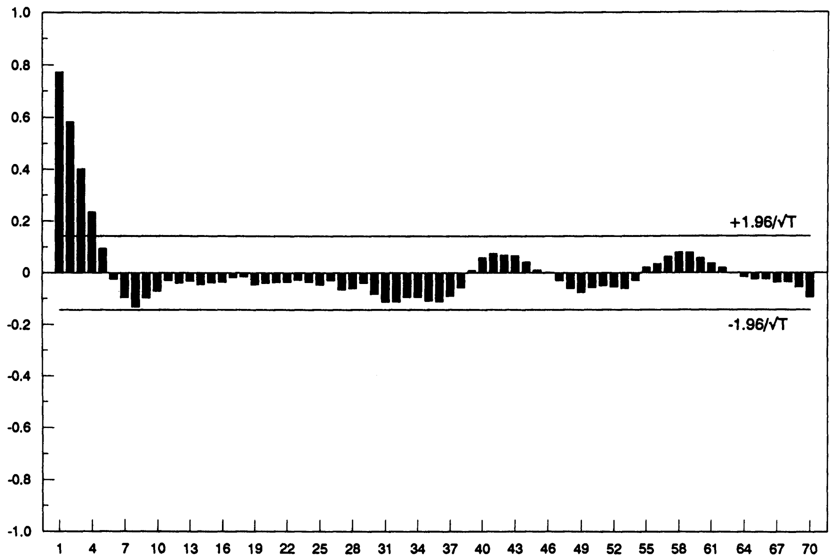

FIG. 6.—Sample autocorrelation function for franc-sterling real exchange rate

TABLE 3

ESTIMATED AUTOREGRESSIONS

DOLLAR-STERLING

1792–1973

$$\hat{q}_t = \underset{(.049)}{.161} + \underset{(.031)}{.898} q_{t-1}$$

$R^2 = .80$; SER = 6.8 percent; D-W = 1.88; $Q(39) = \underset{(.41)}{40.25}$;

$\text{AR}_{1-5}(5, 171) = \underset{(.45)}{.94}$; $\text{Chow}(2) = \underset{(.92)}{.16}$

1792–1990

$$\hat{q}_t = \underset{(.049)}{.179} + \underset{(.031)}{.887} q_{t-1}$$

$R^2 = .79$; SER = 7.1 percent; D-W = 1.78; $Q(42) = \underset{(.41)}{43.33}$;

$\text{AR}_{1-5}(5, 188) = \underset{(.12)}{1.75}$

FRANC-STERLING

1804–1973

$$\hat{q}_t = \underset{(.101)}{-.333} + \underset{(.076)}{.761} q_{t-1}$$

$R^2 = .57$; SER = 7.9 percent; D-W = 1.89; $Q(36) = \underset{(.92)}{24.93}$;

$\text{AR}_{1-5}(5, 159) = \underset{(.99)}{.03}$; $\text{Chow}(2) = \underset{(.18)}{3.47}$

1804–1990

$$\hat{q}_t = \underset{(.089)}{-.309} + \underset{(.067)}{.776} q_{t-1}$$

$R^2 = .60$; SER = 7.8 percent; D-W = 1.95; $Q(39) = \underset{(.87)}{29.25}$;

$\text{AR}_{1-5}(5, 176) = \underset{(.12)}{1.75}$

NOTE.—Figures in parentheses below estimated coefficients are heteroskedastic-consistent standard errors (White 1980). R^2 is the coefficient of determination, SER is the standard error of the regression, $Q(l)$ is the Ljung-Box statistic evaluated at l autocorrelations, AR_{1-5} is a Lagrange multiplier test statistic for up to fifth-order serial correlation, and Chow is a test statistic for a structural shift in the coefficients after 1973. Figures in parentheses below test statistics are marginal significance levels.

structural shift in the parameters during the floating period on the basis of a formal (heteroskedasticity-robust) statistical test (Chow).

