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ABSTRACT

Two propositions are common in the international finance literature: (1) the real exchange rate is a random walk, (2) the real exchange rate time series properties essentially depend on the nominal exchange rate regime. The first proposition has been used in support of the claim that PPP cannot even be considered a long run relationship since deviations from it are permanent in nature. The second proposition has been used as evidence of price stickiness. Contrary to the first proposition, this paper presents evidence that the random walk behavior of the real exchange rate is just a characteristic of the post-WWII period, while in the prewar period we observe the presence of transitory fluctuations. Also, although real exchange rate volatility appears to be different between fixed and flexible exchange rate regimes, these differences are not as systematic and large as the postwar data suggest.

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I. INTRODUCTION

Two propositions are common in the international finance literature:

(1) The behavior of the real exchange rate over time depends essentially on the nominal exchange rate regime.

(2) The real exchange rate is a random walk.

The first proposition has an important tradition in international finance. Numerous authors have stressed the different behavior of the real exchange rate under alternative nominal exchange rate systems (see, for example, Stockman (1983)). This evidence has been used by many others in support of price stickiness. Mussa (1986), for instance, attributes a major role to the nominal exchange rate system as a determinant of the volatility of the real exchange rate. He finds that the variance of the real exchange rates of the major industrialized countries is eight to eighty times higher during floating exchange rate periods than during fixed exchange rate periods. He concludes that this evidence supports the hypothesis of sluggishness in the adjustment of national price levels.

The second proposition has been used in support of the claim that Purchasing Power Parity (PPP) cannot be considered even a long-run relationship since deviations from it are permanent in nature (see Adler and Lehman (1983)). Contrary to Mussa's results, this second proposition suggests that price stickiness is unlikely to be an important source of real exchange rate fluctuations since price stickiness is typically thought to be a transitory phenomenon.

Most of the evidence which has been adduced to support these two propositions has been based on data from the last three decades. It is not clear whether this evidence could be regarded as of general validity or whether it neglects the specific developments of the 1970's or 1980's. In particular, it may well be the case that the high volatility of the real exchange rate since the breakdown of the Bretton Woods system largely reflects the effects of shocks unrelated to the nominal exchange rate regime such as the two oil price hikes in the seventies or the increased amplitude of fluctuations in interest rates in the late seventies and in the eighties.

In this paper, in order to control for the possibility that real disturbances requiring adjustments of real exchange rates happened to be larger after 1973, we investigate the behavior of the real exchange rate for a much longer sample period, from January 1885 to December 1986. The cost of using such a long time series is that we have to restrict ourselves to just one exchange rate, i.e. the dollar-pound rate. Nevertheless, we believe that the properties of this rate are quite representative of the general historical properties of real exchange rates.

Our basic findings are easily summarized. First, we confirm that the volatility of the real exchange rate during the Bretton Woods regime is relatively small compared to the one during the floating period since 1973. However, we find that the small variability of the real exchange rate observed during the Bretton Woods system is inherent to this particular time period, and was not a feature of the pre-WWII fixed exchange rate periods. That is, the Bretton Woods period appears extremely stable when compared not only to flexible exchange rate periods but also to other fixed exchange rate periods. If we limit the analysis to a comparison of sample standard deviations, it is true that the volatility of the real exchange rate appears to be different between nominal and fixed exchange rate regimes also before World War II, even if these differences are not as large as Mussa's analysis suggests. It is interesting, however, that when we test for differences in the probability distributions generating the rate of change of the exchange rate under the two alternative nominal arrangements, we cannot reject that such distributions were the same during the prewar period.

Second, while our results confirm that movements in the dollar-pound real exchange rate in the post-WWII period have been dominated by shocks to the long run equilibrium real exchange rate, in the prewar period we also observe the presence of transitory shocks contradicting proposition 1. Both results suggest that the behavior of the real exchange rate is more a function of the specific historical period than of the nominal exchange rate arrangement. These results imply that in order to evaluate the behavior of the real exchange rate, it is crucial to use an historical prospective and investigate the evolution of economic institutions, market structure, and of monetary and fiscal policies, and not focus just in the exchange rate regime.

The paper is organized as follows. In Section II we present a brief chronology of the different exchange rate regimes since 1885. In Section III, we present the results of different tests of the hypothesis in proposition 1. In Section IV we test the hypothesis in proposition 2. Finally, in Section V we conclude by discussing possible explanations for the different behavior of the real exchange rate in the prewar and postwar periods, and future areas of research.

II. CHRONOLOGY OF EXCHANGE RATE REGIMES BETWEEN THE DOLLAR AND THE POUND

While in our analysis we refer to only two types of nominal exchange rate rules, *fixed* and *floating*, under these two generic labels we group arrangements which are not perfectly homogeneous. In this section we intend to provide a brief description of the evolution of the exchange rate systems which will help clarify our classification.

1. **The Gold Standard Period, January 1879 - June 1914:** The Gold Standard dates from 1819, when the British Parliament passed the so called Resumption Act. Although the United States can be said to have joined the international gold standard regime in 1879 when it pegged the paper "greenbacks" issued during the Civil War to gold, it continued to coin silver even after 1879 under the terms of the Bland-Allison Act of 1878. It was not until the passage of the Gold Standard Act of 1900 that gold was declared to be the "standard unit of value" and hence the United States was unequivocally on the Gold Standard. Since 1879 the U.S. Treasury redeemed most kinds of Treasury-issued paper money in gold coin, allowing gold outflows necessary for the gold standard to work. During this period the dollar-pound exchange rate was 4.8665.

2. **Transition to Wartime Markets, July 1914 - November 1914:** The gold standard was swept away in a few days at the outset of the First World War. The refusal of London financial institutions to extend credit created a shortage of sterling for the payment by foreigners of short-term sterling debts. Sales of sterling securities in London bridged the gap for a few days until the London Stock Exchange closed during the week of July 27 to July 31, 1914. Shipment of gold from abroad stopped due to wartime risks. Even before war had been declared, in the last week of July following the assassination of Archduke Ferdinand on 4 July 1914, the pound sterling rose from near its mint par of 4.8665 to 6.35.

