Price Level Variations as Predictors of Flexible Exchange Rates

by

Richard J. Rogalski*
and
Joseph D. Vinso*

Working Paper No. 12-76a

RODNEY L. WHITE CENTER
FOR FINANCIAL RESEARCH

University of Pennsylvania

The Wharton School

Philadelphia, Pa. 19104

PRICE LEVEL VARIATIONS AS PREDICTORS OF FLEXIBLE EXCHANGE RATES

I. INTRODUCTION

In a perfectly competitive environment, an equilibrium rate of exchange will establish itself between two countries A and B as long as no alteration is made in the purchasing power of either currency. This concept is referred to as the Purchasing Power Parity (PPP) theorem. More specifically, if inflation takes place in the currency of country A, the value of A's currency in country B should be reduced by the proportion in which the purchasing power has been diminished by inflation. In general, if both currencies have been inflated, the new equilibrium rate of exchange should be equal to the old rate multiplied by the quotient between the degrees of inflation of both countries.

This method (PPP) presupposes that changes in the internal purchasing power of a currency have a much greater influence on rates of exchange than any other conditions of international trade. These additional considerations include tariffs and hindrance to trade, transport costs, capital flows and expectations, transaction costs, and uncertainty and/or risk (where there are transport delays or possible contract defaults). It is important to recognize that any of these could drive a wedge into the PPP relationship.

The existing exchange regime determines how the exchange rate adjustment is made. Under the Bretton Woods agreement, exchange rates were changed when the official intervention points were changed. Experience has shown that most countries first attempt to combat external disequilibrium through controls on capital, current account transactions, and internal measures such as fiscal and monetary policy before resorting to a change in exchange rates.[1] In a period of floating exchange rates, arbitrage activity in the commodity markets leads to changes in the supply and demand for the country's currency. This imbalance of supply and demand is adjusted by changes in the relative prices of the currencies. In a period of pure float, the currencies adjust to changes in economic conditions without any exchange market intervention by the government. Finally, in a dirty float period currencies adjust to economic conditions but governments intervene to maintain orderly markets or to prevent precipitous changes in currency values.

The forecasting of exchange rate changes is an important function in the multinational corporation as the management of exchange risk is a fundamental activity of the firm. Under fixed exchange rates, such forecasting not only involves analyzing the economic pressure on a currency to change its value but also the likelihood that policy makers in the government would resort to devaluation to return a currency to equilibrium. In fact, the latter impact is usually the more important factor in attempting such forecasts. In a period of floating exchange rates, however, forecasting of exchange rate changes is much more dependent on understanding the role of the various economic factors. In particular, it is quite important to understand the role that different inflation rates (rates of change in price levels) have on the exchange value of a currency. The purpose of this paper is to investigate this relationship between changes in relative price levels and changes in exchange rates.

Actually, there are three specific interpretations of PPP in the literature. One interpretation is that changes in monetary factors, measured by some index of prices in one country relative to another country, are the sole determinant of the exchange rate. Another version is that monetary factors in two countries measured by the ratio of some pair of price indices in each country exactly determine the exchange rate. The third or broader version (due to Cassel (4)) maintains there are both monetary and nonmonetary determinants of the exchange rate plus other relevant variables.

Each of these versions has been investigated.[2] The most comprehensive analysis has been done by Ballassa (1) and Gailliot (11) who suggest that exchange rate changes are directly related to relative prices change. A question ignored until recently, however, involves the time needed for exchange rate adjustments and the implications of the time factor for exchange rate forecasting. That is, do changes in relative prices affect exchange rate changes with a lag? If so, a model for forecasting exchange rates should result. Thomas (19) has investigated these questions and concludes that exchange rates react to changes in relative prices with a lag. He admits, however, that his results should be viewed with skepticism due to the existence of serious serial correlation in his analysis. Hodgson and Phelps (14) analyzed distributed lag structures of price level changes. They find that price level changes precede exchange rate changes by up to eighteen months. Likewise, Folks and Stansell (10) demonstrate that past values of relative prices can be used to forecast exchange rate movements through the use of discriminant analysis. In sum, these studies seem to agree with the proposition that exchange rates adjust to changes in relative price levels but with long lags.

These results may conflict with a body of knowledge developed by Fama (7) and others which demonstrates that speculative markets are efficient. That is, new information received by the market is incorporated into prices so rapidly that <u>current</u> prices reflect <u>all currently available</u> information.

In this respect the relevant question is whether all publicly available information is incorporated into the foreign exchange market. Since Hodgson and Phelps (14) and Thomas (19) and others argue that current exchange rates are a function of lagged values of changes in relative prices, they are implying that the foreign exchange market may be inefficient with respect to price level changes.[3]

This conflict between previous studies on PPP and the efficient markets hypothesis leads to the relevant questions for investigation in this paper: 1) Do currency exchange rates depend on changes in relative prices between countries? 2) Do currency exchange rates depend on changes in relative prices between countries, but with a lag? An affirmative response to the first question would support PPP and would not conflict with the efficient market hypothesis while a positive finding to the second question would still uphold PPP but would be in conflict with the hypothesis of market efficiency.