These results suggest that sterling real exchange rates against the franc and the dollar over the past 200 years are adequately characterized as realizations from stationary AR(1) processes. It is also interesting to note that the estimation results again indicate a higher degree of persistence in the dollar-sterling real exchange rate than in the franc-dollar real rate: The coefficient point estimates indicate that shocks to the real exchange rate are corrected at the rate of some 23 percent per year for franc-sterling but at only some 11 percent per year for dollar-sterling, implying a half-life of real exchange rate shocks of about 6 years for dollar-sterling and a little under 3 years for franc-sterling. This may be a reflection of the larger role that France has traditionally played as a trading partner for the United Kingdom and, relatedly, the closer physical proximity of these two countries. Alternatively, the results may reflect the presence of a larger permanent component in the real dollar-sterling exchange rate series. It is well known that autoregressive integrated moving average processes can be expressed as the sum of stationary and permanent components. We interpret rejection of nonstationarity as evidence that these permanent components are relatively small rather than identically zero.[18] Our aim is to examine whether mean reversion is a good first approximation to real exchange rate behavior. We now explore one way of judging how good that first approximation is.

C. *Out-of-Sample Forecasting*

The empirical results presented so far demonstrate that the mean-reverting behavior of the real exchange rate during the recent float may be, in its salient characteristics, no different from its behavior during the previous one and three-quarter centuries. It still remains a *possibility,* however, that the real exchange rate has followed a random walk during the float, but that this period is too short to influence significantly the full-sample data characteristics. This issue can be addressed by constructing out-of-sample forecasting tests. Our contention is that, if the random walk model is closer to the truth for the floating period, then a random walk model ought to outperform an autoregressive model in out-of-sample dynamic forecasting. We

[18] Rogers (1994) uses a general equilibrium optimizing model to identify real and nominal shocks to the dollar-sterling real exchange rate over the period 1859–1990 and finds that nominal mean-reverting shocks account for 45–55 percent of the variance in the real exchange rate over short horizons. Estimates of time-varying permanent and transitory components of real exchange rates under the float are also provided by Evans and Lothian (1993).

thus constructed 1–5-year-ahead dynamic forecasts, for each year of the float, by using the AR(1) models with the coefficients held fixed at their prefloat values (i.e., at the estimates obtained using data through 1973). Second, we constructed dynamic forecasts using recursively reestimated coefficients. The root mean square errors (RMSEs) of the forecasts were then constructed for each of the five forecast horizons and for both the fixed-coefficient and recursive-estimation cases. We considered two yardsticks against which to judge the performance of the autoregressive models: a random walk real exchange rate model and a random walk model with drift. In the case of the random walk with drift, the drift term was estimated recursively.

The results of these exercises are given in table 4. The first point to notice is that there is little difference in the fixed-coefficient and recursive-estimation results: for dollar-sterling, the fixed-coefficient RMSEs are slightly lower than the recursive-estimation RMSEs; for franc-sterling, the converse is true. This similarity between the two sets of estimates reflects the stability of these autoregressive equations over the period.

Judged against the real random walk models, however, the stationary AR(1) forecasts perform remarkably well. Moreover, the relative superiority of the AR(1) forecasts increases monotonically, as the forecast horizon is extended, for both exchange rates, from between 3 and 5 percent at the 1-year horizon to between 25 and 31 percent at the 5-year horizon.[19]

We regard this as strong evidence that the mean-reverting behavior that characterizes real exchange rate movements in the long period before the float did not give way to nonstationary behavior during the recent float.

V. Conclusion

Using data that at their longest span two centuries, we find that the two real exchange rates that we examine over this period—dollar-sterling and franc-sterling—are both significantly mean-reverting. Stationary, first-order autoregressive, univariate models are capable of explaining some 80 percent of the variation in the dollar-sterling real rate during the past two centuries and 60 percent of the variation

[19] As a check on the robustness of these results, we replicated the dynamic forecasting exercises over the floating rate period, 1974–90, using coefficients estimated with data for only the first 100 years of the data sets, 1792–1892 for sterling-dollar and 1804–1904 for sterling-franc. Expressing the resulting RMSEs as a ratio to the RMSE from the pure random walk forecast at the same horizon and stacking the ratios in a vector with the n-step-ahead ratio in the nth element, we have (.97, .89, .82, .74, .70) for sterling-dollar and (.91, .87, .81, .72, .67) for sterling-franc; the results are confirmed.