3. **Controlled Floating, December 1914 - March 1919:** The dollar-sterling rate returned to par by December and was stabilized at approximately par for the course of the war. This was accomplished through extensive exchange and trade controls, purchase and sale of British treasury bills in New York and the

extension of U.S. credits, as it is analyzed in Warren and Pearson (1933):

> "England did not legally prohibit the export of gold, but all shipment of gold out of the country was the result of government action. No data are available concerning prices actually paid for gold in London during the war. South African producers were compelled to sell their gold only in England and at the fixed price. Through the acquisition of dollars and other securities, and the pooling of the gold reserves of England, France and Russian, the dollar exchange rate was pegged."[page 25]

4. First Inter-War Floating, April 1919 - April 1925: On March 21, 1919, the British authorities ceased intervention in the exchange market, and all other currencies began to float along with the sterling. By February 1920 sterling had depreciated from the pegged wartime rate of about $4.76 to less than $3.40. Thereafter it fluctuated within the $3.40 to $4.00 range until the end of 1921. At the time, floating was viewed as an interim measure until price-level adjustment would permit a return to the 1913 gold parities. Since 1922 the pound rate began a slow and persistent climb toward the prewar parity of $4.86 with very little official intervention and with only a major setback in late 1923 and early 1924.

The Chamberlain-Bradbury Committee, set up in June 1924, recommended an immediate return to gold at parity. Winston Churchill announced in his Budget Speech in April 1925 that Britain would immediately return to gold.

5. Gold Exchange Standard, May 1925 - August 1931: In 1925 Britain removed its embargo on the export of gold. Britain was back on the gold standard at the prewar parity of $4.86. Between the return of Britain to the gold standard in 1925 and the French de-jure stabilization in 1928, most of the other principal countries of the world had returned to the gold standard. But this situation was short-lived as it is clearly analyzed by Dam (1982):

"But the reconstruction was short-lived. It had been fueled with large-scale U.S. capital exports, which helped to provide the stabilizing countries with the requisite liquidity, but the capital export flow virtually stopped in 1928 as funds were diverted into short-term financing of the New York Stock Exchange boom.

The drop in U.S. capital export, coupled with the growth of French reserves and their conversion into gold, put strong pressure on the pound. British gold reserves were probably less ample than before World War I and now Britain suffered from an overvalued currency to boot. When the 1931 Macmillan report showed, in an attempt to reassure the foreign exchange markets, that Britain's net short-term liabilities were only 254 million pounds, the market found the news anything by reassuring in view of the fact that the Bank of England's total holding of gold were only about 150 million pounds and most of that was required as domestic backing for the pound. In July alone the Bank of England lost nearly 32 million pounds of gold. Despite foreign credits, withdrawal of foreign balances beginning in mid-July reached 200 million pounds by mid-September. On September 21 the British government suspended payments of gold against legal tender currency, and Britain thereby left the gold standard."[pages 43-44]

6. Second Inter-War Floating, September 1931 - August 1939: The September 1931 decision was in essence a devaluation of the sterling, but in practice the pound was allowed to float. In 1932 the pound fluctuated between $3.27 and $3.74. During this year the British authorities decided to create an Exchange Equalization Account, which was going to permit intervention in the foreign exchange markets while insulating the domestic money supply from the otherwise direct influence of those transactions. The U.S. abandoned the Gold Exchange Standard in March 1933 when, following the bank panic, gold payments were suspended and foreign exchange controls introduced. Among these measures was the executive order that forbade the holding of gold to private citizens, which were supposed to surrender their gold by January 17, 1934. Unlike Britain, who continued to peg the exchange rate as long as its dwindling gold reserves permitted, the U.S. chose to devalue the dollar in the foreign exchange markets even though its gold reserves were not exhausted. The gold value of the dollar declined from the pre-1933 parity of $20.67 per ounce to more than $34 in mid-January 1934. Finally, in late January 1934, the U.S. acted to peg the gold price at $35 per ounce, ending this turbulent transition period.

7. **Wartime Controls of Foreign Exchange, September 1939 - September 1949:** With the declaration of war with Germany in September 1939, the Bank of England announced official buying and selling rates for the sterling of $4.04-4.02, while the sterling continued to trade in New York at a discount in the unofficial markets. By September 1940 the free market in sterling ceased functioning and quotes are simply the official rate. In July 1944, the Bretton Woods agreement established a system of parities to be maintained within a band of 1 percent. With the cessation of hostilities in August 1945, trading in the sterling resumed but with restrictions. In contrast with floating rates after WWI, exchange rates were held steady, but with the aid of strict controls. Bilateralism, disorderly cross rates, and multiple-currency practices were common.[1] The Anglo-American Agreement signed in December 1945 set July 15, 1947 as the starting date for the pound convertibility. But convertibility was short-lived. Following a run against the pound, Britain lost about $ 1 billion worth of gold and dollars and had to abandon convertibility. After convertibility failed, British exchange control regulations reverted to the earlier type. Nevertheless, new steps were taken to slowly eliminate foreign exchange restrictions, the most important ones being the First Agreement on Multilateral Monetary Compensation signed in November 1947 and two successive Agreements for Intra-European Payments and Compensations signed in October 1948 and September 1949. The exchange controls in effect during this period proved inadequate to stop speculative movements against the pound. In September 1949 the pound was devalued by 30 percent setting off a world-wide wave of devaluations.

8. Fixed Exchange Rates and The Bretton Woods System, October 1949 - February 1973: In 1950 the European Payment Union (EPU) was formed under the auspices of the OEEC. Under this new regime European countries did not have to strive for bilateral balance with each trading partner. The means of settlement were gold and dollars administered by the EPU. On December 24, 1958, the EPU was officially disbanded and exchange restrictions against dollar imports were removed.

By the late 60s there was increasing concern with the adequacy of the Bretton Woods system, but no agreement could be reached on with what to replace it. During March 1968 the London gold market was closed as discussions of how to provide for official exchanges of gold at par value were pursued. In August 1971 the U.S. suspended convertibility of official dollar reserves into gold. The disorder in exchange markets continued until the December 1971 Smithsonian meeting which attempted to create order by devaluating the dollar. This measure had no lasting impact as countries individually searched for a viable exchange rate system. A second devaluation of the dollar in February 1973 was followed the next month by adoption of floating rates by the major countries.