To observe the impact of a specific economic factor it is important to choose a period when governments did not manipulate exchange rates using direct market intervention; i.e., a pure float period.[4] For this reason, the post-World War I period (1920-24) is used in this study. The data consist of monthly changes in exchange rates and relative price levels from six countries in this period. To observe the impact of differential inflation rates when there exists a certain amount of governmental intervention in the exchange markets (a dirty float period), the Canada-U. S. exchange rate between 1953-1957 is also investigated.

The results of the investigation reveal that, indeed, the broad form of the PPP holds. That is, changes in relative price levels are a determinant of exchange rates. The direction is also correct; i.e. increasing relative prices lead to develuation of a currency. Furthermore, there is not perfect positive correlation between changes in relative price levels and currency exchange rates as was found in earlier research.

Unlike previous studies, however, no information lag is detected especially at long lags. In other words, changes in price levels depend on changes in exchange rates but the information conveyed to market participants is taken into account instantaneously or nearly so. Thus, the foreign exchange market appears to be efficient with respect to inflation rates (represented by changes in relative prices).

The next section discusses the methodology. A discussion of data analysis follows. Results are then presented and interpreted. The paper closes with a summary and conclusions.

II. METHODOLOGY FOR DEPENDENCE AND CAUSALITY TESTING

In order to investigate the causal relationship between two series such as exchange rate changes and relative price level changes, the existence and direction of causality between unexplained variations in both series must be determined. The method of examining this causality is now reviewed.

A generally accepted definition of causality, as formulated by Granger (12), is based upon the time series notion of predictability. That is, given a universe consisting of at least the two variables X and Y, X is said to cause Y (without feedback) if Y is (in a mean-square error sense) more accurately predicted by taking into account both lagged Y's and lagged X's than it is by taking into account only lagged Y's. In other words, lagged Y's do not aid in the prediction of X once lagged X's have been taken into account. Granger's definition is not necessarily the only accepted definition of causality but is widely used because it is especially appealing for use in empirical testing. Therefore, it will be applied in this study.

The method used herein for application of this definition was developed by Haugh (13), who suggests that series X and Y be initially filtered into white noise series.[5] The white noise series resulting from this transformation procedure are then cross correlated. If the cross correlation coefficients at particular lags are found to be significantly different from zero, a relationship exists between X and Y and the direction of the relationship can be examined using a chi-square test of significance. In particular, given an estimate of the cross correlation function, r_k, (for lag k) between two prewhitened series, Haugh (13) has shown that the statistic S*:

$$S^* = N^2 \sum_{k=L_1}^{L_2} r_k^2 (N-|k|)^{-1} \tag{2.1}$$

is chi-square distributed with $(|L_1|+|L_2|+1)$ degrees of freedom where N is the number of sample observations, L_1 represents the number of future lags, and L_2 the number of past lags. Once L_1 and L_2 are chosen, the statistic S^* can be computed and compared to a χ^2 value with $(|L_1|+|L_2|+1)$ degrees of freedom for a given confidence level.

Hence we have a practical statistical test for independence. First, the cross correlation function between X and Y is estimated after pre-filtering each to a white series using Box and Jenkins (2) univariate analysis.[6] Then the chi-square test is applied to determine whether the series are independent by setting L_1 and L_2 equal to lags appropriate for the series under consideration. Directions of causality between two series, X and Y can be examined using the same chi-square test. For example, if causality runs from X to Y, future values of X should have coefficients insignificantly different from zero, as a group. This relationship can be examined by choosing both L_1 and L_2 to be negative numbers when computing S^*. Similarly, one can determine if causality runs from Y to X by examining future values of Y.

In applying these χ^2 tests, one should bear in mind that the absolute size of the individual correlations is also important regardless of the χ^2 value. The fact that future lags of the independent variable have coefficients as a whole insignificantly different from zero only shows that unidirectional causality is possible. If the estimated correlations on future values are larger than those on past lags, bidirectional causality may be important despite the insignificant χ^2's.

Causality detection via the procedure as outlined above should be distinguished from the well-known Sims' method (18). The approach herein uses (a) <u>separate</u> filters on X and Y which are empirically determined from the sample data and (b) cross correlation analysis rather than regression analysis on the filtered data.[7] Separate filters are preferred to Sims' ad hoc filters, especially when the primary purpose of this filtering is to remove serial correlations in the regression residuals. In fact, Haugh (13) shows that if filtering procedures are not geared to the individual series, spurious regressions may bias results. Even if the estimated residuals from separate filters are used, spurious independence may occur. However, the resulting bias in significance is of a smaller order of magnitude than the bias arising from the failure to adequately treat the univariate serial correlation.