TABLE 4

Root Mean Squared Forecast Errors from Recursive Estimation, 1974–90 (%)

Horizon (Years)	Dynamic Forecast RMSE for the Real Exchange Rate: Stationary Autoregression (Coefficients Held Fixed) (1)	Stationary Autoregression (Coefficients Reestimated) (2)	Real Random Walk (3)	Real Random Walk with Drift (4)	(1)/(2)	(1)/(3)	(1)/(4)
			Dollar-Sterling				
1	9.63	9.71	10.12	10.16	.99	.95	.94
2	14.97	15.23	16.72	16.85	.98	.89	.89
3	18.94	19.42	22.27	22.50	.97	.85	.84
4	20.48	21.17	25.74	26.10	.96	.79	.78
5	20.25	21.03	26.86	27.35	.96	.75	.74
			Franc-Sterling				
1	5.41	5.37	5.53	5.56	1.01	.97	.97
2	8.48	8.41	8.93	9.00	1.01	.95	.94
3	10.29	10.19	11.60	11.73	1.01	.88	.88
4	11.56	11.48	14.98	15.20	1.01	.77	.76
5	12.92	12.88	18.27	18.60	1.00	.71	.69

in the franc-sterling real rate. In a series of ex post dynamic simulations for the float, we also find that first-order autoregressive models, estimated on data ending in 1973, perform remarkably well during the float, in that they produce better forecasts of the actual real exchange rates than alternative random walk models. This forecasting superiority, moreover, increases with the time horizon, which is as it should be if real exchange rates are in fact slowly mean-reverting. In line with other recent studies, we find that this process of mean reversion is indeed quite slow, with estimated half-lives of adjustment of 3 years for franc-sterling and 6 years for dollar-sterling (see Frankel 1986, 1993; Abuaf and Jorion 1990; Lothian 1991). This slow adjustment, coupled with the low power of conventional unit root tests in any but the longest time series, we believe, accounts for the widespread failure of such tests to reject the unit root null hypothesis in data for the float alone.

Foremost among the economic implications of these purely statistical findings is what they tell us about PPP as an equilibrium condition: In the long run it remains a useful empirical first approximation. Unless one were to argue that permanent real shocks fortuitously canceled one another out in the sample periods and exchange rates we have examined, one can therefore rule out models that rely on such shocks as the principal driving force. What the statistical results do not do is allow us to make any finer distinctions with regard to model selection. The nature of the deviations from PPP that we observe is consistent with the existence of persistent yet slowly mean-reverting influences, which may be either real[20] or monetary (e.g., regime changes coupled with learning). Translated to the level of economic policy, these findings reinforce the idea of PPP as a long-run constraint.

Appendix

Data Sources and Methods

France

Wholesale price index: 1802–1948, *European Historical Statistics* (Mitchell 1975, pp. 772–74, table I1); 1949–90, various issues of *International Financial Statistics* (IFS). We linked these separate subseries in each instance by multiplying the later series by the ratio of the earlier to the later series in the overlap year. We then rebased the resultant linked series to 1914 = 100. We

[20] Because of international technology diffusion, e.g., the effects of technological innovations on *relative* outputs of countries may be long-lasting but in the end dissipating. Tariff-induced distortions to trade during particular periods conceivably might also generate persistent yet slowly decaying deviations from PPP.

followed the same procedure in constructing the other two countries' wholesale price indexes.

Exchange rate: 1803–1940 and 1945–80, Paris franc-sterling exchange rate from *British Historical Statistics* (Mitchell 1988, pp. 702–3), table entitled Financial Institutions 22. Foreign Exchange Rates—1609–1980, adjusted for a break in 1931 by taking a weighted average of the 124.06 rate prevailing for the first three quarters of that year and the 94.02 rate in the last quarter; 1941–44, derived as a cross rate using New York dollar-sterling rates and Swiss quotations of franc-dollar rates graciously provided by Philippe Jorion; 1981–90, derived as a cross rate from yearly average dollar-sterling and franc-dollar rates from the IFS.