9. Floating Exchange Rates, March 1973 - present: This period is characterized by wide fluctuations between the dollar and the British pound.

III. NOMINAL EXCHANGE RATE REGIMES AND REAL EXCHANGE RATE VOLATILITY

> "Under a floating exchange rate regime, real exchange rates typically show much greater short-term variability than under a fixed exchange rate regime....The observed empirical regularities provide strong evidence against theoretical models that embody the property of nominal exchange rate regime neutrality"[Mussa, 1986, pages 117-118].

The conclusions in Mussa (1986) were obtained by studying thirteen countries for the period 1957 to 1984. The central issue is to what extent these results can be indeed regarded as "empirical regularities" or to what extent they are a reflection, albeit an important one, of the post-WWII period. To resolve this issue we discuss below the results obtained from an examinantion of the pre-WWII data.

III.1 SUMMARY STATISTICS

Table 1 presents the mean and standard deviations of the (absolute value of the) monthly rate of change of the real and the nominal exchange rates:

$$(1) \quad \mu_x = \sum_{i=1}^{n} |\Delta x_i|/n \qquad (2) \quad \sigma_x = [\sum_{i=1}^{n} (|\Delta x_i| - \mu_x)^2/n]^{1/2} \qquad x = e,\ q$$

where e is the log of the nominal exchange rate, q is the log of the real exchange rate using the producer price indexes in the U.S. and the U.K as deflators, and n is the sample size.[2] From Table 1 it is evident that the Bretton-Woods period was quite special as far as stability of real exchange rates is concerned. If we were to restrict our analysis to the post-WWII era, the mean of the monthly (absolute) rate of change of the real exchange rate would be four to five times larger during the post-1972 floating period than during the fixed Bretton-Woods period. However, this difference is greatly reduced if we only consider the pre-WWII period. For example, the pre-1914 gold standard period and the 30's floating period look very much alike in this respect.[3]

Figure 1 makes this point more explicit. In this figure we graph the sample annual variances of the real exchange rate. Once again, the Bretton Woods era stands out for its atypical volatility for measures of the real exchange rate. Another interesting feature is that 1981 and 1985 are special too. Volatility in these years is comparable only to the one during official devaluation years or war years.

III.2 WALD-WOLFOWITZ TEST [4]

The above analysis seems to suggest that, more than the nominal exchange rate arrangement, what seems crucial for the behavior of the real exchange rate is the particular historical period. More evidence of this basic result is provided by the use of the Wald-Wolfowitz (1940) test.

Wald and Wolfowitz (1940) proposed a non-parametric test designed to test whether two samples are from the same population. The test is quite intuitive and can be described as follows. Consider two samples, $(X_1,\ldots,X_m)$ and, $(Y_1,\ldots,Y_n)$, composed of independent observations. First, merge the two samples and arrange the observations in ascending order. Next, construct a complementary sequence to the one obtained above, composed of 0's in the place of the X's and of 1's in the place of the Y's. This will produce a sequence of alternating sets of 0's and 1's. Each such set of 0's and 1's is called a run. Let n_0 be the number of runs whose elements are 0 and n_1 the number of runs whose elements are 1. The statistics on which the test is based is:

$$(3) \quad u = n_0 + n_1$$

Wald and Wolfowitz (1940) derive the exact distribution of u under the null hypothesis that the X's and the Y's come from identical distributions. They showed that the mean and the variance of u are given by:

(4) $$E(u) = \frac{2mn}{(m + n)} + 1$$ (5) $$\sigma^2(u) = \frac{2mn(2mn - m - n)}{(m + n)^2(m + n - 1)}$$

They also show that as $m,n \to \infty$ so that $(m/n) \to \lambda > 0$, the distribution of $[u - E(u)]/\sigma(u)$ converges to the normal distribution N(0,1).

In our application, we split the observations on the monthly *rate of change* of the real exchange rate into two samples, depending on whether they belong to a fixed or flexible nominal exchange rate period. The results of this test are reported in Table 2. If the whole period is analyzed, the hypothesis that the rate of change of the real exchange rate during fixed and flexible exchange rate belongs to the same population is strongly rejected. The rejection still holds when we exclude from the sample war and nominal devaluation periods. However, if we now exclude the Bretton-Woods period, the hypothesis cannot be rejected at the 10 percent marginal significance level. These results hold even stronger if we limit the analysis to the pre-WWII era.

Before concluding this section, we should point out that the assumption of independence of the observations may be too strong for the case under study. In fact, we will show in Section IV that the rate of change of the real exchange rate appears to be characterized by a small positive autocorrelation in the post-WWII data and a negative autocorrelation at long horizons in the pre-WWII data. Intuition suggests, however, that the presence of positive (negative) autocorrelation should bias the results against (in favor of) the null hypothesis that the samples are from the same distribution. This intuition was confirmed by Monte Carlo simulations, as reported in Table A1. There we show that the ability of the test to discriminate between different underlying distributions of the shocks is not affected by the presence of a small degree of serial correlation. We feel confident, therefore, that our conclusion is not just the spurious consequence of the presence of serial correlation in the data.

IV. TRANSITORY AND PERMANENT SHOCKS TO THE REAL EXCHANGE RATE

As noted in the Introduction, the notion that the real exchange rate follows a random walk process has become almost a paradigm in the international finance literature. On that account, in the 1980s economists have increasingly rejected the purchasing power parity hypothesis. The logic is simple enough: If the real exchange rate follows a random walk process, PPP does not hold even in the long-run since deviations from it are permanent in nature. But the generality of these results is still an open question, since most of the studies supporting this notion are only based on post-WWII data. We now perform different tests to analyze whether this characteristic continues to hold in the prewar period.