III. INVESTIGATION OF DATA SERIES

A critical part of this investigation is the development of correct and consistent data. First, a measure of price level changes must be specified. Balassa (1) indicates that an adequate measure of such changes is the country's wholesale price index (WPI) as it contains far less non-traded commodities such as services.[8] However, we are not concerned with actual price level changes in each country but rather the relative degree of inflation between the United States (US) and various countries at some time, t. With this in mind, one can define the relative inflation between country i and the US by the ratio:

$$iRATIO(t) = \frac{iWPI(t)}{USWPI(t)} \tag{3.1}$$

where iWPI(t) is the wholesale price index of country i for month t, and USWPI(t) is the wholesale price index of the United States for month t. The relative inflation rate between country i and the US is then taken to be the percentage change of this ratio:

$$iRINF(t) = [iRATIO(t) - iRATIO(t-1)]/iRATIO(t-1) \tag{3.2}$$

As defined, an increase in foreign country i prices relative to US prices will cause iRINF(t) to rise while a deterioration in US prices relative to country i will have an opposite effect on iRINF(t).

Next, the exchange rate series must be specified. In an attempt to minimize timing bias by having the exchange rates measured as nearly as possible over the same period as the price level changes, the exchange rate series were prepared as nonoverlapping averages of daily closing exchange rates for each month.[9]

The data consist of monthly changes in these average exchange rates and monthly changes in the relative inflation rates for six countries during the period 1920-1924 and Canada from 1953-1957. Professor William Poole was kind enough to supply exchange rates for these periods. The WPI was obtained from the League of Nations Bulletin of Monthly Statistics for the post World War I period and International Financial Statistics for Canada in the 1950's.[10]

Before investigating the processes generating the underlying data series, the time period to be studied deserves further discussion. Some studies have attempted to examine periods of fixed exchange rates and others have centered on periods of floating exchange rates. Under a fixed exchange rate regime, PPP only describes the fundamental disequilibrium of exchange rates since governments can maintain rates past the time when they should be changed. Thus, the impact of a particular economic factor can be observed much more clearly during periods of flexible exchange rates because the market is free to adjust to the receipt of new information. Although the current period beginning in 1973 is such a period, it is inappropriate. Dooley and Shafer (6) demonstrate that interference by central banks (the so-called "dirty float") has introduced inefficiencies into the current foreign exchange market. On the other hand, flexible exchange rates in the post World War I period provide episodes when governments tended not to interfere with fluctuations in the exchange rate. Such a period, therefore, provides an ideal opportunity to study the impact of PPP on exchange rates.

It would be interesting to observe what impact governmental interference in the exchange markets has on PPP. Such a situation was Canada in the 1950's. Pippenger and Phillips (17) conclude that the Canadian Exchange Stabilization Fund reduced short-run fluctuations by systematic intervention in that period. These results compare favorably to those presented by Dooley and Shafer (6) for the current period. Thus, Canada in the 1950's is used in our analyses.[11]

To apply the methodology of Haugh as outlined in Section II it is necessary that all series for subsequent analyses be filtered to white noise series. Table 1(a) provides a summary of the fitted models for the various exchange rate series. The criterion of model selection followed in this study has been the representation of each series in the most parsimonious form that is consistent with its stochastic structure. Parameters included in the models are those for which estimates are significant or which are required to eliminate serial correlation in residuals. Thus, the procedure has not been to minimize the variance of prediction errors but to obtain the simplest adequate representation. Parameter values and standard errors are also shown along with the Q-statistic for the first twenty-four residual autocorrelations. These values of the Q-statistic are especially noteworthy because they support the notion that the individual series have been reduced to white noise series.

It can be seen in Table 1(a) that all exchange rate series except for England, Italy and Norway are represented by a first order moving average process. England follows a random walk despite the induced averaging.

Italy and Norway include a third and fifth order moving average term respectively. The reason for the additional parameters may be that although the time period used was chosen because of minimal influence with the functioning of exchange markets by central banks, some interference may have been exerted by the central banks of Italy and Norway. Such an effect has been noted by Dooley and Shafer (6) in current floating exchange rates.

The relative inflation rate series were also filtered for each country. Table 1(b) presents a summary of the models fitted. Again, all series except Norway (which follows a mixed order autoregressive-moving average model) are a white noise or a first-order moving average series.

IV. PRICE LEVEL CHANGES AND CHANGES IN EXCHANGE RATES

Now that the various series have been adjusted to obtain the unexplained variations or white noise series, the direction of causality for price level changes and exchange rates can be investigated. The results of these investigations are summarized in Tables 2 and 3. Table 2 presents values of the S* statistic of equation (2.1). Causality is investigated by choosing various values of L_1 and L_2. It should be noted that only selected lags are reported here. In fact, many more combinations were examined but space limitations do not allow presenting them all.[12] Values of S* which are significant at the 10% level under the null hypothesis of independence between the two series are indicated in the table with asterisks.