United Kingdom

Wholesale price index: 1791–1939, 1946–48, Jastram (1977, pp. 32–33, table 2); 1939–45, Board of Trade, wholesale price index for 1930–50, as reported in *British Historical Statistics* (p. 730), table entitled Prices 5; 1948–90, IFS, various issues.

United States

Wholesale price index: 1791–1800, Warren and Pearson (1935, pp. 30–32, table 1), with a missing observation for 1792 interpolated as the arithmetic average of the 1791 and 1793 observations; 1800–1976, Jastram (1977, pp. 145–46, table 7); 1976–90, IFS, various issues.

Exchange rate: 1791–96, annual averages of the White exchange rate series in the form of percentage deviations of sterling from parity (in dollars per pound) from Officer (1983, pp. 610–12, app. table 1) adjusted by the parity values in his table 5; 1797–1820, annual averages of the White exchange rate series in the form of percentage deviations of sterling from parity inclusive of U.K. paper currency depreciation from worksheets provided by Lawrence Officer, adjusted by parity values in Officer (1983, table 5); 1821, annual average of the White series inclusive of paper currency depreciation (first quarter) and appendix table 1 (remaining three quarters) adjusted by the parity values in Officer (1983, table 5); 1822–29, same construction as for 1791–96; 1830–99, annual averages of percentage deviations of sterling from parity from Officer (1985, pp. 563–65), adjusted by the parity values in Officer (1983, table 5) (which are variable until 1837 and fixed at 4.8666 thereafter) and further adjusted in the years 1837–43, 1857, and 1862–78 for U.S. currency depreciation on the basis of the estimates reported in Warren and Pearson (1935, p. 154, table 2); 1900–1985, Friedman and Schwartz (1982, pp. 130–37, table 4.9); 1976–90, IFS.

References

Abuaf, Niso, and Jorion, Philippe. "Purchasing Power Parity in the Long Run." *J. Finance* 45 (March 1990): 157–74.

Adler, Michael, and Lehmann, Bruce. "Deviations from Purchasing Power Parity in the Long Run." *J. Finance* 38 (December 1983): 1471–87.

Baxter, Marianne, and Stockman, Alan C. "Business Cycles and the Exchange-Rate Regime: Some International Evidence." *J. Monetary Econ.* 23 (May 1989): 377–400.

Becketti, Sean, and Hakkio, Craig. "How Likely Is It That the Real Exchange Rate Is Stationary?" Manuscript. Kansas City: Fed. Reserve Bank, November 1992.

Dickey, David A., and Fuller, Wayne A. "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root." *Econometrica* 49 (June 1981): 1057–72.

Diebold, Francis X.; Husted, Stephen; and Rush, Mark. "Real Exchange Rates under the Gold Standard." *J.P.E.* 99 (December 1991): 1252–71.

Dornbusch, Rudiger. "Expectations and Exchange Rate Dynamics." *J.P.E.* 84 (December 1976): 1161–76.

Dornbusch, Rudiger, and Frankel, Jeffrey A. "The Flexible Exchange Rate System: Experience and Alternatives." In *International Finance and Trade in a Polycentric World,* edited by Silvio Borner. London: Macmillan (for Internat. Econ. Assoc.), 1988. Reprinted in *On Exchange Rates,* by Jeffrey A. Frankel. Cambridge, Mass.: MIT Press, 1993.

Evans, Martin D. D., and Lothian, James R. "The Response of Exchange Rates to Permanent and Transitory Shocks under Floating Exchange Rates." *J. Internat. Money and Finance* 12 (December 1993): 563–86.

Flood, Robert P., and Taylor, Mark P. "Exchange Rate Economics: What's Wrong with the Conventional Macro Approach?" In *The Microstructure of Foreign Exchange Markets,* edited by Jeffrey A. Frankel, Giampaolo Galli, and Alberto Giovannini. Chicago: Univ. Chicago Press (for NBER), 1995.

Frankel, Jeffrey A. "International Capital Mobility and Crowding-out in the U.S. Economy: Imperfect Integration of Financial Markets or of Goods Markets?" In *How Open Is the U.S. Economy?* edited by Robert W. Hafer. Lexington, Mass.: Lexington, 1986.

