NBER WORKING PAPER SERIES

EMPIRICAL STUDIES OF EXCHANGE RATES: PRICE BEHAVIOR, RATE DETERMINATION AND MARKET EFFICIENCY

Richard M. Levich

Working Paper No. 1112

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge MA 02138

April 1983

I am grateful to William Branson, Jacob Frenkel, Peter Kenen and Doug Purvis for helpful comments on an earlier draft of this paper. The research reported here is part of the NBER's research program in International Studies and project in Productivity in the World Economy. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

NBER Working Paper #1112
April 1983

Empirical Studies of Exchange Rates: Price Behavior, Rate Determination and Market Efficiency

Abstract

Theoretical and empirical research completed over the last decade has dramatically increased our understanding of exchange rate behavior. The major insight to come from this decade of research is that foreign exchange is a financial asset. In an asset pricing framework, current exchange rates reflect the expected values of future exogenous variables.

The purpose of this paper is to survey the empirical evidence on exchange rate behavior, market efficiency and related topics. Section 2 presents a stylized history of exchange rate behavior during the 1970's. Alternative measures of volatility and transaction costs are reviewed. Tests of specific exchange rate determination models are presented in section 3. Empirical studies have been fairly successful in constructing models to explain cross-sectional exchange rate differences and to explain time series exchange rate developments over the medium-run and long-run. Following the asset market framework, recent studies have demonstrated that unanticipated exchange rate changes are significantly correlated with "news" concerning fundamental macroeconomic variables.

Evidence on foreign exchange market efficiency is summarized in section 4. Efficiency studies remain difficult to formulate (because of small samples and unobserved variables) and difficult to interpret (because of the joint hypothesis problem). Several recent studies claim that speculative profit opportunities are present, but it is unclear whether these are related to risk premiums or actual market inefficiencies.

Richard M. Levich
Graduate School of Business
Administration
New York University
90 Trinity Place
New York, NY 10006

212-285-6176

TABLE OF CONTENTS

1. Introduction-Historical Setting 1

2. Stylized Empirical Results About Exchange Rate Behavior 7

2.1. Describing Exchange Rate Movements 7

2.1.1. Alternative Measures of a Currency's Foreign Exchange Value 7
2.1.2. Recent Exchange Rate Behavior 9

2.2. Time Series Behavior, Volatility and Distributional Properties 12

2.2.1. Overview of Theory 14
2.2.2. Empirical Results 15
2.2.3. Methodological Issues and Agenda 19

2.3. Transaction Costs in Foreign Exchange Markets 21

2.3.1. Concepts of Transaction Costs 22
2.3.2. Empirical Measures 23
2.3.3. Methodological Issues and Agenda 24

3. Exchange Rate Determination-Tests of Specific Models 25

3.1. Purchasing Power Parity 28

3.1.1. Overview 28
3.1.2. Empirical Results 29

3.2. Monetary Theory and Exchange Rates 32

3.2.1. Overview 32
3.2.2. Empirical Evidence 34
3.2.3. Methodological Issues 39

3.3. Currency Substitution 40

3.4. The Portfolio Balance Approach 41

3.4.1. Overview 41
3.4.2. Empirical Evidence and Methodological Issues 43

3.5. Exchange Rate Dynamics 44

3.5.1. Overview 44
3.5.2. Empirical Evidence 46

3.6. The Asset Approach and the Role of News 47

3.6.1. Overview 47
3.6.2. Empirical Evidence 48

4. Tests of Foreign Exchange Market Efficiency 49

4.1. The Efficient Market Hypothesis 49

4.2. Empirical Evidence-Certainty and Risk-Free Investment 54

4.2.1. Currency Arbitrage 54
4.2.2. Interest Rate Parity and Covered Interest Arbitrage 56

4.3. Empirical Evidence--Uncertainty and Risky Investment 59

4.3.1. Spot Market Efficiency 60
4.3.2. Forward Market Efficiency 64

4.4. Methodological Issues and Agenda 70

Footnotes: F-1,... F-12

Tables: T-1,... T-4

Figures: FIG-1,... FIG-9

References: R-1,... R-12

LIST OF FIGURES

Figure 1. Selected Nominal Exchange Rates, 1970-1981.

Figure 2. Effective Exchange Rates, 1970-1981.

Figure 3. Real Effective Exchange Rates, 1970-1981

Figure 4. Monthly Average of Daily Exchange Rates

Figure 5. Consumer Price Indices, the Spot Exchange Rate and Forward Premium--Monthly Percentage Changes, U.S./Germany, July 1973-February 1979

Figure 6. Consumer Price Ratios, the Spot Exchange Rate and Forward Premium--Monthly Observations, U.S./Germany, July 1973-February 1979

Figure 7. Exchange Rate Overshooting: Definition II

Figure 8. Efficient Market Behavior with the Equilibrium Expected Return Constant.

Figure 9. Efficient Market Behavior Where the Equilibrium Expected Return Wanders Substantially

LIST OF TABLES

Table 1. Mean Absolute Percentage Changes in Prices and Exchange Rates.

Table 2. Equations Explaining the Monetary Approach to Exchange Rate Determination, the $/DM Rate, 1973:2 - 1979:4.

Table 3. Equations Explaining the Portfolio Balance Approach to Exchange Rate Determination, the $/DM Rate, Monthly Observations, August 1971-Decemher 1976.

Table 4. Equations Explaining Unanticipated Depreciation of the Nominal Effective Exchange Rate of the Dollar, 1973:2 - 1979:4.

1.0. Introduction-Historical Setting

The introduction of floating exchange rates in the early 1970's marked a major systematic change for international financial markets. With the exception of the Canadian experiment (1950-1962), a pegged but adjustable exchange rate system as specified under the Bretton Woods agreement dominated the post-World War II experience of all industrialized countries. Exchange rate behavior under the Bretton Woods system was characterized by relatively large, discrete and infrequent exchange rate changes. Consequently, economists and market analysts concentrated their attention on balance of payments data and international reserves. Sustained payments imbalance along with substantial shifts in international reserve holdings would increase the probability that the central bank could no longer support the pegged rate. These pressures being slow to accumulate, analysts could be certain of the direction of exchange rate change. The magnitude of exchange rate change (i.e. the amount required to restore payments balance and to halt international reserve flows) could be estimated from a Purchasing Power Parity (PPP) model or from other data. However, the ultimate decision to change the peg was fundamentally a political decision, and economic analysis was of little use in picking the breaking points of political officials.

Since the early 1970s, exchange rates have been determined largely by private market forces within a floating exchange rate system. However, central banks have continued to intervene in the market, so some would prefer the label managed floating system.[1] Exchange rate behavior under the current floating rate system can be characterized by relatively small and continuous price changes that occur quickly in response to new information. The search for a rational explanation of exchange rate behavior and its role in an integrated international financial market has been the central thrust of empirical research over the last decade.

This broad research topic can be divided into three partially distinct categories. First, many empirical studies have examined the relationship between the spot exchange rate (S_t) and a set of independent variables. The purpose here, of course, is to test a particular model of exchange rate determination, perhaps with the objective to forecast exchange rates or to examine the effect of other economic policies on exchange rates and vice-versa. Secondly, other studies have analyzed the statistical properties of other variables constructed using S_t. For example, variables such as the percentage change in the spot rate ($\dot{S}_t = (S_t - S_{t-1})/S_{t-1}$), the forward premium ($\Pi_t = (F_t - S_t)/S_t$) and the forward rate forecasting error ($D_t = S_{t+n} - F_{t,n}$) provide information on the historical risk and return of particular currency trading strategies. Finally, these empirical studies have sought to ascertain the efficiency of foreign exchange and international financial markets. As we will emphasize in section 3, tests of market efficiency involve an implicit hypothesis concerning the nature of the equilibrium exchange rate or equilibrium returns. Because of their joint hypothesis nature, the results of efficient market studies have been difficult to interpret.

The major insight to come from this decade of research is that foreign exchange is a financial asset. One aspect of this conclusion is that the current spot exchange rate reflects the expected value of future exogenous variables, discounted back to the present. This is, of course, analogous to the notion that a security's price reflects the present value of expected future cash flows. A second conclusion is that the price of a currency is determined by its demand as a financial asset relative to the demand for other currencies. In the case of foreign exchange, this may be based on the currency's utility as a medium of exchange, store of value and unit of account. The demand for foreign exchange, therefore, considers a broader range of arguments than a typical security with an asset demand function that depends on return and risk relative to a market index.

The most recent modeling of exchange rates reflects a combination of capital market theory and macroeconomics. The popular capital asset pricing models (CAPM) developed in the 1960s and 1970s solved for the price of financial assets in a setting where returns are stochastic and investors are risk averse utility maximizers.[2] The CAPM framework incorporated two notable assumptions. First, assets were assumed to be in fixed supply. Consequently, the relative demand for securities, scaled by fixed supplies, was sufficient to determine price. Trivial supply shocks, such as a stock split, had a direct effect on share prices and were easily incorporated by a change in scale. However, stochastic supply shocks (e.g. exercise of convertable bonds, warrents, or executive stock options) have a much more complicated and ambiguour effect in a general equilibrium model of share prices.

Second, the CAPM framework assumes that there are many securities, each of which is small. Consequently, dramatic shocks affecting any individual security do not induce wealth effects elsewhere. Investors do not need to re-balance their portfolios so there are no feedback effects on other securities.

Asset models for exchange rate determination cannot make either of these assumptions and hope to provide a realistic explanation of floating exchange rate behavior. First, the supply of foreign currency and official government assets denominated in foreign currency is definitely not fixed and probably not a simple, predictable function. In turn, the private demand for foreign currency and foreign currency denominated assets will depend on how well the foreign currency contributes to private utility--by providing services as a medium of exchange and store of value at low risk. Presumably, monetary discipline (i.e. slow and predictable money growth) and fiscal discipline (i.e. federal budget balance rather than deficits financed through official debt) will have a positive impact on currency demand. Therefore, an asset framework for currency pricing ought to account for the simultaneous determination of demand and supply and the stochastic nature of supply. Notably, the original CAPM models use a partial equilibrium framework, and this has obvious limitations in the context of foreign exchange.

Second, while there may be thousands of traded securities and millions of investors, so that there is little need for portfolio re-balancing in response to security-specific shocks, this is not likely to be the case in the foreign exchange market. More than 90% of world financial wealth is denominated in only six currencies and world financial wealth is similarly concentrated in a small number of countries. The result is that a small change in the perceived risk and return properties of a particular currency may lead to portfolio re-balancing that has a significant impact on other currency prices. Similarly, shifts in the international distribution of wealth, through current account imbalances, toward countries with different currency preferences may also effect currency prices. Here, the popular examples are the current account surpluses in Japan and Germany, presumably with a preference toward domestic currency denominated assets, and the OPEC current account surpluses, with an initial prefernece toward U.S. dollar denominated assets. Finally, a shift in spending patterns away from U.S. goods, toward Japanese and German goods, may cause risk averse currency managers to hold transaction balances in yen and DM rather than U.S. dollars.

The above discussion suggests that at a conceptual level, the combination of capital market theory and macroeconomics offers a fairly close approximation to the real world setting of foreign exchange markets which may be capable of explaining complex exchange rate movements. However, capital market theory places major emphasis on expectations, which are unobservable and may be difficult to approximate empirically. In this case, it might be extremely difficult to empirically document exchange rate behavior, especially short-run behavior, and to accept a particular model of exchange rates while rejecting all others.

The empirical work completed over the last decade has dramatically increased our understanding of exchange rate behavior. For example, it has been amply demonstrated that the nominal exchange rate is a function of both nominal variables (e.g. current and anticipated values of the money supply and the inflation rate) and real variables (e.g. real income and current account balances). Empirical studies have been fairly successful in constructing models to explain cross-sectional exchange rate differences (e.g. 1300 Italian lira per U.S. dollar versus roughly 2 DM per U.S. dollar) and to explain time series exchange rate developments over the medium-run and long-run (e.g. quarter-to-quarter and year-to-year rate changes). Our ability to explain day-to-day or month-to-month exchange rate changes is much more limited. In part, this is because many of the variables which play an important role in typical exchange rate models cannot be measured daily (e.g. the money supply or real income) and expected values of future exogenous variables cannot be observed directly.

The nature of the forward exchange rate--its determinants and relationship to the future spot rate--is an important empirical issue which is currently unresolved. While the forward rate may approximate the market's expectation of the future spot rate, it has been demonstrated clearly that the percentage forward premium is a poor predictor of the percentage future exchange rate change. However, the unanticipated portion of exchange rate change does appear to be significantly correlated with "news" concerning fundamental macroeconomic variables.

The plan for the remainder of this chapter is as follows. Section 2 presents an overview of stylized empirical results concerning recent exchange rate behavior. Alternative valuation measures, time series and distributional properties are covered along with estimates of transaction costs in the foreign exchange market. Empirical tests of specific exchange rate determination models are reviewed in section 3. This section begins with the simple monetary approach, where exchange rates are determined by the relative demand for two moneys, and then proceeds to a portfolio balance model which introduces bonds. A review of a generalized asset model and the role of news round out section 3. Tests of foreign exchange market efficiency are presented in section 4. After an overview of efficient market theory, evidence on the efficiency of markets to remove risk-free profit opportunities is presented. Evidence of the efficiency of markets to remove risky profit opportunities follows. This segment includes evidence on the forward rate/future spot rate relationship.

2. Stylized Empirical Results About Exchange Rate Behavior

2.1. Describing Exchange Rate Movements

The purpose of this chapter is to present a critical review of methodological issues and empirical studies concerning exchange rates. However, before we set about this task, it is essential to introduce basic terminology and to highlight particular institutional arrangements in the foreign exchange market.[3] In order to observe the dependent variable that is the subject of our analysis, we will also report simple time series plots of recent exchange rate behavior.

2.1.1 Alternative Measures of a Currency's Foreign Exchange Value.

The most common notion of currency value is the bilateral exchange rate that is quoted by a foreign exchange trader or reported in a newspaper. This is a nominal exchange rate because it expresses the number of units of one currency that are offered in exchange for a unit of another currency (e.g. \$0.50/DM or \$2.00/£). The spot exchange rate, S_t (by definition, today's rate for an immediate exchange of currencies) and the forward exchange rate,

$F_{t,n}$ (by definition, today's rate for an exchange of currencies n-periods in the future) are particular examples of nominal bilateral rates.[4] A nominal, bilateral exchange rate is essential, obviously, for translating cash flows in one unit of account, say DM, in their U.S. dollar equivalent.

The real exchange rate, however, expresses the value of a currency in terms of real purchasing power.

The real exchange rate can be calculated based on absolute purchasing power parity. For example, unrestricted goods arbitrage will establish that

$$S_t = C_t \cdot P_{\$,t}/P_{DM,t} \qquad (19.1)$$

where $P_\$$ and P_{DM} represent the absolute prices of U.S. and German market baskets. The term C_t represents the real exchange rate with units of U.S. market basket per German market basket.

Very often, the real exchange rate is expressed as an index of the actual exchange rate relative to the PP exchange rate

$$S_{real,t+n} = S_{t+n}/S_{ppp,t+n} \qquad (19.2)$$

where

$$S_{ppp,t+n} = S_t \cdot \frac{P_{\$,t+n}/P_{DM,t+n}}{P_{\$,t}/P_{DM,t}}$$

This formulation assumes that relative purchasing power parity will be maintained (i.e. the factor C_t in expression (19.1) is constant) and that period t is an equilibrium base period. Values of S_{real} greater (less) than unity indicate real depreciation (appreciation) of domestic currency, i.e. more (less) U.S. goods are required in exchange for one German market basket. Values of S_{real} equal to unity indicate that the real exchange rate and relative purchasing power parity were maintained, i.e. the nominal exchange rate change was exactly offset by the differential change in U.S. and German price indices. Consequently, the real exchange rate is a useful device for measuring the competitiveness of domestic goods in international markets, for predicting future changes in trade patterns and for evaluating long-term real investment projects.

The effective exchange rate is a multi-lateral rate that measures the overall nominal value of a currency in the foreign excahnge market. For example, the effective U.S. dollar excahnge rate combines many bilateral exchange rates using a weighting scheme that reflects the importance of each country's trade with the United States. Several institutions (International Monetary Fund, Federal Reserve Bank, Morgan Guaranty Trust Bank, and others) regularly calculate and report effective exchange rates. Each institution uses a slightly different weighting scheme. The effective exchange rate is a useful statistic for gauging the overall supply and demand for a currency on the foreign exchange market. By its nature, however, the effective exchange rate conceals the price behavior of individual bilateral markets.