It is helpful to review the absolute size of individual correlations in conjunction with the S* statistics. Table 3 presents the estimated cross correlations between the several series for various lags as required to provide an understanding of the values reported in Table 2.

An examination of the independence tests in Table 2 for the countries in the post World War I period shows that for all countries except Sweden changes in exchange rates are not independent of changes in relative prices as would be expected if PPP holds. An examination of the cross-correlations in Table 3(a) to 3(f) verify these results. The large correlations at lag zero for all countries except Sweden lead us to conclude that a strong instantaneous relationship exists.

Now that dependence has in general been established, it is necessary to investigate the direction of causality. Columns (a) to (f) of Table 2 reveal that there are no significant relationships for any combination of lags in either direction for England, France, Japan, and Norway. Examination of the cross-correlations in Table 3(a), 3(b), 3(c) and 3(e) generally confirms these results. Except for France, there are no significant correlations at any lag other than lag zero.

France shows some correlation when changes in relative prices lag changes in exchange rates by one month. Several reasons for this result suggest themselves. Such a result may be due to chance alone. On the other hand, it may be a function of the way price levels are transmitted through the French economy. That is, price levels change more slowly and exchange rates do not respond until sufficient changes have occurred to be noted by participants in the market. This situation is a possibility in that the correlation at lag 1 is half that at lag zero. More likely, however, is that a publication lag is being observed. It should be noted that in the League of Nations Bulletin of Monthly Statistics from which the WPI information was obtained, only for France is the published WPI a "provisional figure" which is revised the next month (See footnote 10). This implies that the market reacts to an "information effect" rather than an economic effect.

These results suggest that, for England, France, Japan, and Norway the foreign exchange market reacts immediately or nearly so to changes in relative price levels as predicted by PPP. Since the correlations are large but significantly different from positive one, the broad version of PPP appears to be valid. Unlike the results reported by Hodgson and Phelps (14) and Thomas (19), however, no lagged relationship is observed. Thus the foreign exchange markets for these currencies were efficient with respect to information on changes in relative prices. These results are also consistent with the recent work of Cummins et al. (5) who conclude that foreign exchange markets are efficient with respect to interest rate information as given by the Federal Reserve rediscount rate. Furthermore, the findings obtained here extend the work of Balassa (1) and Gailliot (11) by demonstrating that the long-run relationships they observed also appear valid in the short run.

A similar analysis for Italy and Sweden in Table 2(c) and Table 2(f) shows somewhat different results. Both countries indicate a significant relationship going from price level changes to exchange rate changes; i.e. changes in relative price levels influence changes in exchange rates. Reviewing the cross correlations in Table 3(c) and Table 3(f) reveals the cause. For Italy, the cross correlations are not significantly different from zero except at lags zero and eleven. Such correlations may again be due to chance. The estimated autocorrelation function for the wholesale price index ratio provides another clue as to what may be happening.[13] A significant correlation exists between current relative inflation and past relative inflation in each month of the previous fourth quarters. Thus, finding the current exchange rate a function of the relative inflation rate at lag 11 is not surprising because the current exchange rate is a function of the current change in relative inflation which in turn is also a function of changes in relative inflation for lags 10-12. This lag structure, however, does not allow a forecast of future exchange rates to be made because one must still know the current relative inflation. And the correlation at lag 11, while significant, is roughly only half that at lag zero. Thus, it appears that the lira-dollar exchange market is both dependent upon price level changes as predicted by PPP <u>and</u> efficient.

The case for Sweden is not as clear. In Table 3(f), it can be seen that the only significant cross correlations occur at lags seven and twelve.

Unlike the other countries studied, there is only a moderate but insignificant correlation at lag zero. There is no readily apparent reason for this structure. Unlike France, there is no indication from the data sources that a publication lag exists. And reviewing the autocorrelation functions for the individual series do not reveal any inconsistencies. One possibility, however, is that the results obtained are due to a structural characteristic of the Swedish economy. Sweden in the 1920's primarily exported raw materials which tend to be sold on long term contracts with prices adjusted infrequently (such as annually or semi-annually) and generally after a lengthy notification process. This notification process most likely would have been initiated only after changes in the equivalent domestic prices. Since the WPI is based on list prices as opposed to transaction prices, such adjustments may be delayed. While highly speculative, such a structure may explain the observed findings. For Sweden, therefore, it appears that PPP is a useful tool for explaining short-run exchange rate changes but, unlike the other countries studied, there appears some type of structural inefficiency in the foreign exchange market the source of which is not all apparent.[14]

Thus, for flexible exchange regimes it appears that changes in relative inflation rates between countries are an important determinant of changes in currency exchange rates as argued by the proponents of PPP. However, as Cassel (4) and others have suggested, changes in relative price levels are not the only, albeit a major, determinant of exchange rates. Furthermore, exchange rates under such a regime adjust to changes in relative price levels as soon as the information is available. Using past values of relative inflation rates do not allow more accurate forecasts of future spot rates (in a mean square error sense) than not including them in the information set.