———. "Zen and the Art of Modern Macroeconomics: The Search for Perfect Nothingness." In *On Exchange Rates,* by Jeffrey A. Frankel. Cambridge, Mass.: MIT Press, 1993.

Frankel, Jeffrey A., and Meese, Richard. "Are Exchange Rates Excessively Variable?" In *NBER Macroeconomics Annual 1987,* edited by Stanley Fischer. Cambridge, Mass.: MIT Press, 1987.

Frenkel, Jacob A. "A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence." *Scandinavian J. Econ.* 78, no. 2 (1976): 200–224.

———. "The Collapse of Purchasing Power Parities during the 1970's." *European Econ. Rev.* 16 (May 1981): 145–65.

Frenkel, Jacob A., and Johnson, Harry G., eds. *The Economics of Exchange Rates: Selected Studies.* Reading, Mass.: Addison-Wesley, 1978.

Friedman, Milton, and Schwartz, Anna J. *A Monetary History of the United States: 1867–1960.* Princeton, N.J.: Princeton Univ. Press (for NBER), 1963.

———. *Monetary Trends in the United States and the United Kingdom: Their Relation to Income, Prices, and Interest Rates, 1867–1975.* Chicago: Univ. Chicago Press (for NBER), 1982.

Froot, Kenneth A., and Rogoff, Kenneth. "Perspectives on PPP and Long-Run Real Exchange Rates." In *Handbook of International Economics,* edited by Kenneth Rogoff and Gene Grossman. Amsterdam: North-Holland, in press.

Fuller, Wayne A. *Introduction to Statistical Time Series.* New York: Wiley, 1976.

Gailliot, Henry J. "Purchasing Power Parity as an Explanation of Long-Term Changes in Exchange Rates." *J. Money, Credit and Banking* 2 (August 1970): 348–57.

Grilli, Vittorio, and Kaminsky, Graciela. "Nominal Exchange Rate Regimes and the Real Exchange Rate: Evidence from the United States and Great Britain, 1885–1986." *J. Monetary Econ.* 27 (April 1991): 191–212.

Hakkio, Craig S., and Rush, Mark. "Cointegration: How Short Is the Long Run?" *J. Internat. Money and Finance* 10 (December 1991): 571–81.

Hamilton, James D. *Time Series Analysis.* Princeton, N.J.: Princeton Univ. Press, 1994.

Huizinga, John. "An Empirical Investigation of the Long-Run Behavior of Real Exchange Rates." *Carnegie-Rochester Conf. Ser. Public Policy* 27 (Autumn 1987): 149–214.

Jastram, Roy W. *The Golden Constant: The English and American Experience, 1560–1976.* New York: Wiley, 1977.

Johnson, David. "Unit Roots, Cointegration and Purchasing Power Parity." In *The Exchange Rate and the Economy.* Ottawa: Bank of Canada, 1993.

Kim, Yoonbai. "Purchasing Power Parity in the Long Run: A Cointegration Approach." *J. Money, Credit and Banking* 22 (November 1990): 491–503.

Lothian, James R. "A Century Plus of Japanese Exchange Rate Behavior." *Japan and the World Economy* 2 (January 1990): 47–70.

———. "A History of Yen Exchange Rates." In *Japanese Financial Market Research,* edited by William T. Ziemba, Warren Bailey, and Yasushi Hamao. Amsterdam: Elsevier, 1991.

Lothian, James R., and Taylor, Mark P. "Real Exchange Rate Behavior." Discussion Paper no. 9503. Liverpool: Univ. Liverpool, Dept. Econ., January 1995.

Lucas, Robert E., Jr. "Interest Rates and Currency Prices in a Two-Country World." *J. Monetary Econ.* 10 (November 1982): 335–59.

McCloskey, Donald N., and Zecher, J. Richard. "How the Gold Standard Worked, 1880–1913." In *The Monetary Approach to the Balance of Payments,* edited by Jacob A. Frenkel and Harry G. Johnson. Toronto: Univ. Toronto Press, 1976.