The real effective exchange rate is calculated by dividing the home country's nominal effective exchange rate by an index of the ratio of average foreign prices to home prices. The real effective exchange rate attempts to measure the overall competitiveness of home country goods in international markets. While it is important to gauge international competitiveness, a summary statistic such as the real effective exchange rate should be interpreted with caution.[5]

2.1.2 Recent Exchange Rate Behavior. Prior to the early 1970s, most exchange rates were pegged to the U.S. dollar and their values were held within 1% of the central rate through official intervention. In response to a fundamental disequilibrium, the central bank would permit a discrete, step-adjustment in the currency value and then resume its official support at a new central rate.

Since March 1973, the values of major industrial currencies have been determined primarily by free-market forces in a floating exchange rate system. (The Canadian dollar began floating in June 1970 and the British pound in June 1972.) From time to time, central banks have intervened ostensibly to smooth "disorderly" market conditions, making the term managed floating more appropriate. This changeover from a pegged to floating exchange rate system has been associated with a dramatic increase in the volatility of exchange rates.

Figure 1 presents an index of selected bilateral exchange rates in U.S. dollars per foreign unit. The graph clearly illustrates how the values of bilateral exchange rates, once pegged for long stretches of time, have strayed over a wide range since 1973. The Swiss franc, German mark and Japanese yen demonstrated a strong tendency to appreciate over the period while the Canadian dollar and Italian lira generally weakened. The British pound depreciated sharply until late 1976, and has gradually appreciated since then. From 1973 through mid-1975, several currencies (noticeably the DM) demonstrated a cyclical pattern leading observers to propose that exchange rates may overshoot their equilibrium value. During mid-1975 through mid-1977, exchange rate movements were relatively flat. The strong appreciation of the Swiss france, German mark and Japanese yen resumed in mid-1977 to be capped by the major U.S. intervention announced on November 1, 1978. The U.S. dollar appreciated during 1980 and 1981 against most currencies, with the exception of the British pound. Exchange volatility in this most recent period continued to be high, reflecting the violent swings in U.S. interest rates.

The exchange rates in Figure 1 represent the typical dependent variables that we seek to model in section 2. These time series plots suggest that there is a substantial amount of variation to explain. However, visual inspection of Figure 1 suggests that each exchange rate has not followed a stationary time series process over the entire floating rate period. This may be the result of shifting volatility in the independent variables, erratic government intervention or a highly complicated exchange rate determination process. The implication for empirical studies is that a fixed coefficient model, without adjustments for government intervention, is unlikely to provide an adequate explanation for the entire sample period. A further implication is that any fixed coefficient model that provides a good fit to a limited sample period, is unlikely to produce good forecasts in the post-sample period.

The record of effective exchange rates is illustrated in Figure 2. Since most countries will appreciate against some of their trading partners and depreciate against others, the pattern of effective exchange rates should be smoother than for bilateral exchange rates.[6] The Swiss franc is an exception since it appreciated vis-a-vis every currency and for some currencies (notably the Italian lira and British pound) the appreciation was considerably more than against the U.S. dollar. Analogously, the Italian lira depreciated against all other currencies. So the lira's effective depreciation (about 42% by 1980) exceeds its depreciation vis-a-vis the U.S. dollar (about 30%). Figure 2 also illustrates the effective value of the U.S. dollar. Even though the U.S. dollar depreciated substantially against the Swiss franc, German mark and Japanese yen, the U.S. dollar appreciated against the Canadian dollar. And because the Canadian share of U.S. trade is large (roughly 50%), the effective value of the U.S. dollar has changed relatively little since 1973. At the end of 1980, the effective U.S. dollar exchange rate stood at 99.9 but climbed to 107.7 at the end of 1981. Thus, the average appreciation in the U.S. dollar of 7.7% since March 1973 throughly disguises the varied performance of the dollar against individual currencies.

A set of real effective exchange rates are illustrated in Figure 3. The pattern of real effective exchange rates is generally less volatile than other series because relative inflation rates often move to offset exchange rate changes. Several individual currencies are interesting to examine more closely. The effective exchange rates for Germany and Switzerland at the end of 1981 were 137.1 and 186.6 respectively, reflecting the substantial appreciation of these currencies vis-a-vis most others. However, the real effective exchange rates for Germany and Switzerland stood at 98.7 and 112.7 suggesting that most, but not all, of the exchange rate change was offset by differential inflation rates across countries. The figure for Switzerland suggests that the real purchasing power of the Swiss franc was up by 12.7% on average against its trading partners compared to its purchasing power in March 1973. This is substantial average change.

On the other hand, the end of 1981 effective exchange rates for Canada and Italy were 84.9 and 46.0 respectively. With inflation adjustments, the real effective exchange rates stood at 92.9 and 90.2 for Canada and Italy, again suggesting that most, but not all, of the exchange rate change was offset by differential inflation rates. The United Kingdom presents an odd case. The end-of-1981 effective British pound exchange rate was 77.6 (a nominal devaluation) but the real effective exchange rate was 135.2, suggesting appreciation in real terms. By way of comparison, the real effective U.S. dollar exchange rate hit its low value (88.6) in October 1978, just before the Federal Reserve Bank intervened to offset these rate movements. [7]

2.2 Time Series Behavior, Volatility and Distributional Properties

The motivation for examining the statistical properties of exchange rates can be attributed to three sources. First, to many economists and policy-makers the realized series of exchange rates seemed prone to "excessive" volatility and "prolonged" deviations from PPP. For some critics, this concern simply reflected a problem in positive economics (i.e. exchange rates may be too volatile to be consistent with existing models of exchange rate determination) rather than a normative view (i.e exchange rates may be too volatile to allow countries to reach their targets for internal and external balance). In either case, documenting the extent of turbulence in the foreign exchange market is an important part of the descriptive history of these markets.

Second, some statistical properties of exchange rates reflect the efficiency of foreign exchange markets. In section 2, we will show that the current spot rate is a function of current and expected values of future exogenous variables, so that

$$S_t = \frac{1}{1+b} \cdot \sum_{k=o}^{\infty} \left(\frac{b}{1+b}\right)^k E(Z_{t+k}) \qquad (19.3)$$

where Z represents the vector of exogenous factors that determine the exchange rate. As a consequence, the variance of the exchange rate (σ_s^2) should reflect the variance-covariance structure of the Zs. It would be efficient for exchange rates to be highly volatile if this accurately mirrors the volatility of underlying economic variables.

The efficiency principle can be introduced more directly. If exchange rates are excessively volatile, then unusual profit opportunities ought to exist for speculators who smooth exchange rate movements. Furthermore, efficiency requires that the exchange rate series not contain any patterns or signals which could be used to formulate a profitable trading strategy.

Finally, the statistical properties of exchange rates are important for assessing the riskiness of open foreign exchange positions. Many approaches to the firm's currency exposure management decision rely on an estimate of exchange rate volatility. If the firm works with a portfolio currency exposure management model, then the total risk of a currency may exaggerate its contribution to portfolio risk. However, the total variance in currency prices does play a role in the pricing of currency option contracts.

2.2.1 Overview of Theory. As Kohlhagen (1978) has commented, the early empirical studies of exchange rates had a tendency to borrow techniques freely from studies of efficiency in other financial markets. One result of this was a set of studies testing for the random behavior of exchange rates as a criterion for market efficiency.[8] In his classic paper, Fama (1970) argued that efficiency required that actual prices (or rates of return) follow a "fair game" process relative to expected equilibrium prices (or rates of return). And since expected equilibrium prices (or rates of return) need not be constant or evolve with constant linear growth, efficiency did not require that prices (or rates of return) follow a random walk with zero or constant drift. Levich (1978) applied this argument to the foreign exchange market, noting that many equilibrium exchange rate models and scenarios may lead to a pattern of highly correlated exchange rates. As a consequence, time series analysis of exchange rates is useful primarily as a descriptive technique to measure the parameters of the exchange rate process.

On the issue of excessive exchange rate volatility, theory suggests three important considerations.[9] First, we have noted using expression (3) that volatility in underlying variables contributes directly to exchange rate volatility. Certainly, the recent floating exchange rate period has overlapped with a period of great real and monetary turbulence. Second, the process of expectation formation can contribute to exchange rate volatility. Bilson (1978b) has noted that if market participants classify a current innovation as permanent and they extrapolate its impact into the future, an asset pricing framework such as (19.3) will result in current exchange rate changes that magnify the currently observed innovation. This extrapolative process might be irrational, however, and therefore not a permanent feature of an equilibrium exchange rate process. Finally, some exchange rate volatility may be the result of "overshooting" behavior rather than the arrival of unanticipated news. It has been argued correctly that if this overshooting reflects the failure of domestic prices to adjust quickly or financial wealth portfolios to rebalance quickly, then excessive exchange rate volatility need not entail additional adjustment costs.

With respect to the distribution of exchange rate changes, studies have generally presented the normal distribution (for discrete time) or log-normal (for continuous time) as the null hypothesis. Again, this is another example of borrowed stock market methodology. The normal distribution can be defended on the assumption that any exchange rate change $(S_n - S_1)$ can be split into the summation of a sequence of price changes $[(S_n - S_{n-1}) + (S_{n-1} - S_{n-2}) + \ldots (S_3 - S_2) + (S_2 - S_1)]$. If each individual price change is drawn from a population with finite variance, by the central limit theorem, the aggregate price change $(S_n - S_1)$ should be normally distributed.

Because the normal distribution offered a poor fit to stock price changes, finance studies went on to consider other distributions (e.g. Stable Paretian and Student-t) as well as compound processes and jump processes. As long as exchange markets are subject to periodic direct intervention and national monetary and fiscal policies are subject to abrupt changes, it seems unlikely that the exchange rate process will develop as a stationary time series with stable parameters. As a corollary, it seems unlikely that a well-behaved normal distribution will provide a good fit to exchange rates over the entire floating period.

2.2.2 Empirical Results. One of the first examinations of the time series properties of exchange rates was by Poole (1966,1967) who analyzed the Canadian dollar rate during the 1950-1962 float and European rates during the 1920s. Poole found statistically significant first order serial correlation in many cases, but he concluded that the serial dependence was not great enough to result in economically significant profits. Levich (1979 a) reexamined the Canadian dollar data using Box-Jenkins time series analysis. He concluded that the serial dependencies were significant only in the first and last year of the float. During the remainder of the sample, a simple random walk model was sufficient to describe the data. This finding is consistent with the notion that government intervention was greatest during the first and last year of the Canadian float. Giddy and Dufey (1975) applied Box-Jenkins techniques to the 1920s data and found that the simple random walk model was not adequate to describe the sample data. In a post-sample period, however, the Box-Jenkins forecasts performed worse (larger mean squared errors) than more naive forecasts. A common interpretation of these Box-Jenkins analyses is that the time series properties of exchange rates are not stable over long time periods, although the precise explanations for this phenomenon are not well understood.

Frenkel and Levich (1977) used Box-Jenkins procedures to analyze the similarities of exchange rate behavior across different currencies and time periods. Frenkel and Levich observed that the time series process for spot and forward rates during two sample periods (1962-67 and 1973-75) were remarkably more similar than during a third, more turbulent sample period (1968-69). This result is striking because the two similar time series processes were drawn from two different legal exchange rate systems--pegged rates in the former and floating rates in the latter. Frenkel and Levich interpreted their results to mean that the time series pattern of exchange rates depends principally on the behavior of underlying economic variables rather than on the legal exchange rate system.

Quite naturally, the changeover to a floating rate system reawakened interest in the volatility of exchange rates. Figures 1, 2 and 3 suggest the degree of volatility in both nominal and real rates. Figure 4 provides an illustration of daily exchange rate volatility. This picture suggests that it is not uncommon for exchange rates to change by 0.5%, 1.0% or even 2.0% in a single day. Many tests attempt to determine if this volatility is "excessive" relative to some benchmark standard. As Levich (1978) and others have reemphasized, empirical tests of excessive volatility require a joint null hypothesis and are, therefore, similar to efficient market tests. And as Huang (1981) has added, any test for speculative excesses "should be judged on the basis of exante expectations rather than expost occurrences."

Huang (1981) tests for excess volatility in line with the above comments. Huang's methodology is to compare actual exchange rate variability with the variance bounds implied by a monetary model of exchange rates under rational expectations. In an analysis of pound sterling and DM rates over the period 1973-1979, Huang concludes that the implied variance bounds are often significantly violated. It follows that either the market is inefficient (i.e. excessively volatile) or the rational expectations monetary model is incorrect, or both. As we will see in section 2, other studies also suggest that PPP and simple monetary models were not adequate to explain exchange rate movements in the 1970s.

Another perspective on exchange rate volatility is offered by Frenkel and Mussa (1980). Their data, reported in Table 1, indicates that recent exchange rate volatility, measured as the mean absolute percentage change, is considerably greater than the volatility of relative cost-of-living indices. This suggests that other factors (e.g. volatility in relative income, government intervention or unanticipated news events) may have contributed to exchange market volatility. As we have noted earlier, since exchange rates, like other asset prices, adjust quickly relative to goods prices, these results do not seem very surprising. Table 1 also indicates that recent exchange rate behavior has been less volatile than stock market behavior. Most national stock markets are felt to be fairly efficient in the sense that price swings in these markets represent a reasonably accurate assessment of changing real economic events and changing expectations. Frenkel and Mussa conclude that, by this standard, recent exchange rate volatility does not appear to be excessive or unprecedented.

The first empirical study on the underlying probability distribution for exchange rates was conducted by Westerfield (1977). In common with earlier stock price literature, Westerfield tested the null hypothesis that exchange rate changes conformed to a normal distribution. Her methodology considered the variable $R_t = \ln S_t - \ln S_{t-1}$ (the weekly continuous exchange rate change) for five major currencies during a fixed rate and floating rate period (roughly 1962-1971 and 1973-1975). The alternative hypothesis was that exchange rate changes conformed to a Stable Paretian distribution with characteristic exponent $\alpha < 2.0$.[10] Westerfield concluded that the Normal distribution was not adequate to describe the sample data and that the Stable Paretian distribution, with α in the range roughly 1.3 - 1.7, provided a superior fit for both the fixed and flexible rate periods.

Rogalski and Vinso (1978) reexamined Westerfield's data to consider an alternative non-normal distribution, the Student-t distribution with degrees of freedom, $d<\infty$.[11] Using likelihood ratio tests, Rogalski and Vinso confirm that a stable paretian distribution is adequate to describe exchange rates during the pegged rate period, However a student-t distribution (with d≈ 4.0) provides a better description of floating rates. The authors also note that the switch from pegged to floating rates was associated with a decline in the peakedness of the distribution of exchange rate changes and an increase in the dispersion or variability factors. In broad terms, this finding is consistent with risk averse behavior in an efficient foreign exchange market.

2.2.3 Methodological Issues and Agenda. Empirical studies of volatility are an important part of the ongoing analysis of a floating exchange rate system. An important issue here is whether or not bolatility is "excessive." These tests are difficult to formulate and interpret because they reflect a joint hypothesis based on market efficiency and normal volatility resulting from an equilibrium exchange rate model. Nevertheless, these studies are important since any claim of excess volatility might provoke policies to increase direct government intervention in the foreign exchange market, aid private speculation or move away from the floating rate system.

Another issue is whether volatility is influenced by the choice of the legal exchange rate system. As an empirical matter, exchange rate volatility increased in the post -1973 period. However, there is also evidence to suggest that the time series pattern of exchange rates may be very similar in pegged and floating rate periods and some pegged rate periods (1968-1969) may be marked by extreme turbulance. Clearly, national economic policies and exogenous international economic events may be tranquil or turbulent, regardless of the legal exchange rate system. The question remains whether the private demand for foreign exchange--either for transaction balances in international trade or for rebalancing financial portfolios in response to changes in expected returns and risk--is more volatile under a floating exchange rate system.