While the results obtained for a completely flexible exchange rate regime are interesting, it is also of interest to investigate market structures of more current relevance; i.e. those which (although flexible) are characterized by official intervention. Such was the case of Canada in the 1950's. Although the Canadian dollar was ostensibly floating against the U. S. dollar, the Canadian central bank attempted to smooth out fluctuations in exchange rates by intervening in the market. The effect of such intervention on PPP can be seen in Table 2(g). No significant dependence between Canada's exchange rate and relative inflation rate is observed. An assertion of independence, however, may be premature. The cross-correlations of Table 3(g) reveal a significant coefficient when the relative inflation rate lags exchange rates by one month. Such a result suggests that intervention by the central bank may mitigate the change in exchange rates in response to changes in relative price levels. Under a floating exchange rate regime such changes are inevitable and appear to be fully reflected in prices by the next period. Thus, it appears that intervention by the central bank reduces the impact of relative price changes on exchange rates and induces a certain amount of inefficiency into the market. Although only one such series is investigated (and is by no means conclusive) it appears that under flexible exchange rates long lag structures as suggested by Hodgson and Phelps (14) may exist even with intervention by governmental authorities.

The results obtained here have implications for both multinational firms and governmental policy. To the extent that a country pursues monetary and fiscal policies which produce inflation rates different from its trading partners, it can expect (under a flexible exchange regime) a change in the value of its currency with attendant impact on employment and economic activity as soon as these policies are reflected in changes in relative prices. Efforts to thwart the process through intervention by the central bank in the exchange markets may be unsuccessful although the impact may be lessened to some extent.

V. SUMMARY AND CONCLUSIONS

The results reported herein generally suggest that freely floating foreign exchange markets react immediately or nearly so to changes in relative inflation rates. This finding is consistent with both Purchasing Power Parity (PPP) theory and the efficient market hypothesis. In particular, no significant lagged relationship has been observed as in previous research by others. It also seems probable that determinants of exchange rates should include both monetary and nonmonetary factors plus random disturbances as originally thought by Cassel. Although preliminary, it appears that intervention by central banks may introduce inefficiencies into foreign exchange markets by disrupting the "normal" flow of information.

Several problems, however, occur when empirically examining PPP. The theory emphasizes monetary factors as the primary determinants of exchange rates. In reality the possibility of transaction costs, tariffs, and transportation costs could disrupt the PPP relationship, irrespective of data problems. Note, however, that the WPI is constructed from list prices rather than actual transaction prices. The greater the extent that sellers consummate a sale at list prices which include such expenses, the less significant this bias.

Regarding the data, wholesale price indices may be an imperfect measure of tradable goods prices. Not only is it likely that some non-tradables are included and some tradables omitted, but the weighting scheme used in the WPI is certainly different from the commodity weights required by a "tradable goods" index. Moreover, with the WPI one may be measuring integration of the goods market. In a perfectly integrated goods market, prices adjusted for exchange rates will be the same everywhere, and PPP becomes a tautology. Thus, tests of PPP using the WPI may be indicative of full integration of the goods market rather than the response of exchange rates to price level changes.

Due to these problems with WPI one might suggest that another index such as the GNP price deflator as a consumer price index (CPI) be used instead. In the period being studied (1920 to 1924), however, the GNP deflator did not exist. And at the beginning of 1953 there was a substantial upgrading of the CPI. Prior to 1953, the CPI was based on a small number of items and monthly sampling of items was not the general rule. Sampling index items less frequently than monthly creates a positive serial correlation bias. (See Fama (8)) Balancing these fundamental reasons against the problems associated with the WPI led us to choose WPI as a more logical measure of relative price levels.

TABLE 1
SUMMARY OF FITTED MODELS

Country (60 obs)	(a) Models Fitted To Exchange Rate Series	Residual Variance	Q 24
ENGLAND	$EEXCH(t) = \varepsilon(EEXCH:t)$	.1101E-02 (60 d of f)	22.6 (36.4)
FRANCE	$FEXCH(t) = (1+.265B)\varepsilon(FEXCH:5)$ (.124)	.5964E-02 (59 d of f)	11.0 (35.2)
ITALY	$IEXCH(t) = (1+.359B-.384B^{3})\varepsilon(IEXCH:t)$ (.115) (.100)	.4684E-02 (58 d of f)	23.2 (33.9)
JAPAN	$JEXCH(t) = (1+.266B)\varepsilon(JEXCH:5)$ (.128)	.3864E-03 (59 d of f)	9.5 (35.2)
NORWAY	$NEXCH(t) = (1+.651B-.255B^{5})\varepsilon(NEXCH:t)$ (.095) (.088)	.2169E-02 (57 d of f)	15.9 (33.9)
SWEDEN	$SEXCH(t) = (1+.402B)\varepsilon(SEXCH:t)$ (.122)	.1065E-02 (56 d of f)	23.0 (35.2)
CANADA	$CEXCH(t) = (1+.495B)\varepsilon(CEXCH:t)$ (.116)	.2857E-04 (59 d of f)	29.2 (35.2)