First, we estimate several unit root tests to check whether the series are stationary. However, in the event that we reject stationarity, we cannot conclude that the real exchange rate follows in fact a random walk process. This is because unit root tests do not provide us with an analysis of the importance of the permanent shock relative to transitory shocks in the stochastic process followed by any variable. The analysis of the relative importance of transitory and permanent shocks has, however, become one of the most important topics in the international literature. This debate has mostly been centered around the dollar fluctuations since the breakdown of the Bretton Woods System. For example Obstfeld (1985) claims that U.S. monetary policy played a key role in the sharp dollar depreciation in 1977-79 and that perceptions about U.S. monetary policy were the main factor leading to the appreciation of the dollar in 1979-82. If this were the case, we should expect movements in the dollar exchange rate in these periods to have been dominated by unanticipated transitory shocks since it is widely believed that monetary shocks have real effects due to the imperfections in the goods and/or labor markets (i.e. sticky wages and prices in the short run), but these imperfections are transitory in nature. Instead if shocks affect the long run equilibrium real exchange rate like shocks in preferences or permanent changes in fiscal policy, the opposite will be true. Naturally one way of capturing the determinants of the fluctuations of the real exchange rate would be to estimate a completely specified model of exchange rate determination. However, this approach is not possible for the prewar period given the unavailability of monthly data for most of the variables. Hence, we now perform some univariate tests that can shed some light on properties of relationships among several variables.

The test for serial dependence, proposed by Cochrane (1986) and Lo and Mackinlay (1987), allows us not only to analyze whether movements in the real exchange rate have been dominated by shocks to the long-run real exchange rate, but also provides us with a more powerful test against the null hypothesis of a random walk.[5]

IV.1 UNIT ROOT TESTS

In this section, we perform several tests to determine whether the real exchange rate followed a nonstationary process during 1885-1986. Similar tests are performed for the different exchange rate regime periods as described in Section II. We perform the tests proposed by Phillips (1987). We prefer these tests to the Dickey and Fuller (1979) test because the latter is confined to the case where the sequence of innovations driving the model is independent with common variance. However, independence and homoscedasticity are rather strong assumptions, especially when dealing with the real exchange rate (See, for example, Cumby and Obstfeld (1982)). Instead, the Phillips (1987) tests allow for weakly dependent and heterogeneously distributed innovations. The null and the alternative hypothesis are described below:

	H_0	H_1	
Z_α:	$q_t = q_{t-1} + \epsilon_t$	$q_t = \rho q_{t-1} + \epsilon_t$	$\|\rho\| < 1$
Z_τ:	$q_t = q_{t-1} + \epsilon_t$	$q_t = \rho q_{t-1} + \epsilon_t$	$\|\rho\| < 1$

These tests, however, do not allow us to evaluate the nature of the nonstationarity. In particular, they do not help in determining whether the trend is stochastic, through the presence of a unit root, or deterministic through the presence of a polynomial time trend. Also, they do not allow to accommodate models with a fitted drift. To overcome these restrictions we also present the results of the unit root tests proposed in Phillips and Perron (1987). The null and the alternative hypotheses for each test are described below:

	H_0	H_1	
$Z_{\alpha\mu}$:	$q_t = q_{t-1} + \epsilon_t$	$q_t = \alpha + \rho q_{t-1} + \epsilon_t$	$\|\rho\| < 1$
$Z_{\tau\mu}$:	$q_t = q_{t-1} + \epsilon_t$	$q_t = \alpha + \rho q_{t-1} + \epsilon_t$	$\|\rho\| < 1$
$Z_{\alpha\tau}$:	$q_t = \alpha + q_{t-1} + \epsilon_t$	$q_t = \alpha + \beta(t-T/2) + \rho q_{t-1} + \epsilon_t$	$\|\rho\| < 1$
$Z_{\tau\tau}$:	$q_t = \alpha + q_{t-1} + \epsilon_t$	$q_t = \alpha + \beta(t-T/2) + \rho q_{t-1} + \epsilon_t$	$\|\rho\| < 1$

While they allow for a more general error structure, these tests have the same asymptotic local power properties as the standard Dickey-Fuller test and are thus subject to the same type of critique. In particular, Phillips and Perron (1987) provide simulation results which indicate that their Z tests suffer considerable distortion in presence of moving average errors with negative serial correlation. Their result is consistent with the analysis of Schwert (1987), who also finds that the Phillips (1987) and Phillips and Perron (1987) tests may be unreliable in presence of large moving average parameters. In this case, it appears that the hypothesis of non-stationarity is rejected too often. These potential problems, however, do not seem to be of relevance for this study. In fact, in the sample periods in which we reject the hypothesis of non-stationarity, the MA coefficient obtained by estimating an ARIMA(1,0,1) or an ARIMA(0,1,1) are quite small, never exceeding 0.25.

Table 3 summarizes the results of the unit root tests for the producer price index-based real exchange rate. The real exchange rate seems to be stationary when the whole period January 1885-December 1986 is analyzed. However, once we consider specific subperiods, we discover that in general we cannot reject the unit-root hypothesis. Only in the Bretton Woods period the evidence is more tenuous. In some cases, such as during the October 1949-October 1967 period, we can reject the null hypothesis of nonstationarity in favor of stationarity about a deterministic trend.

IV.2 VARIANCE-RATIO TEST

This test exploits the properties of data sampled at different frequencies. Let us suppose first that the log of the real exchange rate (q_t)

follows a random walk,

$$(6) \quad q_{t+1} = q_t + \epsilon_t \qquad\qquad \epsilon_t \sim N(0, \sigma_\epsilon^2)$$

In this case the variance of the first difference of the log of the real exchange rate will be equal to

$$(7) \quad \text{var}(q_{t+1} - q_t) = \sigma_\epsilon^2$$

and the variance of longer and longer differences of the log of the real exchange rate under the hypothesis in (6) grows linearly with the difference,

$$(8) \quad \text{var}(q_{t+k} - q_t) = k\sigma_\epsilon^2$$

In contrast, a temporary component in the log real exchange rate induces negative autocorrelations that cause the variance of $(q_{t+k} - q_t)$ to grow less quickly than k. For example, if the log of the real exchange rate is the sum of a temporary component and a random walk component, the variance of k-differences is less than k times the variance of the first differences (see Cochrane (1986)).