Another important aspect of this topic is the impact of exchange rate volatility on other key macroeconomic variables--e.g. the prices and volume of international trade, the transmission of national economic disturbances and the independence of national economic policies. Studies by Hooper and Kohlhagen (1978) and Kreinin (1977) suggested that incresed exchange rate volatility under floating rates had no measurable impact on the prices or volume of international trade. Broadly speaking, this result is consistent with Friedman's (1953) claim that low-cost hedging services would become available to protect importers and exporters from unanticipated exchange rate swings. A recent study by Cushman (1983) considers the volatility in real exchange rates and, contrary to earlier studies, reports a significant impact on the prices and volume of international trade. This result seems more consistent with standard trade theory models and terms of trade volatility. The distinction between real and nominal magnitudes is a critical methodological issue to keep in mind in all aspects of international financial research. A companion study analyzing the impact of real exchange rate volatility on portfolio capital flows and direct foreign investment flows is an important topic for future research. [12]

Empirical studies on the distribution of exchange rate changes may not seem to be very relevant, either for theoretical or practical purposes. As we will discuss in Section 2, the modern concept of exchange risk focuses more on the variability of a currency's real purchasing power or the covariability of an asset's real return with a well-diversified portfolio. However, the equilibrium pricing of currency option contracts will very likely depend on some measure of the own currency's dispersion or volatility. [13] Since currency option contracts will be publicly traded beginning in 1982, interest in estimating the volatility parameter should be renewed. In this regard, it may be important to keep in mind the distinction between transaction time and clock time. A little-referenced paper by Brada, et.al. (1966) hypothesized that non-normality in daily stock returns resulted because the volume of transactions differed across the daily trading interval. When stock returns are calculated across a fixed number of transactions (say 50 or 100 trades), the distribution of returns is, in fact, normal. It is not clear whether this methodology can be replicated for currency price changes since there is no central record of consecutive foreign exchange transactions.

2.3. Transaction Costs in Foreign Exchange Markets

Professional interest in transaction costs has increased over the last ten years. There are several reasons. First, if markets are efficient, transaction costs may be the only "true" cost of using the foreign exchange market. For example, foreign exchange risk management strategies sometimes use the forward premium as the "cost of hedging" or the differential between the forward rate and the expected future spot rate as an "opportunity cost" measure. In an efficient market, alternative hedging opportunities are priced fairly so transaction costs capture all of the real costs involved.

Second, we would expect many international financial relationships (e.g. the interest rate parity condition) to hold exactly in the absence of transaction costs. The presence of transaction costs generally leads to a neutral band, within which deviations from the parity condition persist because they cannot be profitably exploited. One test of market efficiency in these cases, is simply to count the percentage of observations falling within the neutral band. This procedure requires an independent estimate of transaction costs.

Finally, by most any measure, the cost of transacting has risen sharply over the floating rate period. On days when unexpected news reaches the market and uncertainty is high, transaction costs may increase dramatically and reduce, or even completely halt, the flow of trading. Therefore, transaction costs may be interpreted as a barometer for how well the floating exchange rate system is performing. Changes in transaction costs are one component of the real resource costs of operating a floating exchange rate system rather than a pegged rate system.

2.3.1 Concepts of transaction costs. The liquidity theory (Demsetz, 1968) argues that the bid-ask spread is only one component in the total cost of transacting. The spread represents the cost of making a quick exchange of a financial claim for money, i.e. the cost of liquidity services. The theory suggests that the spread should decline as trading volume and the number of market- makers increases. Notably, the spread ignores the costs of producing financial claims, the costs of being informed, etc. More important, the liquidity theory assumes that prices are set at a fair or equilibrium level, and so the trader's major costs are associated with waiting for the arrival of buyers and sellers who want liquidity services. A transactor with inside information may be able to trade at a disequilibrium price and reduce his positioning cost below the quoted bid-ask spread. [14]

The adversary theory (Bagehot, 1971) explicitly considers the impact on transaction costs that results if there are two groups of investors with different information. Adversary theory suggests that there are two groups of traders. One group is "informed", trading to earn unusual profits based on their information advantage. The second group is "uninformed", expecting to trade at fair prices for liquidity purposes only. In theory, the trader or market-maker will respond differently to these two groups because he fears losing money to informed traders and he expects to earn a fair profit from uninformed traders. Adversary theory also helps us to refine the relationship between risk and transaction costs. Price risk suggests the price volatility of the underlying asset while liquidity risk refers to the uncertainty from holding assets that trade a small volume per unit time. Transaction costs are positively related to both types of risk. According to this view, the percentage spread in spot gold prices should exceed the spread in U.S. treasury bill prices. Furthermore, we expect that the (per unit) cost of trading DM 1,000,000 is smaller than for DM 1,000 transaction (because of scale economics). However, the (per unit) cost of trading DM 100,000,000 may exceed the cost for DM 1,000,000 because of liquidity risks.

2.3.2. Empirical Measures. The bid-ask spread measures the cost of buying and then immediately selling an asset. Therefore the percentage cost of one transaction equals ½(Ask Price - Bid Price)/Ask Price. Estimates of transaction costs based on the bid-ask spread vary considerably across currencies and over time. Levich (1979a) reports that during the early 1960s, spreads were extraordinarily small, roughly 0.01% for sterling, 0.02% for DM and 0.03% for Canadian dollars. By the mid-1970s, these figures averaged 0.05% for spot contracts and 0.15% for forward contracts. But a substantial number of spreads in the range 0.25%-0.50% were observed.

Triangular arbitrage offers another approach for measuring transaction costs. Frenkel and Levich (1975 , 1977) argue that during a period when transaction costs are stationary, the upper limits of the deviations from triangular parity ($/DM = $/$C · $C/DM, for example) should equal the cost of one currency market transaction. Estimates using the triangular arbitrage approach should be larger than the bid-ask spread, since they include the costs required to monitor the deviations from traingular parity. Using the triangular approach Frenkel and Levich (1977) reported that transaction costs rose from roughly 0.05% in the 1962-1967 period, to roughly 0.50% in the 1973-1975 period. McCormick (1979) argued that the triangular approach requires carefully collected, time-synchronous data. Based on a six-month sample of high quality data from 1976, McCormick estimated spot transaction costs in the range 0.09% - 0.18%.

A related study by Fieleke (1975) used regression analysis to test the relationship between bid-ask spreads and other macroeconomic variables. As hypothesized, Fieleke reported that the bid-ask spread was positively related to exchange rate volatility and a dummy variable reflecting government announcements likely to effect market uncertainty.

2.3.3 Methodological Issues and Agenda. As a boundary condition for many efficient market tests and general barometer on the functioning of foriegn exchange markets, estimates of foreign exchange transaction costs should be of ongoing interest. The triangular arbitrage estimation procedure seems preferred, in that it represents a more inclusive measure of transaction costs. However, this approach has several major drawbacks--(1) it requires high-quality, time-synchronous data,

(2) it requires a sample period with roughly stable transaction costs and (3) the cross-rate, DM/$C in our example, must be set in a true, independent market. Since these conditions are not easily met, the bid-ask spread approach will continue to supply the most common estimates of transaction costs.

The concept of price dispersion-- the variance of price quotations across market makers in a dispersed market--has been explored in some financial markets (Garbade and Silber, 1976) but not in the foreign exchange market. The cost of searching for the best execution prices across dispersed market markers can be an important part of transaction costs.[15] Although various electronic communication devices link the many world-wide commercial bank trading operations, dispersed market-markers will simultaneously offer different quotations backed by different qualities of related services. These micro-foundations of foreign exchange trading are poorly understood and worthy of further study. One practical result of this study would be a better estimate of the "noise" inherent in a daily series of spot exchange rates and a new dimension on risk in trading in a dispersed market.

3. Exchange Rate Determination-Tests of Specific Models

The evidence presented in section 1 demonstrates that exchange rates, both nominal and real, were substantially more volatile during the 1970s than during the earlier pegged rate period. The central question inspired by these data is clear: What is the model by which exchange rates are determined? The managed floating period offers a complex setting with a variety of economic disturbances (real and monetary, temporary and permanent, anticipated and unanticipated, economy-wide and industry-specific) and structural and institutional parameters (e.g. slow commodity price adjustment, heterogeneous expectations and risk preferneces) that should present a substantial challenge to the model builder.

In section I, we introduced the notion that foreign exchange shares many characteristics of other financial assets. The reader may be painfully aware of the difficulty in forecasting stock prices and the often aired views that certain stocks are currently undervalued (or overvalued) in today's market. Consequently, we might expect to learn that exchange rate modeling, not to mention forecasting, is also a very difficult activity.[16] Our standards for adequate model performance reflect this view. No theory has been proposed seriously as a complete explanation for exchange rate behavior; therefore, we do not expect to explain all empirical exchange rate variation. In most cases, significant parameter coefficients will be taken as support for a theory. Furthermore, we expect to see substantial performance deterioration in models of exchange rate changes relative to models of exchange rate levels. This last result follows because exchange rates themselves are viewed as anticipatory prices which already incorporate expected future exchange rate changes.

The models in this section are developed roughly in chronological order and in order of complexity and richness.[17] We begin with the purchasing power parity (PPP) view of exchange rates. Even though PPP is not a theory of exchange rate determination, it is an important building block and equilibrium condition for international financial models. Evidence on the monetary approach to exchange rate determination is reviewed next. The monetary approach is a direct outgrowth of the PPP model. The monetary approach can be easily modified to accommodate other assumptions--rational expectations of future exogenous variables, slow price adjustment in good markets, or long-term interest rates, wealth and other variables in the demand for money function. Allowing individuals or firms to hold a portfolio of two or more currencies and to substitute among currencies is another modification of the basic monetary approach. Among the potential problems with the monetary approach, we note that the demand for assets, beyond currency, within a portfolio optimizing framework is not considered. Furthermore, from an empirical standpoint, it may not be efficient to introduce real disturbances through real income in the demand for money function. In order to model the impact on exchange rates from shifts in particular real variables--such as the competitiveness of German goods, consumer preferences toward home goods or the OPEC price of oil--it may be better to use a model that prescribes a less ambiguous role for these variables.[18]

The portfolio balance model or generalized asset approach attempts to rectify some of the above problems by specifying asset demand functions and providing an explicit role for the current account. While the portfolio balance model may seem to capture more realism, as we will see, it is a difficult model to implement empirically.

We conclude section 2 by commenting on the empirical studies of exchange rate dynamics and the role of "news" -i.e. explanations for exchange rate changes not predicted by a standard, baseline model.

The most complex exchange rate models, simultaneous equation models developed by DRI, Chase Econometrics, Wharton Econometric Forecasting Associates and the Federal Reserve Board of Governors, are not reviewed here. The DRI, Chase and Wharton models are proprietary and the Federal Reserve model has been tested primarily through simulation exercises.[19]

While any review of empirical studies of exchange rate determination might seem like a "horse race" to see which model is "best", this would not be a correct inference. Our emphasis should be on selecting the appropriate model for the task at hand. For example, a simple monetary model may be adequate to describe exchange rate behavior during a hyperinflation dominated by monetary distrubances, but inadequate to describe periods with real disturbances. Similarly, if we want to analyze the impact of particular events (e.g. announced changes in future money supply policy, changes in spending patterns that alter the current account, or changes in the risk of foreign assets) we need a model that incorporates these variables in a consistent and efficient manner.

3.1 Purchasing Power Parity

3.1.1 Overview: Perhaps the most popular and intuitive model for exchange rate behavior is represented by the theory of purchasing power parity (PPP).[20] The main thrust of purchasing power parity is that nominal exchange rates are set so that the relative purchasing power of currencies is constant over time. As a result, PPP suggests that in the long-run, nominal bilateral exchange rate changes will tend to equal the differential in inflation rates between countries. Economists have long debated whether the PPP doctrine applies to the short-run or the long-run and whether the relevant inflation rate is on a narrow class of goods (e.g. only traded goods) or a broader index (e.g. the consumer price index). Frenkel (1976) has argued that much of the controversy over the usefulness of the PPP doctrine results from the fact that PPP specifies a final, equilibrium relationship between exchange rates and prices without specifying the precise linkages and details of the process. In the world economy, prices and exchange rates are determined endogenously, so PPP represents an equilibrium relationship rather than a precise theory of exchange rate determination.

The heart of PPP doctrine is the Law of One Price, that is, perfect commodity market arbitrage. For example, if the price of oil in New York is $40/barrel, we expect the price in London to be £20/barrel when the exchange rate is $2/£. Absolute purchasing power parity requires that the exchange rate equalize the price of a market basket of goods in the two countries. Since the composition of market baskets and price indexes varies substantially across countries, and because many goods are non-traded or subject to tariffs, it is unlikely that absolute PPP will hold in the real world.[21] Relative purchasing power parity, however, requires that the percentage change in the exchange rate equals the differential percentage change in the price of a market basket of goods in the two countries. If the factors that cause absolute PPP to fail (e.g. tariffs, some goods being non-traded) are constant over time, then we see that relative PPP might hold even when the absolute version does not.[22]

3.1.2 Empirical Evidence: The empirical evidence on PPP is mixed. Moreover, the evidence may be sensitive to the countries, time periods and price indexes that we select. Over long time periods and during periods dominated by monetary disturbances (such as a hyperinflation) PPP offers a fairly good description of exchange rate behavior. However, over shorter time periods, say three to twelve months, it has not been uncommon to observe substantial exchange rate changes, say 10%-20%, which are unrelated to commodity price changes.

We can describe three techniques for testing PPP. The first is regression analysis of the form

$$\ln S_t = a + b \ln (P/P^*)_t + U_t \tag{19.4}$$

which corresponds to the absolute version of PPP and

$$\Delta \ln S_t = b \ln (P/P^*)_t + v_t \tag{19.5}$$

which corresponds to relative PPP. We use the notation S_t to indicate the exchange rate (domestic currency price of foreign currency) and $(P/P^*)_t$ to indicate the ratio of domestic to foreign price indices respectively.

Our notation for the first difference operator is Δ and U_t and v_t denote classical error terms. Because prices and exchange rates are determined simultaneously, a two-stage least squares estimation procedure should be employed. In addition to classical error terms and a high percentage of variation explained, the basic null hypotheses are that a=o in (19.4) and b=1. Further empirical issues, such as the impact of alternative price indices and the equality of coefficients on domestic and foreign prices might also be examined.

Frenkel (1980) reports results on eqs. (19.4) and (19.5) using monthly data drawn from the flexible exchange rate period of the 1920s. The sample includes four countries--Germany, which experienced hyperinflation conditions, and France, Britain and the U.S. which experienced more normal economic conditions. Frenkel concludes that in most cases his data are consistent with the hypothesis that the elasticity of the exchange rate with respect to the price ratio is unity.

Frenkel (1981) reports similar tests on data sampled from the 1970s floating exchange rate period. Here the results are extremely poor. The b coefficient is often far from the hypothesized value, estimated with large standard errors and unstable overtime. Visual inspection of Figure 5 illustrates the weak correspondence between exchange rate changes and relative price changes over the 1970s. Frenkel explains the collapse of PPP (1) by changes in the traded goods/non-traded goods price ratio that occurred unevenly across countries and (2) by the very nature of exchange markets that react quickly to expectations of future events rather than reflect current and past circumstances that are captured in existing price contracts.[23]

A second technique for checking PPP is simply to calculate the exchange rate which satisfies PPP,

$$S_{ppp,t+n} = S_t \cdot \frac{P_{t+n}/P^*_{t+n}}{P_t/P^*_t} \qquad (19.6)$$

and compare it to the prevailing exchange rate S_{t+n}. Figure 6 presents an example of the above calculation for Germany in the 1970s that happens to show substantial and ongoing deviations from PPP. In reference to this general phenomenon, McKinnon (1979, p. 133) observed that "Substantial and continually changing deviations form PPP are commonplace. For individual tradable commodities, violations in the 'law of one price' can be striking."

This last statement refers to a third method for checking PPP. A study by Isard (1977) compared the movement of the dollar prices of German goods relative to their American equivalents for specific goods selected at the 2 and 3 digit levels of the SITC classification. The results implied persistent violations of the law of one price. In part, Isard (1977, p. 942) concluded that "In reality the law of one price is flagrantly and systematically violated by empirical data....Moreover, these relative price effects seem to persist for at least several years and cannot be shrugged off as transitory."

Notwithstanding the above, McKinnon (1979, p. 136) goes on to conclude that

> "Until a more robust theory replaces it, I shall assume that purchasing power parity among tradable goods tends to hold in the long run in the absence of overt impediments to trade among countries with convertible currencies. But...because commodity arbitrage is so imperfect in the short run, it cannot be relied on to contain nominal exchange rate movements within the predictable and narrow limits suggested by the law of one price."

As a consequence, economists have turned to monetary and portfolio balance models of exchange rate determination which are discussed below.

3.2 Monetary Theory and Exchange Rates

3.2.1. Overview. It is perhaps self-evident that whenever a voluntary foreign exchange transaction occurs, say between U.S. dollars and DM, it represents an excess demand for one currency (say DM) and an excess supply of the other currency (in this case, U.S. dollars). If we can identify the sources of this excess demand for DM (perhaps these sources include a transaction demand or a speculative demand for currency, or perhaps DM balances offer a more reliable store of real purchasing power), we have the basis for a monetary theory of exchange rates. The basic monetary approach to exchange rate determination is a direct outgrowth of purchasing power parity theory in combination with the quantity theory of money. While PPP concludes that the exchange rate is the relative price of goods in the two countries, monetary theory suggests that the exchange rate is the relative price of two moneys. In this context, it follows that the exchange rate represents the relative demand for two moneys.