Series (60 obs)	(b) Models Fitted To Relative Inflation Rate Series	Residual Variance	Q 24
ENGLAND	$ERINF(t) = \varepsilon(ERINF:t)$	.1637E-02 (60 d of f)	8.8 (36.4)
FRANCE	$FRINF(t) = (1+.398B)\varepsilon(FRINF:t)$ (.117)	.1597E-02 (59 d of f)	9.7 (35.2)
ITALY	$IRINF(t) = (1+.648B)\varepsilon(IRINF:t)$ (.099)	.100E-02 (59 d of f)	24.0 (35.0)
JAPAN	$JRINF(t) = (1+.686B)\varepsilon(JRINF:t)$ (.094)	.9737E-03 (59 d of f)	19.0 (35.2)
NORWAY	$(1-.527B)NRINF(t) = (1+.391B^{3})\varepsilon(NRINF:t)$ (.113) (.112)	.5799E-03 (57 d of f)	14.0 (33.9)
SWEDEN	$SRINF(t) = \varepsilon(SRINF:t)$	.1135E-02 (60 d of f)	23.7 (36.4)
CANADA	$CRINF(t) = (1-.409B)\varepsilon(CRINF):t)$ (.119)	.3642E-04 (59 d of f)	18.4 (35.2)

NOTES: Exchange rate series for country i at time t are denoted iEXCH(t) with relative inflation rate series denoted iRINF(t) where i = E, F, I, J, N, S, C refers to England, France, Italy, Japan, Norway, Sweden, and Canada, respectively. Corresponding white noise series are represented as ε(iEXCH:t) and ε(iRINF:t). For example, the exchange rate series for England is EEXCH(t) and the corresponding white noise series is ε(EEXCH:t).

Standard errors are shown in parentheses below parameter estimates.

TABLE 1
(Continued)

NOTES (Continued)

Residual variances are reported in exponential form, i.e. .1101E-02 = .001101 with degrees of freedom given in parentheses on the line below.

The Q statistic as discussed in Box and Jenkins (2) is approximately chi-square distributed with (N-n) degrees of freedom where N is the number of residual autocorrelations and n is the number of parameters estimated. In parentheses below the Q value is the χ^2 value for the appropriate degrees of freedom (24) at the 5% level of significance under the null hypothesis of zero serial correlation in the residuals of the model.

TABLE 2

$$S^* = N^2 \sum_{k=L_1}^{L_2} \hat{r}_k^2 (N-|k|)^{-1}$$

Lags (60 Obs) L_1	L_2	(a) ENGLAND ε(ERINF:t) on ε(EEXCH:t)	(b) FRANCE ε(FRINF:t) on ε(FEXCH:t)	(c) ITALY ε(IRINF:t) on ε(IEXCH:t)	(d) JAPAN ε(JRINF:t) on ε(JEXCH:t)
-6	6	21.678*	35.275*	40.456*	19.185*
-1	-6	6.445	11.744	12.198	8.421
-1	-12	12.323	13.781	21.017	11.286
-6	-1	9.089	2.575	7.016	4.696
-12	-1	19.510	4.955	37.404*	5.712

Lags (60 Obs) L_1	L_2	(e) NORWAY ε(NRINF:t) on ε(NEXCH:t)	(f) SWEDEN ε(SRINF:t) on ε(SEXCH:t)	(g) CANADA ε(CRINF:t) on ε(CEXCH:t)	
-6	6	26.803*	15.761	16.483	
-1	-6	5.496	7.218	10.948	
-1	-12	11.001	8.536	19.130	
-6	-1	9.265	5.501	5.385	
-12	-1	15.563	21.403*	13.068	

NOTES: The statistic S^* is approximately chi-square distributed with $(|L_1|+|L_2|+1)$ degrees of freedom where L_1 is the number of future lags and L_2 is the number of past lags.

Asterisks indicate significance at the 10% level under the null hypothesis of independence between the two series.

ε(ERINF:t) on ε(EEXCH:t) refers to the S^* statistic computed using cross correlation estimates with ε(EEXCH:t) as the base variable.