To test whether the log of the real exchange rate follows a random walk, we construct the ratio statistic

$$(9) \quad \text{Ratio}(k) = (1/k)[\hat{\text{var}}(q_t - q_{t-k})/\hat{\text{var}}(q_t - q_{t-1})]$$

where $\hat{\text{var}}(q_t - q_{t-k}) = \sum_{t=k+1}^{n} [(q_t - q_{t-k}) - \sum_{t=k+1}^{n} (q_t - q_{t-k})/(n-k)]^2/(n-k)$

where n is the sample size.

Under the null hypothesis that q_t follows a random walk, this ratio should be equal to one. If instead there are transitory components, the ratio in (9) should be smaller than one. A derived result from this test is the possibility of estimating the contribution of the permanent shock to the variance of the changes in the real exchange rate. It is shown in Cochrane (1986) that the contribution of the permanent component to the variance of the changes in the real exchange rate is equal to ratio(k) when $k \to \infty$.

Lo and Mackinlay (1987) derive the asymptotic distribution of this ratio by using the Hausman specification test. Instead in our paper and since our different samples are small, we derive the empirical distribution of this statistic using Monte Carlo Simulations. We replicate each sample 1200 times under the null hypothesis of a random walk to obtain the critical values of the empirical distribution.[6]

Table 4 shows the ratios of the variance of k-month differences of the log of the real exchange rate to the variance of the first differences for the dollar-pound real exchange rate for the different exchange rate regimes since 1885.

Several interesting patterns emerge from this Table. For the post-WWII period, both for the fixed exchange rate, and the flexible exchange rate regimes, the estimates of the variance-ratio statistic are larger than 1.0 (the value under the null hypothesis of a random walk) in general for all lags. For example, the estimate of the variance-ratio for 12 months to 12 times the variance of one month during the post-Bretton Woods floating is 2.05233, indicating the possibility of an explosive behavior of the real exchange at least in the medium run. The null hypothesis of a random walk can be rejected at 2.5 percent significance level. Similar results are obtained for this period when the aggregation period increases. As the aggregation increases, we observe that the ratio continues to increase and we can reject the null hypothesis at 5 percent significance level up to an aggregation level of 4 years (48 months). Only for longer lags (96 months long differences) does the ratio fall below 1, although in this case this value is not significantly different from 1. This pattern is repeated for both fixed and flexible exchange rate periods after WWII, although the evidence is more tenous in the 1949-1967 period.

We also wanted to analyze whether the pattern followed by the variance-ratio statistic was due to the specific characteristics of the prewar period. We then estimated the variance-ratio statistic for the prewar period. The results are also presented in Table 4. Surprisingly enough the behavior of the real exchange rate looks very similar in both the gold standard and the gold exchange standard, and in the floating in the interwar period, and it is dramatically different from its behavior in the postwar period. Before WWII the variance-ratio test is always smaller than 1 indicating the presence of a mean reverting behavior. The evidence in this case is weaker since neither of these ratios is below the critical values at 0.025 and 0.05. Although we observe the presence of transitory components, we cannot reject the hypothesis of a unit root since the variance-ratio statistic does not converge to zero.

Although the results do not warrant extreme conclusions, it seems clear that we are not able to capture the presence of transitory components and, therefore, the possible presence of overshooting effects in the postwar period. This is not the case in the prewar period. Transitory effects seem to be more important during the gold standard period. For example in this case, the contribution of the permanent shock to the variance of the changes in the real exchange rate, measured by ratio(k) when k = 228, can explain at the most 40 percent of the variance of the change in the real exchange rate. Instead, in the postwar period the permanent component seems to become more important. In general if we measure the relative importance of the permanent component using lim ratio(k) when $k \to \infty$, we obtain that in the post-1973 period it increases to 70 percent on average.[7]

In summary, the test has indicated the presence of transitory components in the prewar period. However, in some of the cases our rejection of the random walk hypothesis is not statistically significant by conventional standards. In support of the rejection of the random walk hypothesis we should mention that the power of these tests for interesting alternative hypotheses, although higher than the power of a test based on the first-order autocorrelation coefficient, is never higher than 20 percent (the simulations are available on request) for small samples like the ones we are analyzing. In view of this problem, Poterba and Summers (1987) have suggested that "significance levels in excess of .05 seem appropriate in evaluating the importance of transitory components in stock prices." If we accept this proposition and choose significance levels so as to minimize the sum of Type I and Type II errors, our results will reject more strongly the random walk hypothesis in favor of the mean reversion hypothesis before WWII. The results are more tenuous for the postwar data.

V. CONCLUDING REMARKS

Several recent empirical studies have suggested the existence of a strong connection between the stochastic properties of the real exchange rate and the nominal exchange rate regime. Our findings, instead, suggest that the real exchange rate is more a function of the specific historical period than of the nominal exchange rate arrangement. We find that *large* differences in the volatility of the real exchange rate between fixed and flexible regimes are present only in the post-WWII period. Similarly, we find that the innovations in the real exchange rate are more permanent after WWII, and that the persistency of the shocks does not depend on the nominal exchange rate system.

These results suggest that, in order to understand the behavior of the real exchange rate, it is crucial to use an historical prospective and investigate the evolution of economic institutions, market structure, and of monetary and fiscal policy. Recent analyses in these areas may already provide some useful insights on this problem. For example, several authors - e.g. Mankiw and Miron (1987), Miron (1987) - have documented how the creation of the Federal Reserve System in 1914 affected the behavior of the nominal interest rate. Moreover, the results in Shiller (1980) and Huizinga and Mishkin (1986) suggest that changes in monetary regimes might have important effects also on real variables and, therefore, on the real exchange rate.

More speculatively, the substantial modifications in fiscal policies that have taken place in the last 100 years might have also been important in this respect. For example, the changes in the level of government expenditure, in the composition of revenues, and in the use of seigniorage and of deficit financing may be partially responsible for the variations in the stochastic characteristics of the terms of trade.

REFERENCES

Adler, M. and Lehman, B., 1983, "Deviations from Purchasing Power Parity in the Long Run," Journal of Finance, 39, 5 December: 1471-1487.

Argy, V., 1981, **The Postwar International Money Crisis - An Analysis**, George Allen & Unwin.

Calomiris, C. and Hubbard, R., 1987, "International Adjustment Under the Classical Gold Standard: Evidence from the U.S. and Britain, 1879-1914," **National Bureau of Economic Research** Working Paper No. 2206.