Economists commonly represent the demand for real money balance (M/P) as some function (L) of real income (Y), interest rates (i), and other factors (K) so that

$$M/P = L\ (Y,\ i,\ K) \qquad (19.7)$$

The relationship between real income and real money balances is direct since an increase in income raises the demand for transaction balances. The relationship between interest rates and real money balances is inverse since an increase in interest rates raises the opportunity cost of holding balances and therefore lowers demand. Other factors (K) are included since, given Y and i, increasing sophistication among banking and financial institutions may increase the velocity of money, and lower money demand.

According to the monetary approach, factors that lead to an increase in the demand for domestic currency (i.e., the U.S. dollar) should lead to an increase in the price of domestic currency on the foreign exchange market. As we just argued, two factors that would increase the demand for domestic currency balances are an increase in U.S. income and a fall in U.S. dollar interest rates. Correspondingly, monetary theory predicts that these factors should cause the U.S. dollar to appreciate on the foreign exchange market. Notably, these predictions are contrary to more standard theories of trade and capital flows.

Trade models correctly argue that higher U.S. income will lead to greater demand for imports, and in turn an increased demand for foreign currency and a depreciation fo the U.S. dollar. But this relationship reflects a partial equilibrium and neglects capital flows that also respond to an increase in U.S. income. Monetary theory argues that in the general equilibrium, the net effect of higher U.S. income should be a U.S. dollar appreciation.

Capital flow models correctly argue that high real U.S. interest rates should attract foreign capital that, in turn, acts to appreciate the U.S. dollar. Monetary theory, however, emphasizes that high nominal U.S. interest rates that incorporate a large inflation premium actually suggest U.S. dollar depreciation via purchasing power parity. If a currency is expected to depreciate, the stock of currency is willingly held only if investors are compensated by higher interest rates. The data strongly confirm that currencies with high interest rates (e.g., Brazil and Argentina) generally have been characterized by depreciation, while currencies with low interest rates (e.g., Germany and Switzerland) generally have been characterized by appreciation.

3.1.2 Empirical Evidence   To implement the monetary apporach, we must first specify an explicit money demand function in place of (19.7). A popular specification is

$$M/P = K \cdot Y^{\eta} \cdot e^{-\varepsilon i} \qquad (19.8)$$

Where η is the income elasticity of demand for real money balances and e is the interest rate semi-elasticity of demand. (A time subscript, t, is suppressed.) If we rearrange terms in (19.8) to isolate the price level, we have

$$P = M/(K \cdot Y^{\eta} \cdot e^{-\varepsilon i}). \qquad (19.9)$$

Let us assume that the same specification of money demand also applies in the foreign country so that

$$P^* = M^* /(K^* \cdot Y^{*\eta} \cdot e^{-\varepsilon i^*}) \qquad (19.10)$$

where as before, an asterisk indicates the foreign country. For simplicity only we assume the elasticities are identical in both countries. Substituting (19.9) and (19.10) into the purchasing power parity expression,

$S = P/P^*$, results in

$$S = \frac{M}{M^*} \cdot \left(\frac{Y^*}{Y}\right)^{\eta} \cdot \left(\frac{K^*}{K}\right) \cdot e^{\varepsilon(i-i^*)} \qquad (19.11)$$

Taking logarithms of (19.11), we get the linear expression

$$s = (m-m^*) + \eta(y^*-y) + (k^*-k) + \varepsilon(i-i^*) \qquad (19.12)$$

where we use the convention that a lower case letter represents the logarithm of a capital letter (e.g. $s = \ln S$).[24] Expression (19.12) can be refined further by setting $(i-i^*)$ equal to the forward rate premium, and then letting the forward rate reflect the future spot rate. These steps are taken in a later section.

In empirical tests, we expect the coefficient of $(m-m^*)$ to be unity, confirming the neutrality of money. The elasticity coefficient should be positive and significant, η in the neignborhood of 1.0 and ε so that ε i approximates the interest rate elasticity of the demand for money, in the neighborhood of 0.04 for monthly data. Naturally we hope that the coefficients are stable, that the model explains a large fraction of exchange rate variation and that the error terms satisfy classical properties.

A large number of empirical studies have been conducted based on (19.12) and its close variants. We will briefly review five different methodological styles based on the monetary approach.

(i) Ordinary and Two Stage Least Squares Regression. Clearly, equation (19.12) could be tested using simple OLS techniques. Frenkel (1976) ports one such test on monthly data for Germany in the 1920s, using the inflation rate as a proxy for exchange rate expectations. His results are fully consistent with the monetary approach; the homogeneity of money is confirmed and the proxy for ε is significant at a reasonable value. These results are also consistent with the view that monetary shocks dominated the sample period and purchasing power parity was maintained.

Dornbusch (1980) contains another test of equation (19.12) based on quarterly data for the 1970s. These results are summarized in Table 2. These results suggest that the estimated coefficients are generally insignificant and that the simple monetary approach offers a poor description of this period. Only the homogeneity postulate survives. Dornbusch proceeds by considering other exchange rate theories. Other authors--Bilson (1978a), for a monthly sample of DM/£ rates in 1970s- and Frenkel and Clements (1981) for a monthly sample of non-DM rates in the 1920s--also report that they cannot accept the monetary approach based only on their sample data. However, these authors revise their empirical methodology, as we describe next.

(ii) <u>Mixed Estimation.</u> A major problem cited in the studies above is imprecise parameter estimates. This is tantamount to saying that there is relatively little information in the sample data either to confirm or reject a particular theory. A Bayesian procedure for obtaining more precise parameter estimates is to supplement the sample information with prior information. In this case, prior information amounts to stochastic restrictions on the elasticities (i.e. regression coefficients) where this prior information is based on previous studies of the demand for money. The mixed estimation procedure, as applied by Bilson (1978b) and Frenkel and Clements (1981), produces coefficient estimates that are more precise and fully consistent with the monetary approach. However, the true test of this procedure is whether in a dynamic simulation, the estimated model closely tracks the actual exchange rate over the sample period.

In both studies, the authors report that the dynamic simulations track the data reasonably well. In other words, a monetary approach with coefficients estimated according to a Bayesian procedure, does not produce results that are inconsistent with actual exchange rate behavior. It should be noted that Bilson's model includes a significant time drift factor that might represent other structural economic factors that could be modelled explicitly.

(iii) Pooled Time Series/Cross Section. Another procedure for increasing the precision of coefficient estimates is to increase the sample size and to increase the variance of the dependent variable. By combining sample data from many countries with a wide range of exchange rate experiences, the pooled time series/cross section methodology accomplishes both objectives at once. Bilson (1976) applies this procedure to yearly data for 37 countries in the period 1956-1973. He incorporates a country specific term to proxy differences in velocity, development of financial institutions, and other factors across countries. Bilson's results offer strong evidence that the monetary approach explains a large fraction of cross-sectional exchange rate variation and that parameter estimates are in line with prior expectations. The mean absolute error, in-sample, is under 15%.

(iv) Short-run/Long-run Interest Rates. The model proposed in equation (19.12) presumes that real interest differentials are zero or constant. While this may be an adequate first approximation during a hyperinflation or a period dominated by monetary shocks, it is not a valid description of the 1970s. Frankel (1979b) modifies the simple monetary model to account for real interest differentials. His final estimating equation is

$$s = (m-m^*)_- + \eta(y-y^*) + \alpha(i-i^*) + \beta(\dot{p}-\dot{p}^*) \qquad (19.13)$$

Where $\dot{p}$ and $\dot{p}^*$ are the current values of expected long-run inflation at home and in the foreign country, α is hypothesized negative and β is hypothesized positive and greater than α in absolute value. For econometric purposes, the opportunity cost of money balances (i and i^*) is proxied by a short-run interest rate, while long-term interest rates are used to proxy $\dot{p}$ and $\dot{p}^*$.

Frankel's original study using monthly data on the $/DM rate for the period July 1974-February 1978 showed results very favorable to his hypothesis. However, the model indicated signs of breakdown in the last few months of the sample. The results in Table 2 by Dornbusch (1980) confirm that this variation on the monetary model is not supported by the $/DM rate's behavior in the 1970s. In a follow-up paper, Frankel (1982a) revises his model to include financial wealth as an argument in the demand for money function. This modification appears to correct the post-1978 deterioration of the baseline model. Frankel concludes that the monetary model with wealth as an argument succeeds in explaining the $/DM rate when alternative approaches fail.

(v) In-Sample/Post-Sample. The final empirical methodology is represented in an ambitious paper by Meese and Rogoff (1981). The authors estimate several competing exchange rate models, including a monetary approach, using a "rolling regression "format to estimate parameter coefficients based on the most recent information available. With these estimated models, Messe and Rogoff proceed to generate one to twelve month horizon forecasts in the post-sample period. The authors conclude that even though the models perform well in-sample, they perform poorly in the post-sample period and fail to outperform the random walk model or the forward rate.[25]

In a subsequent paper, Messe and Rogoff (1982) rule out parameter sampling error as a reason for poor post-sample performance. Instead, they suggest that model misspecification resulting from instability in the underlying money demand function and insufficient attention to risk factors and shifting real exchange rates may be at the heart of the problem.

3.2.3 Methodological Issues. Among the methodological issues affecting studies of the monetary approach is parameter instability. While this is a potential problem in any regression framework, monetary models applied in the 1970s may be particularly susceptible, because of the range of monetary conditions and financial innovations that characterized the period. Studies by Frankel (1979b,1982c) and Meese and Rogoff (1981,1982) suggest that further studies on parameter instability may be rewarding.

Correcting possible model misspecification is another important avenue for research. Notably, the real side of the monetary approach has been confined to real income and the relative price of traded versus non-traded goods. But other real factors--major changes in energy prices, or major changes in current accounts that result from changes in tastes, international competitiveness, or the desire to re-balance portfolios-- do not enter cleanly into the traditional monetary model. Equally important for short-run exchange rate determination is the specification of the money supply process. Traditional monetary models take the money supply as given but possibly the money supply should be made endogenous in the short-run. For the long-run, we might assume that central bank sterilization or intervention policies are of limited importance. We also note that the standard monetary approach disregards risk considerations, but perhaps these are more logical to include in a model where investors exercise protfolio behavior.[26]

A final issue that will apply to all empirical analyses of exchange rates is the degree of accuracy that we ought to expect from any stylized economic model. In section 1, we noted that exchange rates often change 1-2% in a day--conceivably a day when nothing an economist can measure has changed. Again drawing an analogy to the stock market, we might argue that a model which describes monthly or quarterly exchange rate behavior within a tolerance of 5% - 15% is performing very well.

3.3 Currency Substitution.

An extension of the monetary approach allows domestic currency to be held by foreigners and vice-versa.[27] That domestic residents might demand foreign currency stems from the assumption that domestic residents might desire transaction balances to minimize transaction costs or reduce exchange risk or domestic residents might feel that foreign currency provides a more secure store of value. Significantly, even if both currencies are equal in terms of their own return and risk, as long as returns are not perfectly correlated (and ignoring transaction costs), risk averse individuals will hold portfolios containing both currencies.

Frenkel and Clements (1981) develop a straightforward extension of the simple monetary approach in which the aggregate demand for money is the sum of domestic demand and foreign demand components. The final exchange rate equation is similar to (19.12) except two new terms enter λ and λ^*--the fraction of domestic and foreign currency respectively, held locally. When $\lambda = \lambda^* = 1$, their model reduces to

(19.12) The authors do not present empirical evidence on the model.

Miles (1978) presents a model in which residents hold both domestic and foreign currencies because both contribute to the level of money services. The residents are assumed to maximize the production of monetary services, subject to an asset constraint. Miles' empirical analysis is for Canada and the United States over the period 1960 IV — 1975 IV. Miles reports that during floating rate periods, the elasticity of substitution between Canadian dollars and U.S. dollars is significant. This suggests that portfolio considerations ought to be incorporated into exchange rate models of the Canadian dollar.

The major drawback of the currency substitution model is the limited menu of assets (i.e. currency) under consideration. A portfolio balance framework expands the list of assets that may be substituted, and therefore appears more realistic.

3.4 The Portfolio Balance Approach

3.4.1 Overview An extension of the monetary/currency substitiution framework argues that individuals' excess demand is not for currency qua currency, rather individuals desire to shift from one set of financial assets (for example, dollar denominated) into another set (DM) financial asset. In the portfolio balance model, demand in the foreign exchange market for currencies is derived largely from demand for financial asset As a consequence, if wealth accumulates (e.g., via current account surpluses) in a country that traditionally prefers DM assets, it is likely that the value of the DM will increase. To take another example, if the spending patterns of a country shift (e.g., the United States changes its taste toward German products) or if a country (e.g., Saudi Arabia) accumulates a substantial amount of financial wealth, prudent risk management prinicple suggest that investors in these countries will diversify their asset portfolios. And in our examples, diversification is away from dollar assets and toward DM assets.

The essential building blocks of the model are domestic money, M; domestic bonds, B, that earn interest rate r and are not internationally traded; and foreign-issued bonds, F, that earn fixed return $\bar{r}$.[28] Foreign bonds cannot be traded for M or B, so they can only be accumulated through a current account surplus. The asset market equilibrium conditions are given in the following equations:

$$M = m(r,\bar{r})W \tag{19.14}$$

$$B = b(r,\bar{r})W \tag{19.15}$$

$$eF = f(r,\bar{r})W \tag{19.16}$$

$$W = B + M + eF \tag{19.17}$$

The exchange rate is given by e and W represents domestic financial wealth.

The portfolio balance approach is appealing because it presents a rich setting to analyze important real factors affecting exchange rates, and yet maintain a tractable model. The model provides a clear link between real factors which affect the current account, the current account itself (i.e. flow changes in F) and the exchange rate. Furthermore, we can investigate the impact of shifts in the distribution of financial wealth (across currencies) on the exchange rate. Finally, the model is suited to analyzing the impact of risk (e.g. the lack of monetary discipline) and individual portfolio behavior on exchange rates.[29]

3.4.2 Empirical Evidence and Methodological Issues. Empirical studies of the portfolio balance approach suffer from two important methodological problems. The first is a data problem; it is very difficult to track the holdings of financial assets broken down by currency of denomination. In practice, most studies have started with a benchmark observation on the private stock of foreign assets held and then accumulated current account balances for each country, less holdings of central banks. Necessarily, this method ignores capital gains on foreign assets, but moreover, it assumes that only domestic residents hold domestic assets and that all foreign assets are denominated in foreign currency. German corporation's Euro-dollar bonds and U.S. corporations Euro-DM bonds are the counter-examples here.

The second methodological problem is specifying stable asset demand functions. Frankel (1982a) argues that while it may be appropriate to assume stationarity of expected returns in the context of a micro CAPM, it is inappropriate for a macro model since changes in expected returns are essential to the international adjustment process. Frankel contends that the stationary expected returns assumption helps to explain the sharp changes in "optimal" portfolio weights across currencies and the sometimes negative weights (for currencies in positive supply) that have been reported in the literature.

Perhaps because of these problems, empirical tests of the portfolio balance model have not met with great success. In a study of the $/DM rate in the 1970s, Branson, Halttunen and Masson (1977) report OLS coefficient estimates with the expected signs, but they are generally not significant and some serial correlation remains in the residuals (See Table 3). However, using a two stage least squares procedure, the authors produce consistent parameter estimates that show greater significance and explanatory power.

A more recent study by Frankel (1982b) tests the portfolio balance model in the 1970s through mid-1981 for five countries. Single equation models are estimated using the Cochran-Orcutt technique. The results are dismal; many parameters are significant with the incorrect sign. As in Frankel (1982a), Frankel resorts to a synthesis of monetary and portfolio balance approaches. Coefficients of the portfolio balance parameters assume the correct sign and are generally significant, but the monetary variables remain insignificant.

3.5 Exchange Rate Dynamics.

The general issue of exchange rate dynamics is covered in Chapter 18 of this Handbook. In this section, we focus on empirical studies of exchange rate overshooting.

3.5.1 Overview

The recent period of floating exchange rates has caused some market observers to wonder whether exchange rate volatility, by some standard, is excessive. The term "overshooting" was coined to describe exchange rate changes in excess of this standard. Interest in overshooting arises from two general concerns. First, exchange rate overshooting may signal that the market is inefficient and profit opportunities exist and/or some sort of government corrective action (not necessarily intervention) is required. Second, if the foreign exchange market is operating efficiently, overshooting may simply suggest that investing in foreign currency assets is somewhat riskier than suggested by more simple models. Levich (1981c) proposes the following three definitions of overshooting:

(1) The current spot exchange rate (S_t) does not equal some long-run equilibrium rate ($\bar{S}$) that may be based on purchasing power parity or another long-run model.