TABLE 3

ESTIMATED CROSS CORRELATIONS BETWEEN EXCHANGE RATES AND PRICE LEVEL CHANGES

COUNTRY (60 Obs)	LAGS	CROSS CORRELATIONS 0	1	2	3	4	5	6	7	8	9	10	11	12
(a) ε(ERINF:t)	0 to 12	-.31	-.19	-.10	.14	.03	-.04	-.09	-.18	-.23	-.11	.02	.02	.24
on ε(EEXCH:t)	-1 to -12		-.13	.21	-.01	.18	-.03	-.05	-.22	-.08	-.09	-.12	.15	.16
(b) ε(FRINF:t)	0 to 12	-.59	.00	.15	.06	.06	-.05	-.08	-.09	-.01	.04	-.01	.07	-.13
on ε(FEXCH:t)	-1 to -12		-.30	.22	.15	.08	.15	.06	-.09	-.01	-.04	-.03	-.07	-.11
(c) ε(IRINF:t)	0 to 12	-.59	-.25	-.07	-.09	.19	-.00	.01	.01	.05	-.22	-.07	-.31	-.15
on ε(IEXCH:t)	-1 to -12		-.22	.08	.09	.24	.28	-.04	.04	-.01	-.23	-.19	-.05	-.18
(d) ε(JRINF:t)	0 to 12	-.32	-.08	.22	.12	.06	.03	.06	.02	.03	-.00	-.03	.11	.01
on ε(JEXCH:t)	-1 to -12		-.22	-.02	.16	-.22	.08	-.06	-.04	.08	.09	-.07	-.10	.09
(e) ε(NRINF:t)	0 to 12	-.45	-.24	.01	.10	-.05	.07	-.11	.00	-.10	.05	-.11	-.00	.24
on ε(NEXCH:t)	-1 to -12		.17	-.16	-.12	-.03	.12	.25	-.03	-.23	.00	.07	.00	-.18
(f) ε(SRINF:t)	0 to 12	-.23	-.04	.07	.14	.06	.07	-.23	-.32	-.17	-.19	-.03	.00	.26
on ε(SEXCH:t)	-1 to -12		.23	-.16	-.04	.10	-.11	.14	-.00	-.08	-.08	.08	-.01	-.01
(g) ε(CRINF:t)	0 to 12	-.05	-.11	.17	-.16	-.11	.06	-.07	-.07	.09	-.14	.05	-.14	-.22
on ε(CEXCH:t)	-1 to -12		.27	.11	-.02	.15	-.18	.18	-.07	-.23	.15	.17	-.08	.05

NOTES: Results are presented for lags 0 to 12 in the first row. Lags -1 to -12 in the second row represent 1 to 12 months in the future.

$1/\sqrt{N} = .13$

FOOTNOTES

*Assistant Professor of Finance, The Amos Tuck School of Business Administration, Dartmouth College and Assistant Professor of Finance, The Wharton School, The University of Pennsylvania. Helpful comments and suggestions were provided by Irwin Friend, Marshall Blume, Richard Herring, and anonymous referees. Research support was provided by the Tuck Associates Program and the Rodney L. White Center for Financial Research.

[1]The devaluation of the pound in 1967 and the franc in 1969 are prime examples as both were delayed long after economic factors dictated adjusting exchange rates.

[2]Officer (16) provides references of over twenty articles which discuss tests of PPP. While each of these studies proposes to investigate some aspect of this question, all suffer from various data problems.

[3]Of course the results of Thomas (19) and Hodgson and Phelps (14) may also result from imprecise data or data containing internal inconsistencies.

[4]Although it is assumed herein that governments do not actively intervene in exchange markets in a pure float period, this assumption does not preclude indirect market involvement such as manipulation of interest rates.

[5]A white noise series is a random sequence which is independent, normally distributed with zero mean and constant variance.

[6]Because no discussion of the theory and methods of this particular filtering procedure is probably better than a necessarily brief one, the reader is referred to Box and Jenkins (2) for a complete discussion.

[7]Examples of the regression approach are found in the work of Feige and Pearce (9) where they analyzed the relationship between money and income and Fama (8) who analyzed short-term interest rates as predictors of inflation.

[8]Obtaining a measure of relative inflation rates is not a trivial matter. The purchasing power of a currency is determined by goods and services used at home as well as those which are traded, even though according to PPP exchange rates only adjust to traded goods and services. All government reported measures of relative inflation, including WPI, include non-traded goods as components. The weighting scheme used in such measures does not necessarily reflect the trading impact of the items included. The WPI was used because it has fewer of these objections than other indices (but like the other indices is by no means exempt from criticism).

[9]It must be noted that unlike most economic series, the WPI is not measured at a given point of time. Rather prices are measured over a month and then averaged to compute an index of prices. Our exchange rate series are being constructed in a similar fashion. Such an averaging process not only introduces timing bias but, more importantly, it also changes the character of the underlying structure. Working (20) demonstrates that when first differences are taken of a random series which has been averaged, the

FOOTNOTES (continued)

resulting series can have first order moving average components. Previous authors were either unaware or chose to ignore this result. This may account for some of the observed autocorrelation in their results. Failure to filter the induced autocorrelation would render results of such analyses suspect. Such inattention to data preparation has been discussed by Officer (16), Kohlhagen (15) and others.