Cumby, R. and Obstfeld, M., 1982, "International Interest Rate and Price Level Linkages under Flexible Exchange Rates: A Review of Recent Evidence" in Bilson and Marston (eds), **Exchange Rate Theory and Practice**, The University of Chicago Press.

Dam, K.,1982, **The Rules of the Game: Reform and Evolution in the International Monetary System**, The University of Chicago Press, Chicago.

Dickey, D. and Fuller, W., 1976, "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," **Journal of the American Statistical Association**, 74, 427-431.

Edison, H., 1985, "Purchasing Power Parity: A Quantitative Reassessment of the 1920s Experience," **Journal of International Money and Finance**, 4, 361-372.

Fama, E., and French, K., 1986, "Permanent and Transitory Components of Stock Prices," **Graduate School of Business, University of Chicago**, Working Paper No. 178.

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

Huizinga, J., and Mishkin, F., 1986, "Monetary Policy Regime Shifts and the Unusual Behavior of Real Interest Rates," in Karl Brunner and Allan Meltzer (eds) **The National Bureau Method, International Capital Mobility and Other Essays**, Carnegie-Rochester Conferences Series on Public Policy, North-Holland.

Lo, A. and Mackinlay, C., 1987, "Stock Market Prices Do Not Follow Random Walks: Evidence From a New Specification Test," mimeo.

Mankiw, G. and Miron, J., 1986, "The Changing Behavior of the Term Structure of Interest Rates," **Quarterly Journal of Economics**, Vol. CI, no. 2, 211-228.

Miron, J., 1986, "Financial Panics, the Seasonality of the Nominal Interest Rate and the Founding of the Fed," **American Economic Review**, March, 125-140.

McKinnon, R., 1979, **Money in International Exchange: The Convertible Currency System**, Oxford University Press.

Mussa, M., 1986, "Nominal Exchange Rate Regimes and the Behavior of Real Exchange Rates: Evidence and Implications" in Karl Brunner and Allan Meltzer (eds) **Real Business Cycles, Real Exchange Rates and Actual Policies**, Carnegie-Rochester Conference Series on Public Policy, North Holland.

Obstfeld, M., 1985, "Floating Exchange Rates: Experience and Prospects," **Brookings Papers in Economic Activity**, 369-450.

Phillips, P., 1987, "Time Series Regression with a Unit Root," **Econometrica**, 55, March, 277-303.

Phillips, P., and Perron, P., 1988, "Testing for a Unit Root in Times Series Regression," **Biometrika**, 75, 335-346.

Poterba, J. and Summers, L., 1987, "Mean Reversion in Stock Prices: Evidence and Implications," **National Bureau of Economic Research** Working Paper.

Rush, M., 1985, "Unexpected Monetary Disturbances During the Gold Standard Era," **Journal of Monetary Economics**, vol. 15, 309-321.

Sayer, A., 1948, **Consumers' Prices 1914-1948**, National Industrial Conference Board, N.Y.

Shiller, R., 1980, "Can the Fed Control Real Interest Rates? in S. Fischer (ed), **Rational Expectations and Economic Policy**, Chicago: University of Chicago Press.

Stockman, A., 1983, "Real Exchange Rates and the Alternative Exchange Rate Systems," **Journal of International Money and Finance**.

Warren, G. and F. Pearson, 1932, **Wholesale Prices in the U.S. for 135 years, 1797 to 1932**, Cornell University, Ithaca, NY.

FOOTNOTES

[1] Leland Yeager, **International Monetary Relations: Theory, History, and Policy**, page 428.

[2] The tests in Sections III and IV were also undertaken for the real exchange rate using the consumer price indexes in the U.S. and the U.K as deflators. The results using this definition of the real exchange rate are similar to those using the producer price index as deflator and are reported in a preliminar version of this paper.

[3] The evidence from the price indexes is quite similar. The Bretton Woods System was an exceptionally stable one. One important difference is that, while the real exchange rate in the post-1972 period has been at least as volatile as in the pre-WWII era, prices seem in general more stable after WWII. A complete set of results is reported in a preliminar version of our paper.

[4] We thank Fabio Canova for pointing out to us the existence of this test.

[5] Fama and French (1986) also derived a test to capture the mean reversion behavior in the long run. This test also exploits the properties of data sampled at different frequencies. In a preliminar version of the paper we also performed this test. The results were similar to those obtained using the variance-ratio test.

[6] There are two sources of bias in the measurement of the variance of k-differences. First, the sum of squared deviations is a biased estimate of the variance of long differences in small samples. For example, the sample variance of the n-th difference, where n is the sample size, is zero. To avoid spurious measurement of the permanent component, we have only considered up to m long differences, where $m=.6n_i$, and n_i is the number of observations

in sample i. The results from the Monte Carlo simulations suggest that differences longer than $m = .6n_i$ underestate the relative importance of the permanent component. Second, it is well known that when the mean of a variable is unknown and must be estimated, the estimator given in (9) will be biased (see Fuller (1976) pages 236-244). To correct for this bias we have multiplied the variance of k-differences by the factor:

$$(n-k)/[(n-k)-k+(k^2-1)/3(n-k)].$$

This correction leads to unbiased estimates of the variance when the true process is random walk.

[7] We measure the contribution of the permanent shock to the variance of the changes in the real exchange rate by the variance-ratio statistic evaluated at $k = m$.

APPENDIX 1

DATA: SOURCES AND DEFINITIONS

The log of the real exchange rate in the text is defined as follows: $q = e + p^* - p$, where e is the log of the nominal exchange rate (dollars per pound), p^* is the log of the U.K. producer price index, and p is the log of the U.S. producer price index. The data for these variables were obtained from the following sources.

U.S. PRODUCER PRICE INDEX:

1885-1930 Warren and Pearson (1932) Table I pp.6-10.

1931-1945 U.S. Bureau of Labor Statistics, various issues.

1946-1986 Citibase (tape).

U.K. PRODUCER PRICE INDEX:

1885-1919 Sauerbeck Index, Journal of the Royal Statistical Society, various issues.

1920-1931 Annual Abstract of Statistics.

1932-1938 Board of Trade Journal, various issues.