McNown, Robert F., and Wallace, Myles S. "National Price Levels, Purchasing Power Parity, and Cointegration: A Test of Four High Inflation Economies." *J. Internat. Money and Finance* 8 (December 1989): 533–45.

Mark, Nelson C. "Real and Nominal Exchange Rates in the Long Run: An Empirical Investigation." *J. Internat. Econ.* 28 (February 1990): 115–36.

Mitchell, Brian R. *European Historical Statistics, 1750–1970.* New York: Columbia Univ. Press, 1975.

———. *British Historical Statistics.* Cambridge: Cambridge Univ. Press, 1988.

Mussa, Michael L. "The Exchange Rate, the Balance of Payments and Monetary and Fiscal Policy under a Regime of Controlled Floating." *Scandinavian J. Econ.* 78, no. 2 (1976): 229–48.

———. "Nominal Exchange Rate Regimes and the Behavior of Real Exchange Rates: Evidence and Implications." *Carnegie-Rochester Conf. Ser. Public Policy* 25 (Autumn 1986): 117–213.

Newey, Whitney K., and West, Kenneth D. "A Simple, Positive Semi-definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica* 55 (May 1987): 703–8.

Officer, Lawrence H. *Purchasing Power Parity and Exchange Rates: Theory, Evidence and Relevance.* Greenwich, Conn.: JAI, 1982.

———. "Dollar-Sterling Mint Parity and Exchange Rates, 1791–1834." *J. Econ. Hist.* 43 (September 1983): 579–616.

———. "Integration in the American Foreign Exchange Market, 1791–1900." *J. Econ. Hist.* 45 (September 1985): 557–85.

Perron, Pierre. "Trends and Random Walks in Macroeconomic Time Series: Further Evidence from a New Approach." *J. Econ. Dynamics and Control* 12 (June–September 1988): 297–332.

Phillips, Peter C. B. "Asymptotic Expansions in Nonstationary Vector Autoregressions." *Econometric Theory* 3 (April 1987): 45–68. (*a*)

———. "Time Series Regression with a Unit Root." *Econometrica* 55 (March 1987): 277–301. (*b*)

Phillips, Peter C. B., and Perron, Pierre. "Testing for a Unit Root in Time Series Regression." *Biometrika* 75 (June 1988): 335–46.

Rogers, John H. "Real Shocks and Real Exchange Rates in Really Long-Term Data." Manuscript. University Park: Pennsylvania State Univ., Dept. Econ., January 1994.

Roll, Richard. "Violations of Purchasing Power Parity and Their Implications for Efficient International Commodity Markets." In *International Finance and Trade,* vol. 1, edited by Marshall Sarnat and Giorgio P. Szegö. Cambridge, Mass.: Ballinger, 1979.

Schwert, G. William. "Tests for Unit Roots: A Monte Carlo Investigation." *J. Bus. and Econ. Statis.* 7 (April 1989): 147–59.

Shiller, Robert J., and Perron, Pierre. "Testing the Random Walk Hypothesis: Power versus Frequency of Observation." *Econ. Letters* 18, no. 4 (1985): 381–86.

Stockman, Alan C. "A Theory of Exchange Rate Determination." *J.P.E.* 88 (August 1980): 673–98.

———. "Real Exchange Rates under Alternative Nominal Exchange-Rate Systems." *J. Internat. Money and Finance* 2 (August 1983): 147–66.

———. "The Equilibrium Approach to Exchange Rates." *Fed. Reserve Bank Richmond Econ. Rev.* 73 (March/April 1987): 12–30.

Taylor, Mark P. "An Empirical Examination of Long-Run Purchasing Power Parity Using Cointegration Techniques." *Appl. Econ.* 20 (October 1988): 1369–81.

———. "The Economics of Exchange Rates." *J. Econ. Literature* 33 (March 1995): 13–47.

Taylor, Mark P., and McMahon, Patrick C. "Long-Run Purchasing Power Parity in the 1920s." *European Econ. Rev.* 32 (January 1988): 179–97.

Warren, George F., and Pearson, Frank A. *Gold and Prices.* New York: Wiley, 1935.

White, Halbert. "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity." *Econometrica* 48 (May 1980): 817–38.