(2) The equilibrium exchange rate change that occurs in the short-run (ΔS_{sr}) exceeds the equilibrium exchange rate change in the long-run (ΔS_{lr}).

(3) The actual exchange rate change that occurs in the market place (ΔS_t) exceeds the equilibrium exchange rate change ($\Delta S'_t$) required if the market had full information about economic structure and disturbances.

The first definition reflects the conventional notion of overshooting as it is often reported in the press, such as "The Swiss franc is currently overvalued relative to any reasonable standard." The third definition rests on the idea that agents may have heterogeneous or incomplete information about the world, or be subject to severe trading constraints, thus leading them to place "unfair" prices on financial assets, i.e., a price that does not reflect all available information. This framework posits that the actual exchange rate oscillates about the value that would be achieved if prices reflected all available information. Our purpose here is to consider definition (2).

The second definition of overshooting draws a distinction between short-run and long-run equilibria while maintaining the notion that the exchange rate is priced fairly at all times, a perfect reflection of all information. Overshooting of this type might be viewed as the result of forcing a given amount of international adjustment through a limited number of channels, because other potential adjustment channels are assumed to operate slowly or not to exist. Dornbush (1976) elegantly formalizes a monetary model of the exchange rate in which consumer price adjust very slowly relatively to the speed of adjustment in the foreign exchange market (See Figure 7). Within this framework, an unanticipated change in the money supply leads to exchange rate overshooting because domestic consumer prices cannot move immediately to reflect the money supply change. A similar overshooting result can be illustrated with a portfolio balance model. In this case, a desired accumulation of foreign currency denominated asset proceeds slowly through cumulative current account surpluses. As this slow process evolves, the foreign exchange rate overshoots to establish equilibrium in this market.[30]

3.5.2 Empirical Evidence. The only direct test of the Dornbusch model of overshooting is by Driskill (1981) who analyzes the $/Swiss franc rate over the 1973-1979 period. Using regression analysis, Driskill reports that the elasticity of the exchange rate in response to an unanticipated monetary disturbance exceeds unity, i.e. overshooting is confirmed. For a one-unit monetary innovation, the exchange rate response is 2.30. However, contrary to theory, the empirical exchange rate adjustment path is non-monotonic.

Based on a vector-autoregression analysis, Bilson (1982) concludes that exchange rates and domestic interest rates exhibit significant negative contemporaneous correlation, as the Dornbusch model predicts. A final study by Melhem (1982) reports that short-term forward rates are more volatile than long-term forward rates. This is consistent with Figure 3 and the notion that forward rates reflect the future spot rate. Therefore, the empirical evidence to date seems to be consistent with overshooting, even though by other measures (recall Table 1) exchange rate volatility may not be excessive.

3.6 The Asset Approach and the Role of News

3.6.1 Overview. The monetary and portfolio balance approaches reviewed above suggest that the demand for currency depends on its qualities as a durable asset. If a currency is expected to continue offering services as a medium of exchange (i.e. transaction services) and as a store of value and unit of account (i.e. the choice for denominating portfolio wealth), then the currency will continue to be demanded. One property of financial assets that we associate with stocks and bonds is that their prices are forward looking, depending on future discounted cash flows. The same forward looking property is true of exchange rate pricing and that may be helpful in forecasting.

Refer to equation (19.12) and note the interest rate differential term, $(i-i^*)$. Assuming covered interest parity, $(i-i^*) = f_t - s_t$. Assuming forward rates are set equal to expected future spot rates, $f=E(s_{t+1})$. With these assumptions, we can now write (19.12) as

$$s_t = z_t + \varepsilon[E(s_{t+1})-s_t], \qquad (19.18)$$

where $z_t = (m-m^*) + \eta(y^*-y) + (k^*-k)$.

if we collect terms, we have

$$s_t = \frac{1}{1+\varepsilon} Z_t + \varepsilon E(s_{t+1}). \qquad (19.19)$$

Expression (19.19) shows that the log of today's spot rate depends on today's economic variables (the Z_t) plus our expectation of the spot rate in the next period. But from (19.18), we can see that $E(s_{t+1})$ will depend on $E(s_{t+2})$. And $E(s_{t+2})$ will depend on $E(s_{t+3})$, etc. By this process of forward iteration, we can show that,

$$s_t = \frac{1}{1+\varepsilon} \sum_{k=o}^{\infty} (\frac{\varepsilon}{1+\varepsilon})^k E(z_{t+k}). \qquad (19.20)$$

In other words, the current spot rate depends on our current expectation of all important driving variables (the z's), from now into the indefinite future.[31] The analogy of a security whose current price represents the discounted value of all future cash flows should be clear.

To put expression (19.20) as simply as possible, the current exchange rate reflects what is known or expected about the future. Without a model for the z's, this relationship is not useful for forecasting. However, the other implication of (19.20) is that exchange rates change only in response to unanticipated events. This brings us to the role of news.

3.6.2 Empirical Evidence The implication of the asset market approach is that deviations between the forward rate (which, for now, we take as a proxy for the expected future spot rate) and the actual future spot rate are the result of news. In a regression format, we would write,

$$s_t = a + b\ f_{t-1} + \text{"news"} + w_t. \qquad (19.21)$$

Clearly, news could be modeled in a variety of ways.[32] Frenkel (1981) allows unanticipated changes in the term structure of interest rates to play the role of "news" and he finds a significant relationship in the context of (19.21). Dornbusch (1980) looks at news in terms of unanticipated current account balances, unanticipated cyclical income movements, as well as unanticipated interest rate changes. Again, the empirical, evidence in Table 4 confirms that unanticipated changes in these important variables are significantly related to forward rate forecasting errors. This is especially dramatic since, as Figure 5 suggests, forward rate errors tend to be large and serially uncorrelated.

The implication of these results is that analysts who can forecast one or two key variables better than the market as a whole may be able to outperform the forward rate forecast.

4. Tests of Foreign Exchange Market Efficiency[33]

Market efficiency is a major theme that has motivated numerous empirical studies of international financial markets. Tests of asset market efficiency, focusing on domestic equity and bond markets, began in the 1950s and gained increasing popularity and significance during the 1960s. With the establishment of floating exchange rates in the early 1970s (presumably dominated by free-market behavior), it was natural to begin the investigation of foreign exchange market efficiency. We will point out that some early studies relied too heavily on stock market techniques, and therefore they were not testing appropriate hypotheses. However, we will also argue that, by their nature, efficiency tests are difficult to formulate and subject to ambiguous interpretations. The reason for this, as we will explain in detail, is that efficiency tests implicitly require a joint null hypothesis.

4.1 The Efficient Market Hypothesis

The classic definition of an efficient market is a market where prices "fully reflect" available information.[34]

When this condition is satisfied, it follows that investors cannot earn an unusual profit by exploiting available information. The macroeconomic importance of market efficiency is derived from the role of prices as aggregators of structural information. When asset and commodity markets are efficient (in the above sense of reflecting information), economic agents who make decisions on the basis of observed prices will insure an efficient allocation of resources.

But the previous definition is too general to be tested empirically. We must posit a precise meaning for the term "fully reflect." Typically, this has been accomplished by assuming that market equilibrium can be stated in terms of equilibrium prices or equilibrium expected returns. If we choose the latter, then the excess market return on asset j is given by

$$z_{j,t+1} = r_{j,t+1} - E(\tilde{r}_{j,t+1} | \Phi_t), \qquad (19.22)$$

where $r_{j,t+1}$ is the one-period percentage return and Φ_t represents the information set that is assumed to be fully reflected in the price at time t. When the excess return sequence (z_{jt}) is a "fair game" with respect to the information sequence (Φ_t), the market is efficient.[35]

The critical point of this discussion is that all tests of market efficiency are testing a joint hypothesis--first, the hypothesis that defines market equilibrium prices or expected returns, and second, the hypothesis that economic agents can efficiently set actual prices or returns to conform to their expected values.[36]

For studies that reject this simultaneous test, it is impossible to determine whether an incorrect specification of equilibrium expected returns is responsible for the rejection or whether, in fact, investors were inefficient information processors. And for studies that cannot reject market efficiency, it can be argued that the wrong equilibrium expected-return process was assumed. Relative to the "correct" standard, the market is really inefficient and unusual profit opportunities are available.

To illustrate the importance of this result for empirical testing, consider Figures 8 and 9. In Figure 8 the equilibrium expected return is assumed to be constant at r_0. If actual returns vibrate randomly about r_0, the market is efficient. In this case, prices follow a random walk with drift parameter r_0.

A case where the equilibrium expected return is assumed to wander considerably is illustrated in Figure 9. If actual returns vibrate randomly about the equilibrium, the market is efficient. In this case, equilibrium expected returns and prices are highly serially correlated about their mean values and therefore, do not follow a random walk. But actual returns vibrate randomly around this equilibrium, so expected excess returns are zero and the market is therefore efficient.

Conditional on a constant equilibrium expected rate of return, random price movement suggests market efficiency. But random price movement per se is neither a necessary nor sufficient condition for market efficiency. If the expected equilibrium return varies considerably, market efficiency requires nonrandom walk price movements. It seems obvious that, because of underlying policies, both the level and the rate of change in currency prices might wander considerably. Furthermore, because uncertainty associated with these underlying policies might change, the equilibrium real return from investments in a particular currency might also vary over time.

The early random walk studies in equity markets did not sufficiently recognize this point. However, in equity markets several equilibrium return processes could be assumed and tested. First, we could assume that expected returns on equities are positive in every period, based on the assumption that utility maximizing, risk-averse investors would not willingly accept nondiversifiable equity risk without expecting a positive return. Second, we could assume that expected returns on equities are constant. Fama (1970) suggests that this assumption is plausible for equities, since over the typical differencing interval (one month or less) variation in equilibrium expected returns is small relative to other sources of variation in returns. Third, we could assume that expected returns on equities are generated by a market model or a specific capital asset pricing model.[37]

Since there is probably a considerable consensus across academics and financial practitioners that the equilibrium expected return for equities is positive (and perhaps fairly constant), the empirical studies provide considerable evidence in favor of equity market efficiency.

However, a convincing empirical test of efficiency in the foreign exchange market is made difficult because there is no general agreement on models for equilibrium pricing or equilibrium rates of return which is comparable to that for equity markets.[38]

Simply put, it is difficult to test whether investors efficiently set the actual spot exchange equal to its equilibrium value, unless there is some agreement on what the equilibrium value is. Similarly, it is difficult to test whether risk-bearing is efficiently compensated if there is no agreement on the fundamental nature of foreign exchange risk, no adequate measure of foreign exchange risk, and no model that determines the equilibrium fair return for bearing foreign exchange risk.

Equity markets and foreign exchange markets differ in another important respect. Firms might be characterized by their consistency -- in terms of directors, product lines, financial strategy, customers, etc. This suggests that for firms operating in a stable environment with mature products, investors might be able to learn the risk/return properties of these securities. However, in the foreign exchange market, our confidence that underlying economic policies will be maintained is considerably less. The operation of monetary and fiscal policy is subject to sharp changes, perhaps because personnel in the Executive branch, the Congress, or the Federal Reserve are replaced, or simply because existing personnel change their policies. Furthermore, under a managed floating system, the government may enter the market in a non-profit-maximizing and nonstationary manner. Therefore, it seems likely that the equilibrium path of exchange rates might wander considerably and that a model of equilibrium pricing of foreign exchange ought to include a role for government.[39]

To summarize, the efficient market hypothesis requires a simultaneous test of two hypotheses. A number of plausible alternative models for equilibrium pricing or returns have been incorporated into efficient market tests for equities. However, in the case of foreign exchange there is no firm agreement on a model of equilibrium prices or returns, and still less agreement on the stationarity of any model over time, especially in the presence of erratic macroeconomic policies or government intervention. It is therefore not yet possible to either prove or disprove the efficiency hypothesis in the foreign exchange market.

4.2 Empirical Evidence--Certainty and Risk-Free Investment

In the foreign exchange market, arbitrage is an elementary investment opportunity that promises a certain return with no increase in exposure to exchange risk.[40] In an efficient market, prices of foreign exchange and interest-bearing assets should be set so that "unusual profits" from arbitrage are quickly eliminated. Since arbitrage is essentially risk-free and can be completed in a matter of seconds, any profit in excess of transaction costs is unusual. In arbitrage, the equilibrium expected return is zero.

4.2.1 Currency Arbitrage. The dispersion of quotations on individual currencies across market makers is reduced by spatial arbitrage. Some price dispersion is consistent with market efficiency since there is a cost of searching for spatial arbitrage profits and some risk associated with exploiting them. In addition, however, price dispersion that reflects quotations of different "quality" will persist. These issues have not been studied rigorously on data from the foreign exchange market.[41]

Price differences between interbank forward rate quotations and futures contract of similar maturity on Chicago's International Monetary Market have been examined by Cornell and Reinganum (1981). While the futures contract and the forward contract are similar in many respects, the futures market convention of "marking-to-market" exposes the buyer to an interest rate risk as his funds are either deposited in or withdrawn from his margin account. Explicit margin requirements are not used with interbank forward contracts since only customers with prior credit approval are permitted to use the interbank market. Price differences, therefore, largely reflect differential risk.

A second profit opportunity in currency arbitrage is available through triangular arbitrage--the process which keeps cross-exchange rates (X_1/X_2) consistent with direct exchange rates ($\$/X_1$; $\$/X_2$) where X_1 and X_2 are arbitrary currencies. In most cases triangular parity, $\$/X_2 = \$/X_1 \cdot X_1/X_2$, holds by construction; traders use the formula to prepare quotations. For example, the Swiss franc/Mexican peso rate is simply the product of the \$/peso, franc/\$ rates. This reflects the fact that an independent franc/peso market does not exist and traders use the U.S. dollar as a vehicle currency. However, in the 1960s, independent quotations for £ were offered and in the 1970s, independent DM/£ and DM/Yen markets developed. Triangular arbitrage, or the threat of it, is necessary to keep independent markets (at parity). In this case, empirical studies (Frenkel and Levich 1975, 1977 and McCormick, 1979) have interpreted the upper limit of deviations from triangular parity as a measure of currency transaction costs.

4.2.2 Interest Rate Parity and Covered Interest Arbitrage. One of the key building blocks for open economy macroeconomics is the interest rate parity theory which states that the forward premium and the interest differential are equal so that

$$\frac{F-S}{S} = \frac{i-i^*}{1+i^*} \qquad (19.23)$$

When (19.23) holds, covered arbitrage profit opportunities are fully exploited. Numerous studies measure departures from interest rate parity (see Officer and Willett, 1970 for a survey). A variety of explanations were offered--less than infinite elasticities for foreign exchange and securities, transaction costs, non-comparable risk in securities, exchange controls (political risk) and taxes. Research suggests that all of these factors may play a role in explaining deviations from IRPT. We proceed by raising a methodological issue.

Two natural ways to test (19.23) would be (a) to regress the forward premium against the interest rate differential, expecting a 45° line, or (b) to calculate the deviations between the forward premium and the interest rate differential, expecting the mean deviation to be near zero. Frenkel and Levich (1975) argue that these procedures draw an incorrect inference when individual deviations are large but on average zero or when deviations are very small, but on average non-zero. The essence of market efficiency in these examples relies on the ability of investors to police an arbitrage boundary condition in every single period and not in some average sense. A calculation of the percentage of times that covered arbitrage does not produce a profit allows us to make a direct inference about market efficiency. The higher this percentage, the greater the market efficiency.

Perhaps the most satisfactory studies of interest rate parity are those that analyze covered arbitrage opportunities between Eurocurrency assets. Since Eurocurrency deposits can be comparable in terms of issuer, credit risk, maturity and all other respects <u>except</u> currency of denomination, they offer a proper test of IRPT. Studies by Clendenning (1970), Aliber (1973), Frenkel and Levich (1975, 1977) and others confirm that deviations from interest rate parity in the Eurocurrency markets are small and that a very high percentage of deviations are smaller than transaction costs. Therefore, the Eurocurrency market is efficient in that few opportunities for risk-free arbitrage exist.[42]

It is now well-understood (Deardorff 1979, Levich 1981d) that bank traders <u>use</u> the interest rate parity theory to set forward rates. Traders observe a spot rate (S) and a swap rate (cost of a simultaneous borrowing and lending of Eurocurrency deposits in two currencies, $(1+i)/(1+i^*)$, and use this data to <u>construct</u> a forward rate $F = S(1+i)/(1+i^*)$. The trader <u>must</u> follow interest rate parity or else the customer will exploit the cheaper technique for establishing his forward position. The implication is that arbitrage profit opportunitie should never exist in a single trading room, but they could exist using independent quotations on F, S, i, and i* in a dispersed market. Tests based on time-synchronous data from independent sources have not been reported.