1939-1986 Monthly Digest of Statistics, various issues.

DOLLAR/POUND EXCHANGE RATE:

1885-1889 Commercial and Financial Chronicle, various issues.

1890-1908 National Monetary Commission.

1909-1911 Statist, various issues.

1912-1916 Warren and Pearson (1932).

1917-1986 Federal Reserve (tape).

APPENDIX 2

WALD-WOLFOWITZ TEST: MONTE CARLO SIMULATIONS

Consider the two processes:

(A1) $y_{1t} = \rho_1 y_{1t-1} + \epsilon_{1t}$ $t = 1,\ldots,n$

(A2) $y_{2t} = \rho_2 y_{2t-1} + \epsilon_{2t}$ $t = 1,\ldots,n$

where ϵ_1 and ϵ_2 are iid normal variables, with mean zero and variances σ_1^2 and σ_2^2, respectively; n = 50. We first assumed $\sigma_1 = \sigma_2$ and generated y_{1t} and y_{2t} for different values of ρ_1 and ρ_2. Wald-Wolfowitz was then used to test whether the y_1's and the y_2's were generated by the same distribution. The experiment was replicated 1000 times. In Table A1 we report the fraction of rejections of the null hypothesis, obtained by using a 5% significance level cut-off. Consider first the case in which $\rho_1 = \rho_2$, i.e. the case in which the processes are identical. If the degree of serial correlation is small (less than 0.5), the power of the test seem to be unaffected by the presence of autocorrelation. As expected, however, the number of type one errors increases considerably when ρ is large. In this case we will tend to reject the null too often. In the case in which $\rho_1 \neq \rho_2$, the test does not seem to be able to discriminate between the two processes, especially if the degree of serial correlation is small. The test, therefore, seems to be powerful in determining differences in the distribution of the underlying shocks (the ϵ's), but does not differentiate the ways in which the shocks are propagated overtime. We do not necessarily view this as a shortcoming. The real problem, for our analysis, would be if the test, because of the presence of serial correlation, could not discriminate between y_1's and y_2's generated by considerably different processes for ϵ_1 and ϵ_2 (in particular when $\sigma_1 \neq \sigma_2$).

In order to investigate this issue, we assumed $\sigma_1 = k\sigma_2$, k = 1/2, 1/3, 1/4, and generated the y_1's and y_2's accordingly. Table A1 also reports the percentage rejection of the null hypothesis, obtained by using a 5% significance level cut-off. The test seems to be quite powerful in distinguishing between the two processes, even in presence of autocorrelation. Some loss in power in rejecting the null is experienced only at large levels of ρ_1 (greater than 0.5). Similar results were obtained for ρ_1, $\rho_2 < 0$ (for small absolute values).

TABLE 1

EXCHANGE RATE VOLATILITY

	REAL EXCHANGE RATE		NOMINAL EXCHANGE RATE	
	μ	σ	μ	σ
		Complete Period		
1885:01 to 1986:12	.0131	.0160	.0071	.0164
		Classical Gold Standard		
1885:01 to 1914:06	.0112	.0094	.0018	.0021
		First Inter-War Floating		
1919:04 to 1925:03	.0204	.0187	.0198	.0208
		Gold Exchange Standard		
1925:04 to 1931:08	.0092	.0076	.0009	.0015
		Second Inter-War Floating		
1931:09 to 1939:08	.0183	.0193	.0161	.0264
		Bretton Woods		
1949:10 to 1972:05	.0059	.0130	.0027	.0142
		Selected Bretton Woods		
1949:10 to 1967:10	.0056	.0126	.0020	.0140
		Post Bretton Woods Floating		
1973:03 to 1986:12	.0212	.0167	.0195	.0154

Note: μ and σ are the mean and standard deviation of the (absolute value of the) monthly rate of change of the different variables.

TABLE 2

WALD-WOLFOWITZ TEST

FOR THE RATE OF CHANGE OF THE REAL EXCHANGE RATE

	u	SIGNIFICANCE. LEVEL
	Complete Period	
1885 to 1986	-4.64	***
	Excluding WWII and Devaluations Periods	
1885 to 1931 1934 to 1939 1950 to 1967 1973 to 1988	-3.81	***
	Excluding WWI, WWII, Devaluations and Bretton Woods	
1885 to 1914 1919 to 1931 1934 to 1939 1973 to 1986	-1.23	0.109
	Pre-WWII	
1885 to 1914 1919 to 1939	-0.77	0.220

Note: The null hypothesis is that all observations are from the same population. ***: Rejection < .01 significance level.

TABLE 3

UNIT ROOT TESTS FOR THE REAL EXCHANGE RATE

	COMPLETE PERIOD	PRE WWII PERIOD	CLASSIC GOLD STANDARD	FIRST INTERWAR FLOATING	GOLD EXCHANGE STANDARD	SECOND INTERWAR FLOATING	POST WWII PERIOD	BRETTON WOODS	SELECTED BRETTON WOODS	POST BRETTON WOODS
	Jan1885 to Dec1986	Jan1885 to Aug1939	Jan1885 to Jun1914	Apr1919 to Mar1925	Apr1925 to Aug1931	Sep1931 to Aug1939	Oct1949 to Dec1986	Oct1949 to May1972	Oct1949 to Oct1967	Mar1973 to Dec1986
Z_{α}	-	-	-	-	-	-	-	-	-	-
Z_{τ}	-	-	-	-	-	-	-	-	-	-
$Z_{\alpha\mu}$	***	.050	-	-	-	-	-	-	-	-
$Z_{\tau\mu}$	***	-	-	-	-	-	-	-	.050	-
$Z_{\alpha\tau}$	***	-	-	-	-	-	-	-	-	-
$Z_{\tau\tau}$	.025	-	-	-	-	-	-	-	.025	-

Note: -: Rejection > .05 significance level; ***: Rejection < .01 significance level.