[10]Readers familiar with current reporting practices for the WPI in various countries are aware that there is a considerable lag in publication of the index. Furthermore, this lag is not the same for all countries. However, BLS Bulletin 284 (3) shows that while a publication lag also existed in the period under consideration (although shorter), an information lag did not exist. For example, while the United States WPI for a given month was not published until over a month later, several sources of current WPI information were available on a more timely basis. Furthermore, the bulletin shows that these other indices are very highly correlated with the WPI published by the BLS. The bulletin also shows that similar information was available for all other countries studied here in publications such as the *Analist* and the *Economist*. Thus, it can be assumed that information on changes in prices were readily and currently available, in general, to participants in the foreign exchange market.

[11]The current period cannot be used because sufficient observations are not available at this time.

[12]All results are available upon request.

[13]The estimated autocorrelation functions for both the relative price level index and exchange rates were generated for each country. These functions were then used to develop the models summarized in Table 1(b) but are too voluminous to include here. They are available upon request.

[14]It might be conjectured that such an inefficiency may lead to a profitable trading rule but Cummins et al. (5) show that it is futile to attempt to develop profitable trading rules to out perform buy and hold strategy in foreign exchange markets in the presence of apparent market inefficiencies.

REFERENCES

1. Balassa, Bela, "The Purchasing Power Parity Doctrine: A Reappraisal," Journal of Political Economy, December, 1964, pp. 584-96.

2. Box, George E. P. and Gwelyn M. Jenkins, Time Series Analysis. (Holden-Day Inc., San Francisco) 1970.

3. Bureau of Labor Statistics, "Index Numbers of Wholesale Prices in the United States and Foreign Countries," Bulletin No. 284 (U. S. Government Printing Office, Washington, D. C.), October, 1921.

4. Cassel, Gustav, Money and Foreign Exchange after 1914. (Macmillan Co., New York) 1923.

5. Cummins, Philip A., Dennis E. Logue, Richard James Sweeney, Thomas D. Willett, "Aspects of Efficiency in the U. S./Canada Foreign Exchange Market," Working paper, U. S. Treasury, October, 1975.

6. Dooley, Michael P. and Jeffrey R. Shafer, "Analysis of Short-Run Exchange Rate Behavior, March, 1973 to September, 1975," Working paper number 76, Board of Governors, Federal Reserve System.

7. Fama, E. F., "Efficient Capital Markets: A Review of Theory and Empirical Work," Journal of Finance, May, 1970, pp. 383-41.

8. __________, "Short-Term Interest Rates as Predictors of Inflation," American Economic Review, Vol. 65, No. 3, June, 1975, pp. 269-82.

9. Feige, Edgar L. and Douglas V. Pearce, "The Causality Relationship Between Money and Income: A Time Series Approach," Presented at the Midwest Economic Meetings, Chicago, Ill., April, 1974.

10. Folks, William R., Jr. and Stanley R. Stansell, "The Use of Discriminant Analysis in Forecasting Exchange Rate Movements," Journal of International Business Studies, Spring, 1975.

11. Gailliot, Henry J., "Purchasing Power Parity as an Explanation of Long-Term Changes in Exchange Rates," Journal of Money, Credit and Banking, Vol. II, No. 3, August, 1970, pp. 348-357.

12. Granger, C. W. J., "Investigating Causal Relations by Econometric Models and Cross Spectral Methods," Econometrica, Vol. 37, July, 1969.

13. Haugh, Larry D., "Checking the Independence of Two Covariance Stationary Time Series: A Univariate Residual Cross-Correlation Approach," Journal of the American Statistical Association, Vol. 71, June, 1976, pp. 378-385.

14. Hodgson, John A. and Patricia Phelps, "The Distributed Impact of Price-Level Variation on Floating Exchange Rates," The Review of Economics and Statistics, February, 1975, pp. 58-64.

REFERENCES (continued)

15. Kohlhagen, Steven W., "The Foreign Exchange Markets -- Models, Tests, and Empirical Evidence," presented at a U. S. Treasury conference, Washington, D. C., February 26-27, 1976.

16. Officer, Lawrence H., "The Purchasing-Power-Parity Theory of Exchange Rates: A Review Article," Working paper, International Monetary Fund, September, 1975.

17. Pippenger, John E. and L. Phillips, "Stabilization of the Canadian Dollar, 1952-1960," Econometrica, September, 1973, pp. 797-815.

18. Sims, Christopher A., "Money, Income and Causality," American Economic Review, Vol. 62, September, 1972.

19. Thomas, Lloyd B., "Behavior of Flexible Exchange Rates: Additional Tests from the Post-World War I Episode," Southern Economic Journal, Vol. 40, No. 2, October, 1973, pp. 167-82.

20. Working, Hollbrook, "Note on the Correlation of First Differences of Averages in Random Chains," Econometrica, 28, 1960, pp. 916-18.