A related issue that deserves further attention is deviations from interest rate parity for long-term securities. Hilley, Beidleman, and Greenleaf (1981) report that rates quoted by banks for 3-5 year forward contracts may be significantly worse than rates a customer might obtain by building his own forward position using a spot contract combined with long-term Eurocurrency borrowing and lending. The authors conclude that banks are playing more of a brokerage role and that the opportunity for a small arbitrage profit does not compensate them for the costs of keeping capital tied up for 3-5 years, for the adverse impact on balance sheet ratios, and for (possibly) substantial credit risks. Their finding and interpretation breathes new life into the old elasticities explanation for deviations from IRPT. (see below)

The results for covered arbitrage between domestic or onshore assets are ambiguous. Frenkel and Levich (1975, 1977) and Levich (1979a) report that a much smaller fraction of observations are bounded within the neutral band when arbitrage is between treasury bills or commercial paper traded in different domestic markets. This apparent departure from market efficiency is more pronounced during turbulent periods on the foreign exchange market.

One avenue to explain the failure of interest parity between onshore markets is the role of price elasticities in currency and security markets. Frenkel and Levich (1975, 1977) report that all apparent deviations from IRPT are explained if price elasticities are finite but still large enough to be consistent with a competitive environment.

The second approach follows Aliber (1973) by noting that onshore markets differ in terms of political risk-i.e. the probability that the sovereign may interpose his or her authority between the investor and the market place.[43]

Dooley and Isard (1980) refine this concept by distinguishing between/ the cost of existing capital controls and the risk premium associated with prospective controls. Dooley and Isard analyze German interbank and Eurocurrency interest rates over the period 1970-1974. They conclude that most of the interbank-offshore interest rate differential over this period can be explained by the effective tax imposed by a sequence of known capital controls. However, they estimate that as much as 2% per annum may have been required to induce non-German residents to hold German outside debt in the face of potential capital controls.

Differential tax rates on capital gains and ordinary income are another facet of covered arbitrage flows. Levi (1977) demonstrates that when forward contract gains are taxed at the capital gains rate (t_k) and interest rate gains are taxed as ordinary income ($t_y > t_k$), then the slope of the after-tax IRPT line is $(1-t_y)/(1-t_k)$ which is less than the 45° slope of the pre-tax IRPT line. When taxes are included, the normal incentives to exploit pre-tax arbitrage profits are changed considerably. Levi's model suggests that, ignoring transaction costs, elasticities, etc., a market which is efficient on a pre-tax basis, will not be efficient on an after-tax basis, and vice-versa. No empirical study has fully considered the role of taxes in the IRPT model.

4.3 Empirical Evidence--Uncertainty and Risky Investments

Introducing uncertainty into single period and multiperiod investment models adds a degree of complexity, as well as realism, to tests of foreign exchange market efficiency. When the future spot exchange rate is a random variable, the dollar value of assets denominated in a foreign currency is uncertain. In this case, an investor who holds a net (asset or liability) position in foreign currency is exposed to foreign exchange risk.[44]

In an efficient market, prices (of spot and forward exchange, for example) should be set so that "unusual profits" from risky investment opportunities are quickly eliminated. Since a test of market efficiency tests a joint hypothesis, the specification of the expected equilibrium return for bearing foreign exchange risk is critical. We must have some standard to judge that profits from bearing foreign exchange risk are "unusual".

There are basically two techniques for bearing foreign exchange risk--spot speculation and forward speculation. In spot speculation, the investor borrows domestic currency (at interest rate, i), buys foreign exchange in the spot market (at the rate S_t) and invests in a foreign currency denominated asset (with expected return, i*). A forward speculator can establish a similar long position by simply buying foreign exchange in the forward market (at the rate, F_t). In either case, the profit depends on the future spot exchange rate, $\tilde{S}_{t+1}$, which is uncertain. It is easily shown that when the interest rate parity theorem holds, spot and forward speculation are equivalent investments in that they lead to the same time series of expected profits.

4.3.1 Spot Market Efficiency. Only two approaches have been proposed to examine spot market efficiency. One popular null hypothesis was that, under a regime of freely floating exchange rates, changes in spot exchange rates should be serially uncorrelated. Empirical tests of this hypothesis were reported by Poole (1967) and Burt, Kaen and Booth (1977). In general, this research concluded that there are significant departures from random behavior under floating exchange rates and therefore, the spot market was not efficient. However, as we suggested earlier, market efficiency requires a random behavior of returns only if the equilibrium expected return is constant. Therefore, only in the case where interest rates in the two countries differ by a constant and the equilibrium expected exchange rate follows a linear trend (equal to the constant) should we expect that exchange rates follow a random walk (with a drift factor equal to the constant). By contrast, if the fundamental determinants of exchange rates are serially correlated, then equilibrium exchange rates will be serially correlated also.[45]

A second test of market efficiency in spot speculation has analyzed the performance of investment strategies that use a <u>filter rule</u> as a guide for picking speculative positions. A filter rule is a mathematical rule that can be applied mechanically to produce buy signals and sell signals. An <u>x</u> percent filter rule leads to the following trading strategy: "Buy a currency whenever it rises <u>x</u> percent above its most recent trough; sell the currency and take a short position whenever the currency falls <u>x</u> percent below its most recent peak." A filter rule produces profits when momentum or "bandwagon" effects carry the currency further in the direction indicate by the initial trend. However, the null hypothesis of efficiency suggests that Euro-currency traders should also recognize the expected momentum in the exchange market. As a result, Euro-currency traders would set relatively low interest rates on the appreciating currency and high interest rates on the depreciating currency that tend to offset the anticipated exchange rate change. This summarizes the efficient market process--Euro-deposit interest rate differentials should exactly offset the expected exchange rate change, so there are no expected profits from the filter rule strategy.

An early study by Poole (1967) reports filter rule profits for the Canadian dollar during the floating rate period, 1950-62, and for nine other series of flexible exchange rates in the post-World War I period. Poole finds evidence of statistically significant first-order serial correlation in exchange rate changes. As a result, filter rule strategies tend to make large profits relative to a buy-and-hold strategy. Profits are not adjusted for the interest expense of a short position, the interest income of a long position, or the cost of transacting. Because of the last factor, Poole believes his results do not conclusively reject market efficiency.[46]

More comprehensive and rigorous studies of spot market efficiency have been conducted by Dooley and Shafer (1976, 1982). Dooley and Shafer report filter rule profits for nine currencies using daily spot rates over the 1970s floating rate period. The authors' calculations are adjusted to reflect the interest expense and income of short and long positions, and transaction costs are incorporated by using bid and asked foreign exchange quotations. Dooley and Shafer hypothesize that if the market is efficient, then filter rule profits, adjusted to reflect the above costs, should be a "fair game" (or martingale) process as in (19.22). Any gross profits from the filter rule strategies imply net, abnormal profits and therefore reject market efficiency.

Dooley and Shafer's results indicate that small filters ($\underline{x}$ = 1, 3 or 5 percent) would have been profitable for all currencies over the entire sample period. However, there appears to be some element of riskiness in these trading rules, since each filter would have generated losses in at least one currency during at least one subperiod. Furthermore, it is not clear that ex ante the size of the filter can be determined that optimizes or assures profits. Finally, because the filter rule actively switches the investor between currencies, the investor faces greater risk (i.e. loss of time diversification) than if he passively held a portfolio with both currencies.

Since filter rule trading involves risk, the key question is whether unusual profit opportunities are available to spot speculators ex ante. Levich (1979b) suggests performance tests based on a mean-variance model, but these raise further problems concerning the appropriate market portfolio and risk measure.

A recent paper by Goodman (1981) examines the performance of professional foreign exchange advisors that issue buy and sell signals based on technical analysis. Goodman reports that large profits in excess of the risk-free rate are generally available to users of these professional signals. There are also risks; the largest individual loss on one buy/sell signal was 2.4 times the average initial 5% margin and the largest stream of losses was 2.9 times the initial margin. Goodman suggests that these risks are small for large investors with the capital to withstand intermittent losses and who use professional signals on a regular basis. To further bolster this case, Goodman reports that if investors use a composite signal based on two or more advisors, the risk/return trade-off improves.

4.3.2. Forward Market Efficiency. Tests of forward market efficiency have focussed on the relationship between the current n-period forward rate ($F_{t,n}$), the expected future spot rate ($E(\tilde{S}_{t+n})$), and the actual future spot rate (S_{t+n}). Market efficiency requires that market agents are able to process available information and form rational expectations (i.e. $E(\tilde{S}_{t+n})=S_{t+n}$). However, market efficiency allows for the possibility that investors may demand a risk premium on forward contracts: Therefore, market efficiency does not require that $F_{t,n}=E(\tilde{S}_{t+n})$. As a result, the relationship between the current forward rate ($F_{t,n}$) and the actual future spot rate (S_{t+n}) is ambiguous, even in an efficient market.

To restate these points, what we might call the simple efficiency hypothesis is that

$$F_{t,n}=E(\tilde{S}_{t+n}) \text{ and } E(\tilde{S}_{t+n})=S_{t+n}.$$

If this hypothesis is true, then deviations between $F_{t,n}$ and S_{t+n} should have mean zero and zero serial correlation. In a regression of the form

$$S_{t+n}=a + b\, F_{t,n} + c\, X_t + e_t \qquad (19.24)$$

our null hypothesis, given simple efficiency, is that a=o, b=1 and the coefficient of any other variable, c=o. The residuals, e_t, should of course be free of serial correlation.

A more general efficiency hypothesis that allows for a risk premium (RP) would presume that:

$$F_{t,n}=E(\tilde{S}_{t+n}) + RP_{t,n} \text{ and } E(\tilde{S}_{t+n})=S_{t+n}$$

We can clearly see that in this case, the equality between $F_{t,n}$

and $E(\tilde{S}_{t+n})$ is broken. Regression equations such as (19.24) that reject the (a,b,c) = (0,1,0) hypothesis are subject to two interpretations.

(I) The simple efficiency hypothesis is rejected. The forward market is inefficient in reflecting exchange rate expectations. Expected profit opportunities through forward speculation exists.

(II) The general efficiency hypothesis cannot be rejected. A new forecast $S_{t+n}=a + bF_{t,n}+cX_t$ can be constructed which will be superior to the forward rate forecast. However, the profits we earn through forward speculation will only be the fair risk premium for the additional risk we incur.

Unfortunately, unless the variable X_t is a good proxy for risk (rather than lagged forecast errors or lagged forward rates) we are not on solid ground accepting interpretation II. And that is approximately where the frontier of research in this area stands today.

(i) Foreign Exchange Risk Premium. As we have argued, whether or not the forward rate is an unbiased forecast depends on underlying economic factors; it is not an inherent property of any economic system, even one which is in equilibrium and processes information efficiently.[47] The theoretical case for forward rates as biased forecasters of future spot rates depends heavily on the existance of a risk premium. The risk premium argument is critical because under a pure floating rate system with no government intervention, small transaction costs, and efficient information processing, only the risk premium argument survives to explain a forward rate bias. Consequently, there has been renewed research interest in this topic.

In the Modern Theory of foreign exchange (Grubel, 1966) investors are assumed to be risk-averse. The speculative demand for forward contracts is not infinitely elastic. Speculators will bear foreign exchange risk only if they are compensated with a risk premium. However, the determinants of the risk premium are not examined.

Portfolio models offer a natural framework for analyzing foreign exchange risk. In general, portfolio models assume that as investors, agents are free to purchase assets denominated in domestic and foreign currencies; the risk of individual assets may differ and returns are imperfectly correlated. As consumers, agents choose among goods whose prices are denominated in a particular currency and imperfectly correlated with prices expressed in other currencies (i.e. deviations from PPP). Exchange risk arises because the unit of account of an agents' cash inflows is imperfectly correlated with the unit of account of the agents' cash outflows.[48]

In a portfolio model, agents will hold assets denominated in foreign currency when the return is sufficient to compensate for the extra risk now associated with consuming domestic goods.

Models described in Frankel (1979a) and Dornbusch (1982) suggest that the risk premium is a function of the relative supply of outside assets denominated in the two currencies. Fama and Farber (1979) emphasize the quality of money balances. In a PPP framework subject to uncertainty, agents will prefer the currency with lower inflation variance and less exposure to purchasing power risks. The portfolio framework suggests the exchange risk premia are correlated with greater monetary discipline, fewer debt-financed government expenditure and perhaps less exposure to real disturbances. This suggests a risk premium which could change signs over the short-run.[49]

Another model by Solnik (1973)

relates the foreign exchange risk premium to relative international investment positions. For example U.S. investors may hold a net asset position in U.K. assets (i.e., U.S. investors own more U.K. assets than U.K. investors own of U.S. assets). If U.S. investors are risk averse, they may wish to hedge the returns on their investment consistently—even at forward rates less favorable than the expected future spot rate.[50]

(ii) Empirical Evidence. Early studies examined the level of spot rates and lagged forward rates using (19.24) or simply calculating mean errors. These studies on exchange rates from the 1920s (Frenkel 1976, 1978, 1980), the Bretton Woods system (Aliber 1974), and the first few years of managed floating (Bilson 1976, Cornell 1977, Levich 1979b, Stockman 1978) could not reject the simple efficiency hypothesis.

Later studies by Tryon (1979) and Levich (1980) reported that the percentage change version of (19.24),

$$\ln(S_{t+n}/S_t) = a + b \cdot \ln(F_{t,n}/S_t) + c \cdot \ln(X_t) + e_t \qquad (19.25)$$

performed very poorly. Figure 5 illustrates that the forward premium is a relatively quiet series that explains very little of actual exchange rate changes.

A potential problem concerning equations (19.24) and (19.25) is the shortage of independent observations.[51] Since there are only four non-overlapping three-month periods per year, there are only four independent observations on three-month contracts per year; fewer independent observations still on longer term contracts. This shortgage of observations is regretable. But if we also assume there may be a time-varying exchange risk premium or heteroscedastic errors because of erratic government intervention, estimation is nearly hopeless with only nine years of floating rate data.

Two studies by Hansen and Hodrick (1980) and Hsieh (1982) solve the data shortage problem by a new generalized least squares estimation procedure. The technique allows the authors to use daily observations and increase the sample size by a factor of 20. Both studies find that lagged variables play a role in explaining current forward rate forecast errors. Therefore, the authors reject the simple efficiency hypothesis.[52] The question remains whether this departure can be explained by a time varying risk premium, or whether the market is actually inefficient. Empirical studies by Meese and Singleton (1980) and Frankel (1982b) are not able to reject the hypothesis that a time-varying risk premium may be responsible for deviations between the forward rate and the future spot rate. However, Frankel admits that the tests probably have little statistical power.

The other avenue for testing the forward market is by comparison with forecasts of professional services. Levich (1980, 1981a, 1981b) reports that individual forecasting services do worse than the forward rate in terms of mean squared error. But the services exhibit significant expertise is predicting whether the spot rate will appreciate or depreciate relative to the forward rate--the key for corporate hedging strategies. Composite forecasts, weighted averages of individual forecasts, perform even better. This suggests further that professional forecasts can outperform the forward rates, but there is no evidence that these speculative profits are unusual in a risk adjusted sense.

Bilson (1981) uses a pooled time-series/cross-section technique to estimate a composite forecasting equation. In a post-sample period, the composite forecast significantly outperforms the forward rate and leads to positive profits.

4.4 Methodological Issues and Agenda

Empirical studies have clearly established the strong role that arbitrage plays in international financial markets. Certainly within the Euro-markets, it has been demonstrated that covered arbitrage profit opportunities are not available. Future research opportunities fall into two groups. At the micro-level, the extent of price dispersion across market-makers has not been investigated. Continuing advances in communications technology and internationalization of markets makes this a relevant topic. Increasing importance of the DM and Yen as independent currency markets may enhance possibilities for triangular arbitrage profits. The development of new financial instruments--currency futures and currency option contracts--further suggests that arbitrage profit opportunities between these financial instruments and the interbank market will have to be policed.

At the macro-level, interest arbitrage between assets that are somewhat different in terms of risk or tax treatment deserves further attention. Arbitrage between long-term securities (in the Euro-market), between onshore securities, and the role of capital gains/ordinary income taxes could benefit from more detailed empirical study.