TABLE 4

VARIANCE-RATIO TEST FOR THE REAL EXCHANGE RATE

k	CLASSIC GOLD STANDARD	FIRST INTERWAR FLOATING	GOLD EXCHANGE STANDARD	SECOND INTERWAR FLOATING	BRETTON WOODS PERIOD	SELECTED BRETTON WOODS	POST BRETTON WOODS
	Jan1885 to Jun1914	Apr1919 to Mar1925	Apr1925 to Aug1931	Sep1931 to Aug1939	Oct1949 to May1972	Oct1949 to Oct1967	Mar1973 to Dec1986
6	1.01092	0.93649	1.13599	1.33560	1.54743**	1.27223	1.76756**
12	1.01117	0.59004	0.67731	1.80106	1.86899**	1.54633	2.05233**
24	0.85014	0.49622	0.42474	1.07313	2.06893**	1.71963	2.11244*
36	0.75221	0.60617	0.38181	0.51845	1.93264*	1.35337	2.40205*
48	0.61817	0.29177	0.34669	0.54750	1.58705	1.11867	2.89042*
60	0.41061	0.01039**			1.31161	1.24505	2.79384
72	0.35424				1.20092	1.34130	2.51794
84	0.33836				1.03508	1.30187	1.91751
96	0.42119				0.90222	1.25980	0.67828
108	0.51932				0.70919	0.81668	
120	0.52239				0.79758	0.81298	
132	0.52542				1.15894	1.11733	
144	0.51181				1.70298		
156	0.52953				2.10228		
168	0.43135						
180	0.36990						
192	0.32684						
204	0.25936						
216	0.35770						
228	0.32256						

Note: * = rejection at .05 significance level; ** = rejection at .025 significance level.
Critical values of the distribution were obtained by Monte Carlo Simulations.

TABLE A1

MONTE CARLO SIMULATIONS

T = 50, Replications = 1000

Fraction of 5% Level Rejections

$\sigma_1 = \sigma_2 = 1$

ρ_2 \ ρ_1	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	0.045	0.049	0.050	0.055	0.046	0.065	0.084	0.125	0.227	0.503
0.1		0.043	0.042	0.063	0.048	0.065	0.088	0.130	0.246	0.488
0.2			0.042	0.057	0.060	0.083	0.079	0.107	0.230	0.483
0.3				0.054	0.083	0.066	0.074	0.132	0.226	0.463
0.4					0.074	0.066	0.096	0.123	0.211	0.438
0.5						0.066	0.106	0.133	0.212	0.443
0.6							0.112	0.127	0.199	0.425
0.7								0.146	0.215	0.405
0.8									0.287	0.397
0.9										0.475

$\sigma_1 = 1;\ \sigma_2 = 2$

ρ_2 \ ρ_1	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	0.499	0.474	0.482	0.435	0.430	0.380	0.286	0.208	0.188	0.264
0.1	0.510	0.484	0.489	0.436	0.412	0.335	0.281	0.229	0.206	0.240
0.2	0.529	0.524	0.513	0.504	0.420	0.367	0.296	0.243	0.206	0.236
0.3	0.591	0.583	0.545	0.531	0.470	0.436	0.352	0.266	0.179	0.245
0.4	0.620	0.618	0.611	0.549	0.562	0.492	0.376	0.311	0.237	0.258
0.5	0.710	0.689	0.669	0.651	0.594	0.553	0.472	0.381	0.297	0.296
0.6	0.775	0.746	0.758	0.721	0.706	0.642	0.558	0.466	0.368	0.337
0.7	0.825	0.830	0.845	0.815	0.783	0.744	0.687	0.620	0.473	0.405
0.8	0.906	0.909	0.919	0.898	0.865	0.848	0.792	0.700	0.640	0.536
0.9	0.958	0.952	0.949	0.953	0.936	0.917	0.911	0.879	0.825	0.753

TABLE A1 CONTINUATION

MONTE CARLO SIMULATIONS

T = 50, Replications = 1000

Fraction of 5% Level Rejections

$\sigma_1 = 1;\ \sigma_2 = 3$

	ρ_1									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
ρ_2										
0.0	0.936	0.926	0.923	0.896	0.879	0.851	0.774	0.675	0.553	0.416
0.1	0.925	0.930	0.922	0.908	0.898	0.832	0.792	0.695	0.574	0.438
0.2	0.942	0.942	0.927	0.909	0.904	0.857	0.812	0.712	0.605	0.464
0.3	0.953	0.930	0.947	0.950	0.916	0.890	0.800	0.734	0.599	0.484
0.4	0.960	0.953	0.946	0.960	0.932	0.891	0.859	0.787	0.640	0.517
0.5	0.963	0.964	0.964	0.952	0.950	0.923	0.888	0.817	0.699	0.576
0.6	0.977	0.987	0.979	0.973	0.962	0.945	0.918	0.856	0.780	0.629
0.7	0.993	0.987	0.990	0.984	0.972	0.972	0.952	0.893	0.850	0.731
0.8	0.994	0.992	0.989	0.996	0.993	0.973	0.966	0.946	0.912	0.812
0.9	0.994	0.997	0.998	0.994	0.994	0.996	0.986	0.975	0.946	0.903

$\sigma_1 = 1;\ \sigma_2 = 4$

	ρ_1									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
ρ_2										
0.0	0.994	0.991	0.991	0.990	0.981	0.979	0.957	0.924	0.841	0.713
0.1	0.996	0.994	0.988	0.988	0.981	0.978	0.972	0.946	0.867	0.726
0.2	0.994	0.997	0.993	0.991	0.991	0.989	0.972	0.942	0.858	0.697
0.3	0.998	0.994	0.989	0.994	0.992	0.984	0.972	0.951	0.875	0.741
0.4	0.998	0.997	0.996	0.994	0.993	0.986	0.977	0.965	0.881	0.782
0.5	0.998	0.997	0.995	0.995	0.994	0.994	0.982	0.973	0.914	0.806
0.6	0.999	0.999	0.998	0.999	0.997	0.996	0.994	0.965	0.947	0.848
0.7	1.000	0.999	1.000	0.997	0.999	0.998	0.996	0.990	0.958	0.892
0.8	1.000	1.000	0.999	0.999	0.999	0.998	0.996	0.996	0.978	0.952
0.9	0.999	1.000	1.000	1.000	0.999	0.999	1.000	0.998	0.992	0.976

FIGURE 1.
REAL EXCHANGE RATE ANNUAL VARIANCE