In a general sense, the efficiency studies suggest that the major foreign exchange markets exhibit behavior that is characteristic of other asset markets. Exchange rates react quickly to news; rates are volatile and difficult to forecast. Both spot and forward rates can be modeled as anticipatory prices, but the exact parameters of the models are unknown.

At a more microscopic level, empirical tests of spot market and forward market efficiency have often been based on small samples using techniques with low statistical power. Nonetheless, these studies have succeeded in surrounding the simple efficiency hypothesis with substantial doubt. Rigorously tested academic models and performance studies of professional forecasters clearly demonstrate that speculative profit opportunities are available. Two questions are clear: Are these profits unusual in a risk-adjusted sense? Do existing portfolio theories adequately explain the time-varying risk premia in the market? What may seem like a short list is a very full agenda for future research.

Footnotes

1. Giddy (1979) has estimated that the daily worldwide volume of foreign exchange trading increased from $50 billion to nearly $200 billion over the 1970s. With 250 trading days per year, the latter figure suggests $50 trillion annual trading volume. Direct intervention by central bank is small relative to this volume. Other economic policies and announcements by government officials can have a major indirect effect on exchange markets.

2. The classic models here are generally attributed to Sharpe (1964), Lintner (1965), Mossin (1966) and Black (1972).

3. A detailed description of these institutional arrangements is presented in Kubarych (1978) and Levich (1981d).

4. The exact delivery conditions for forward contracts are important for tests of market efficiency as we shall see in section 3.

5. Hooper and Morton (1978) present detailed evidence on alternative multi-lateral exchange rates. In part, they concluded that "Any such aggregate measure is subject to problems due to incorrect measurement of prices, incorrect weighting system, and an inability to measure sectoral shifts in productivity. In addition, real exchange rate indexes are rough measures of price competitiveness only and do not measure important nonprice factors such as quality, dependabilitv, and servicing, which have an important influence on trade patterns but may change relatively slowly." (p.787)

6. The data in Figures 2 and 3 are from "World Financial Markets," Morgan Guaranty Trust Company which reports exchange rates as U.S. dollar per local currency. Consequently, values greater (less) than 100 indicate local currency appreciation (depreciation).

7. In principle, the real value of a currency could be computed using one of several price indexes. The real value of the U.S. dollar adjusted with export price indexes, wholesale price indexes, consumer price indexes, and unit labor cost indexes is reported in Hooper and Morton (1978).

8. Burt, <u>et</u>. <u>al.</u> (1977) comment that the purpose of their paper is "to test whether the price changes of the Canadian dollar, German Mark and British pound conform to those which would be expected in an efficient market (i.e. a weak random walk model)." (p. 1325).

9. Further details are provided in section 2 and chapter 18

10. The normal distribution is equivalent to the stable paretian distribution with α=2.0. The stable paretian distribution represents a family of unimodal distributions. With α<2.0, the stable paretian distribution is characterized by both (1) a greater probability of observations occurring in the tails of the distribution, <u>i.e.</u> "fat tails" and (2) a greater probability of observations in the intermediate ranges, <u>i.e.</u>"peakedness In this case, variance is not defined and not appropriate as a measure of risk.

11. With degrees of freedom d=∞, the student distribution is identical to the normal distribution. However, with d>2, the first two moments of the student distribution are known, which Rogalski and Vinso argue, make the student distribution a superior framework for developing international portfolio risk measures

12. Studies by Branson (1968), Kouri and Porter (1974) and Hodjera (1973) have investigated the determinants of international capital flows. See also Chapter 15 of this Handbook.

13. Pricing formulas for stock option and commodity option contracts include a measure of the variance of returns on the underlying asset. Models for currency option pricing remain to be more fully developed. See Feiger and Jacquillat (1979) and Hoag (1981).

14. The possibility of a "negative trading cost" is suggested in Black and Scholes (1974). An empirical test for stock market transactions is in Cuneo and Wagner (1975).

15. Foreign exchange market practitioners seldom acknowlege attempts to minimize transaction costs, arguing that a momentarv price swing can swamp the effect of lower transaction costs. However, one recent application of adversary theory is the so-called discretionary order. The U.S. treasurer places an order for Japanese yen with a U.S. bank, whose traders use their discretion to execute the order in the next 24 hours at the most favorable prices--probably within the Tokyo market. The discretionary order announces that the U.S. treasurer is both uninformed and willing to wait for best execution prices.

16. In section 3, I argue that exchange rate modeling and forecasting ought to be more difficult than stock price modeling.

17. Theories of exchange rate determination are developed in more detail in Chapter 14 of this Handbook. Other useful survey articles are by Isard (1978) and Dornbusch (1980).

18. Certain real disturbances such as a change in the traded goods/non-traded goods price ratio and commercial policies have been modeled within a monetary framework. See Frenkel (1981), Frenkel and Clements (1981) and footnote 23.

19. The DRI, Chase Econometric and Wharton simultaneous equation models utilize between 50 and 900 equations, depending on the company and the currency. Levich (1981b) analyzed the forecasting performance of these companies over the period 1977-1980 and reported that Wharton and DRI significantly outperformed the forward rate. However, they did not significantly outperform other single equation or judgemental forecasters. Further information on the Federal Reserve's multi-country model is in Hernández-Catá, et. al. (1978).

20. The term "purchasing power parity" is associated with Gustav Cassel who studied alternative approaches for selecting official exchange rates at the end of World War I and the resumption of international trade. As Frenkel (1978) has pointed out, the intellectual origins or purchasing power parity can be traced to the early 19th century and the writings of Wheatley and Ricardo. For a recent overview and critique of theory and evidence on purchasing power parity see Katseli-Papaefstratiou (1979).

21. McKinnon (1979, Chapter 6) discusses the sufficient conditions for absolute PPP to hold.

22. It should be clear that when relative PPP holds, the real exchange rate is constant, and the relative competitiveness of countries in foreign markets is unchanged.

23. To account for traded and non-traded goods, assume that the aggregate price level is a Cobb-Douglas function of the prices of traded goods, P_t, and non-traded goods, P_n, so that

$$P = P_n^{\alpha} P_t^{1-\alpha}$$

$$P^* = P_n^{*\alpha^*} P_t^{*1-\alpha^*}$$

where α and α^* are the domestic and foreign expenditure shares on non-traded goods. Now assume that PPP applies only to traded goods (so that $S=P_t/P_t^*$) and re-apply equations (19.4) and (19.5).

24. Again, if PPP applies only to traded goods, as in footnote 22, then equation (19.12) contains terms that capture the relative price of traded to non-traded goods. For an extensive and detailed study of international prices of traded and nontraded goods, see Kravis, et.al (1975).

25. By definition, the professional currency forecasters reviewed in section 5 are analyzed in a post-sample period.

26. Dornbusch (1982) and Kouri (1982) develop models that add risk and portfolio optimizing behavior to the basic asset approach. See also Chapter 15 of this <u>Handbook.</u>

27. Alternative theoretical formulations are presented in Girton and Roper (1976) and Calvo and Rodriguez (1977).

28. The notation follows Branson, Halttunen and Masson (1977).

29. These theoretical relationships are developed in more detail in Branson (1977), Dornbusch (1982), Fama and Farber (1979), and Kouri (1976). See also Chapter 15 of this Handbook.

30. It seems intuitively clear that the more channels that exist and are free to operate, the less likely we are to observe overshooting behavior in exchange rates. A recent paper by Frenkel and Rodriguez (1982) formalizes this idea. Specifically, they show that if prices are free to adjust somewhat (in the Dornbusch model) or if investors elect to spend some of their wealth on nontradable domestic goods (in the portfolio-balance model), then overshooting behavior need not occur.

31. The derivation and algebraic form of (19.20) is adapted from Mussa (1976).

32. See Genberg (9183) for an empirical study of the relationship between the innovations in spot rate and forward rate series.

33. Parts of this section rely heavily on earlier surveys by the author on this topic, see Levich (1978, 1979b).

34. This definition and the initial development of a formal theory of asset market efficiency is attributed to Fama (1970).

35. If the sequence (Z_{jt}) is a fair game, then $E(\tilde{Z}_{j,t+1} | \Phi_t) = 0$ and the Z_{jt} are serially uncorrelated. It follows that in an efficient market a few investors may occasionally make large gains or losses, but no group should make unusual gains or losses consistently.

36. It is interesting that Fama organizes his 1970 survey according to the information set (Φ_t), which is being fully reflected. Information sets are classified as containing only historical prices (that test weak form efficiency), public information (that tests semistrong form efficiency), or all information including insider information (that tests strong form efficiency). However, Fama (1976) organizes the literature based on the underlying assumption for the equilibrium expected return. He considers four alternative equilibrium expected return processes: returns are positive, returns are constant, returns are generated by a market model, returns conform to a specific two-parameter model. The latter survey is more effective in high-lighting the simultaneous nature of efficient market tests.

37. For a critical appraisal of empirical tests of asset-pricing models, see Roll (1977).

38. Once again, the reader is referred to Chapter 15 of this Handbook.

39. It is important to note that government intervention per se does not imply exchange market inefficiency. To the extent that the intervention policy is known, it should be reflected in the price of foreign exchange and in other financial markets. To the extent that intervention is unpredictable, the increased uncertainty may reduce the willingness of traders to take positions. This increase in uncertainty may reduce the liquidity of markets and widen the bid-ask spread, but this is not a market inefficiency in the sense of Fama (1970).

40. The issue of whether exposure to political risk increases will be considered shortly.

41. A stark example of price dispersion due to quality differences comes about from the Falkland Islands episode. Customers might require more favorable quotations on long-term forward contracts from affected British banks because there is a greater probability that these banks will default, vis-a-vis unaffected U.S. banks. For a detailed study of price dispersion in the U.S. Treasury bill market, see Garbade and Silber (1976).

42. For more on the institutional characteristics of the Eurocurrency markets and their impact on international financial relationships, see Dufey and Giddy (1978) and McKinnon (1979, chapter 9).

43. Interest parity holds in a single offshore center because the assets are exposed to the same political risks. Political risk is a fundamental argument behind the elasticity explanation for deviations from interest parity. Presumably, if there were no risks in arbitrage, the arbitrage supply schedule would be perfectly elastic. An alternative explanation for less than perfectly elastic arbitrage supply is that institutional constraints restrict the ability of banks to supply a sufficient number of forward contracts.

44. Political risk was discussed in the previous footnote. Aliber (1973) argues that arbitragers bear political risk, while speculators bear exchange risk. For a model that considers default risk on forward contracts, see Adler and Dumas (1976).

45. Other equilibrium exchange rate models that allow for overshooting will produce serially correlated exchange rate changes. See Chapters 14 and 18 of this <u>Handbook</u> and section 2 of this chapter.

46. As a theoretical matter, adjusting for interest expense and interest income is critical. It is analogous to the importance of divdidends in a filter rule analysis of equities. In the currency case, buying and holding Brazilian cruzerios (as paper currency) in the 1970s surely would have resulted in losses. The correct null hypothesis is that interest income on cruzerio assets just compensates for theexpected exchange rate changes. Studies by Logue, Sweeney and Willett (1977) and Sweeney (1982) have maintained, incorrectly in our view, that the relevant alternative to the trading rule... is holding the foreign currency. See Levich (1982) for further discussion.

47. Our special interest in unbiased forecasts is two-fold. First, if the forward rate is unbiased, then on average, it is an accurate predictor of the future spot rate; no transformation of the forward rate is required to construct a forecast. Second, if the forward rate is unbiased, then any strategy for hedging foreign exchange risk or for speculating in forward contracts has the same long-run expected profit, namely zero.

Our interest in unbiased forecasts should not be construed to mean that this is the only property that matters for evaluating forecasts. Standard econometric methodology assumes that users have a quadratic utility function so that investors desire lower average forecast errors and lower variance of forecast errors. In this setting, users choose the model that minimizes the mean squared forecasting error, even if it happens to be a biased forecast.

In summary then, if users are concerned about the variance, skewness, or other characteristics of the forecast error (in addition to the mean error) then the variance or skewness of the forecast error series may also be important for selecting a forecasting model. Notwithstanding the above discussion, forward rate forecasting bias remains a fundamental property to analyze, especially for investors who seek only to maximize their expected profits without regard to variability.

48. These risks are also present in a closed economy. For example, when agents' wages are in nominal currency units, and inflation is non-neutral, real consumption opportunities are uncertain. For more on exchange risk, see Wihlborg (1978).

49. This concept of an exchange risk premium is fully consistent with liquidty or inflation risk premiums in closed economy term structure theory. If both domestic rates (i) and foreign rates (i*) reflect liquidity and inflation premia, then via interest parity, $F=S\ (1+i)\ /(1+i^*)$, and the forward rate reflects these relative risk factors.

50. For example, assume there is a U.S. firm in London that plans to repatriate a £1 million dividend in ninety days when the exchange rate is expected to be $2.00/£. Unless there is a U.K. firm that wishes to repatriate $2 million from New York to London in ninety days, the U.S. firm must locate someone who currently is in portfolio balance, yet who may be induced to exchange British sterling for U.S. dollars in ninety days. The supplier of the forward dollars may demand compensation for altering his currency portfolio and the U.S. firm, assuming risk aversion, will be willing to pay it. In this case, the U.S. firm may sell its sterling at $1.98 even though it expects the price to be $2.00 in ninety days. The $.02 per pound sterling is the compensation paid to the supplier of forward dollars for altering his initial currency portfolio and taking on additional risk. This framework seems less likely to lead to a risk premium that changes from positive to negative in the short-run.

51. Similar to the "data shortage" problem is the problem of infrequent exchange rate changes in a pegged rate system. Krasker (1980) argues that when there is a small probability of an event that would lead to a large exchange rate change, the standard tests for market efficiency are not necessarily valid. Krasker develops an alternative test procedure that focuses directly on the probability of the unusual event rather than the standard asymptotic distribution theory. These issues were raised during the 1976 Mexican peso devaluation, hence the literature sometimes refers to this as the 'peso problem.'

52. Other studies that use different econometric techniques, but draw the same conclusion are by Cumby and Obstfeld (1981), Hakkio (1980) and Longworth (1981).

TABLE 1

Mean Absolute Percentage Changes in Prices and Exchange Rates

(Monthly Data: June 1973 - February 1979)

Country \ Variable	WPI	COL	Stock Market	Exchange Rate Against the Dollar	COL/COL US
U.S.	.009	.007	.038	-	-
U.K.	.014	.012	.066	.020	.007
France	.011	.008	.054	.020	.003
Germany	.004	.004	.031	.024	.004

Source: Frenkel and Mussa (1980).

TABLE 2

Equations Explaining the Monetary Approach to Exchange Rate Determination, Using the Dollar-Mark Exchange Rate, 1973:2–1979:4 and Subperiods[a]

Equation and sample period	*Independent variable*						*Summary statistic*			
	Constant	$(e + m^* - m)_{-1}$	$m - m^*$	$y - y^*$	$(i - i^*)_S$	$(i - i^*)_L$	R^2	*Durbin-Watson*	*Standard error of estimate*	*Rho*
2-1 1973:2–1979:4	5.76 (2.81)	...	−0.03 (−0.07)	−1.05 (−0.97)	0.01 (1.90)	0.04 (2.07)	0.33	1.83	0.05	0.88
2-2 1973:2–1978:1	4.82 (2.51)	...	1.00	−0.93 (−0.90)	−0.00 (−0.29)	0.07 (5.94)	0.66	1.69	0.04	0.06
2-3 1973:2–1979:4	4.63 (2.12)	...	1.00	−0.76 (−0.66)	0.01 (1.62)	0.04 (1.82)	0.08	1.80	0.05	0.99
2-4 1973:2–1979:4	0.23 (0.12)	0.83 (8.26)	1.00	0.16 (0.17)	0.01 (1.36)	0.01 (0.67)	0.88	1.85	0.05	...

Sources: Exchange rate—Board of Governors of the Federal Reserve System, *Federal Reserve Statistical Release*, G.5, "Foreign Exchange Rates," various issues; U.S. money supply—Board of Governors of the Federal Reserve System; German money supply—International Monetary Fund, *International Financial Statistics*, various issues, and Deutsche Bundesbank; real income—Organisation for Economic Co-operation and Development, *Main Economic Indicators*, various issues; and interest rates—Morgan Guaranty Trust Company of New York, *World Financial Markets*, various issues.

a. The equations were estimated using quarterly data. The independent variables are: e—logarithm of the dollar-mark exchange rate; m—logarithm of the money supply (M_1), seasonally adjusted; y—logarithm of gross national product at 1975 prices, seasonally adjusted at annual rates; i_S—yield on representative money-market instruments; and i_L—yield on domestic government bonds. An asterisk denotes a variable for Germany. The numbers in parentheses are t-statistics.

Source: Dornbusch (1980)

TABLE 3: Equations Explaining the Portfolio Balance Approach to Exchange Rate Determination, the $/DM Rate, Monthly Observations, August 1971-December 1976

Estimation Method	Constant	M1		Foreign Assets		RHO	$\bar{R}^2$	D.W.
		Germany	U.S.	Germany	U.S.			
OLS	-94.3 (6.0)	-0.1034 (6.1)	0.1434 (10.5)	0.2495 (1.1)	-0.2899 (1.8)	N.A.	0.826	0.410
Cochrane-Orcutt	-8.8 (0.2)	-0.0571 (1.6)	0.0889 (2.8)	0.4563 (1.3)	-0.2934 (1.6)	0.8639 (13.7)	0.938	1.333
2 SLS	-4.9 (0.1)	-0.0618 (1.7)	0.0922 (2.8)	0.6758 (1.7)	-0.3976 (1.9)	0.8676 (14.0)	0.937	1.349

Note: Spot exchange rate is in $/DM, as an index 1970 = 100; Money stock is in domestic currency; Assets are private foreign asset stock expressed in dollars; $\bar{R}^2$ is squared coefficient of multiple determination, adjusted for degrees of freedom; and RHO is first order serial correlation coefficient. t-ratios are in parentheses.

Source: Branson, Halttunen, and Masson (1977)

TABLE 4

Equations Explaining Unanticipated Depreciation of the Nominal Effective Exchange Rate of the Dollar, Second Half of 1973 through Second Half of 1979[a]

	Independent variable					Summary statistic			
Equation	*Constant*	*CAE*	*CYC*	*CYC**	*INN*	R^2	*Durbin-Watson*	*Standard error of estimate*	*Rho*
3-1	3.5 (1.88)	−0.49 (−2.62)	1.86 (1.35)	−1.86	...	0.41	2.13	6.2	...
3-2	2.7 (1.69)	−0.31 (−1.82)	0.47 (0.33)	−0.78 (0.57)	13.33 (1.99)	0.63	2.03	5.5	−0.24
3-3	3.1 (2.47)	−0.27 (−2.19)	...	...	13.79 (2.53)	0.61	2.13	5.1	−0.28

Sources: Forecast and actual current account balances and real output growth—Organisation for Economic Co-operation and Development, *OECD Economic Outlook*, various issues; exchange rate—same as table 1; and interest rates—same as table 2.

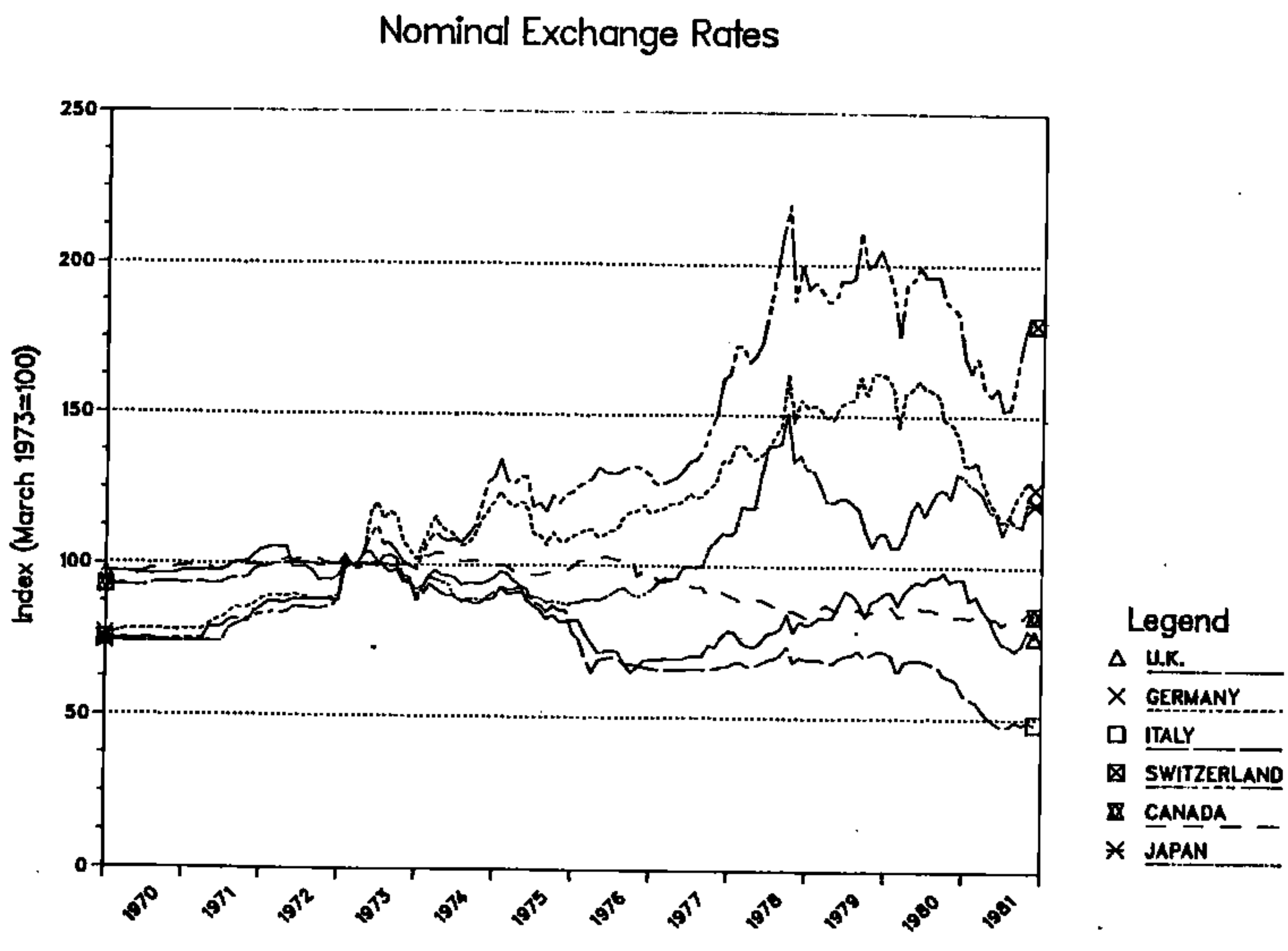
a. The dependent variable, unanticipated depreciation of the dollar, is described in figure 3, note a. *CYC* and *CYC** are unanticipated growth in real output of, respectively, the United States and a trade-weighted average of the five foreign countries in table 1. Unanticipated growth is the difference between the OECD's six-month forecast and realized growth. The data are seasonally adjusted annual rates of growth. *CAE* is the forecast error for U.S. current account balances, using the OECD's forecasts. The data are measured in billions of dollars, seasonally adjusted. *INN* denotes the residuals from an autoregression of short-term interest differentials between the United States and a trade-weighred average of five foreign countries. Trade-weighted variables use the weights in table 1, note a. The numbers in parentheses are *t*-statistics.

Source: Dornbusch (1980)

FIG-1

regular scale

Figure 1



Data Source: International Financial Statistics

FIG-2

regular sca

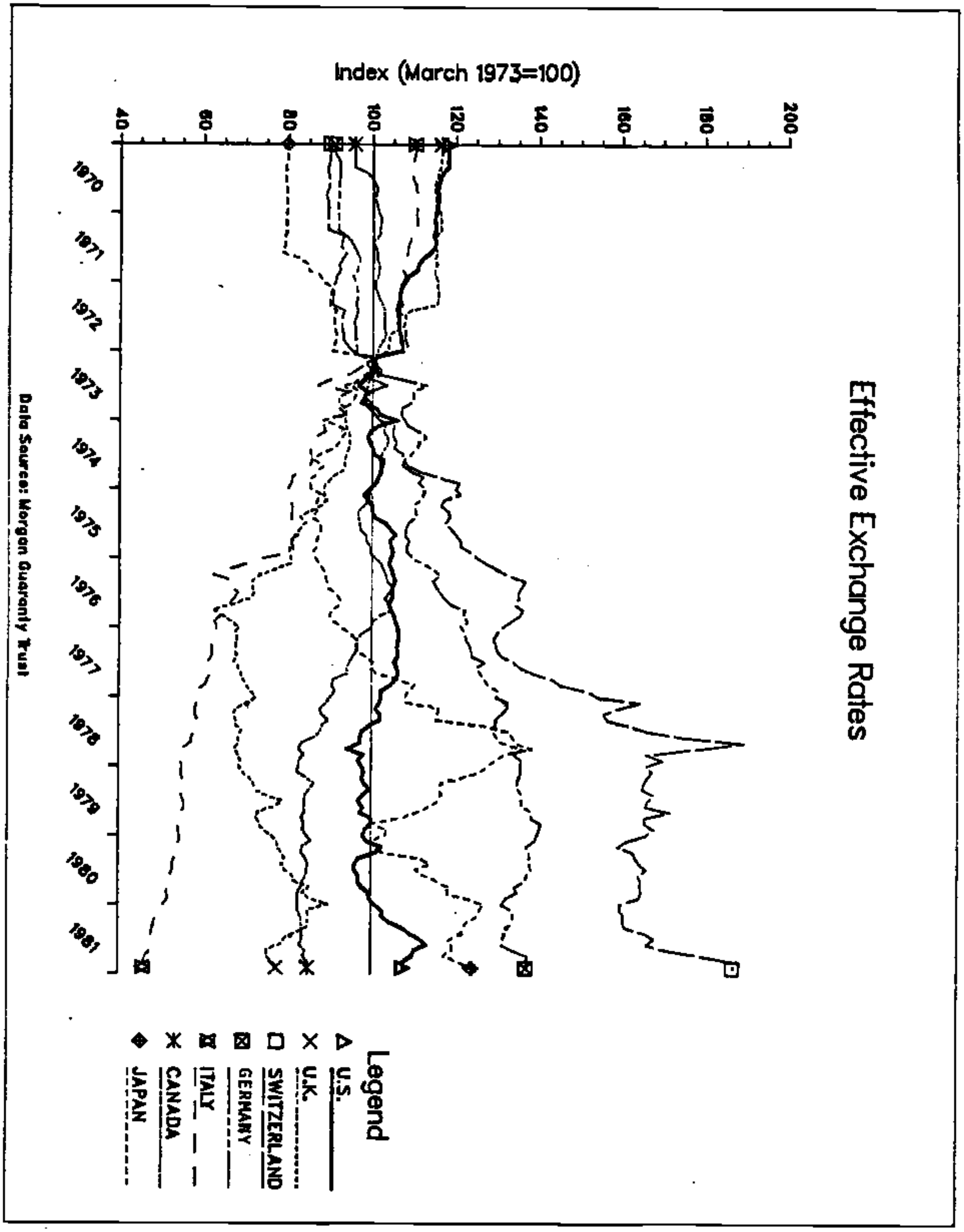
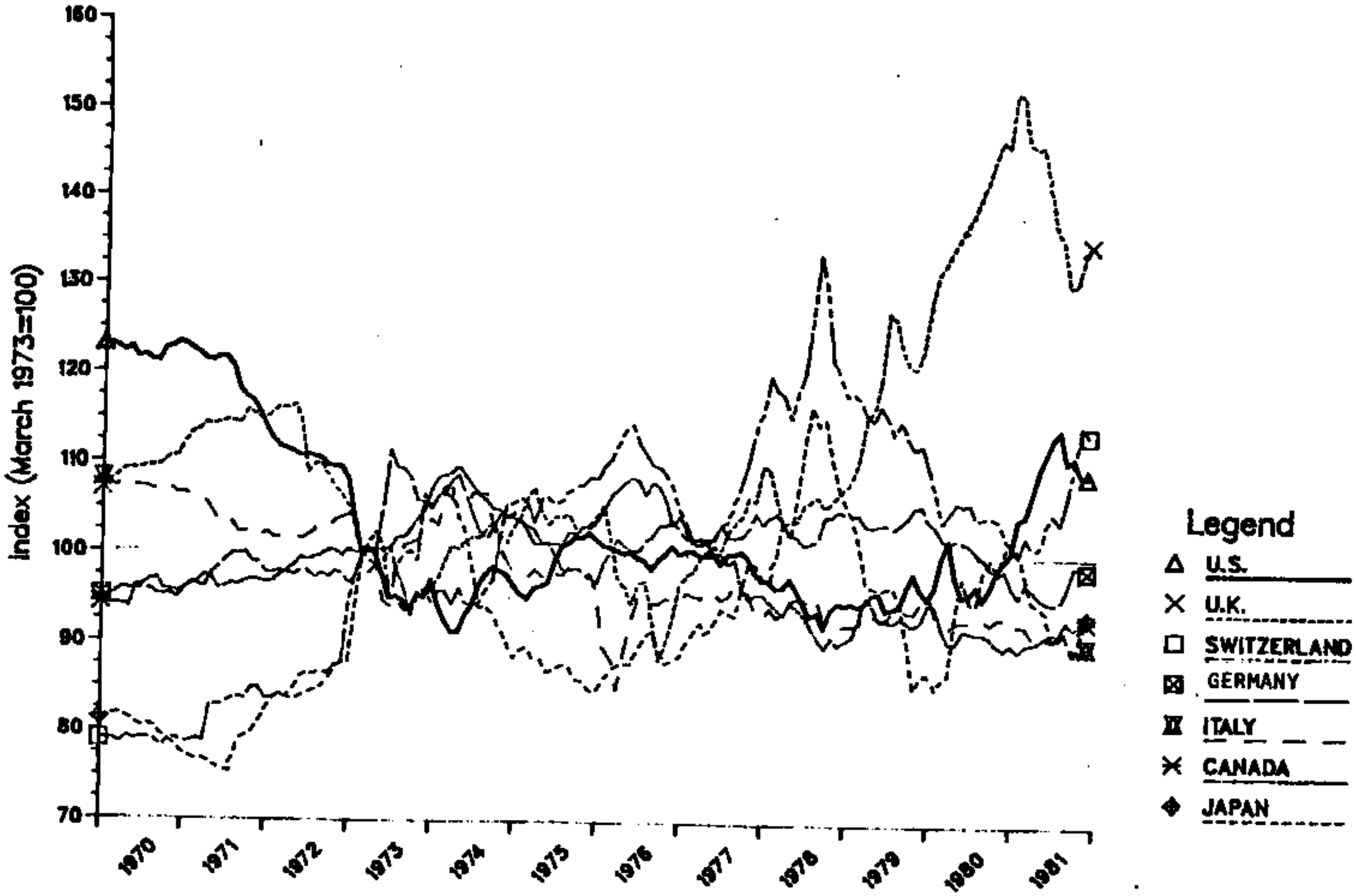


Figure 2

FIG-3
regular scale

Figure 3

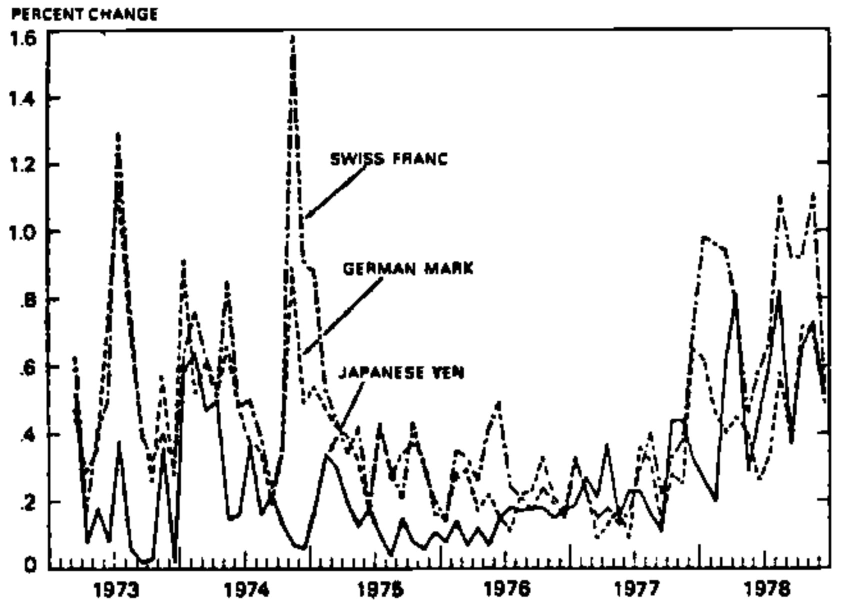
Real Effective Exchange Rates



Data Source: Morgan Guaranty Trust

FIGURE 4

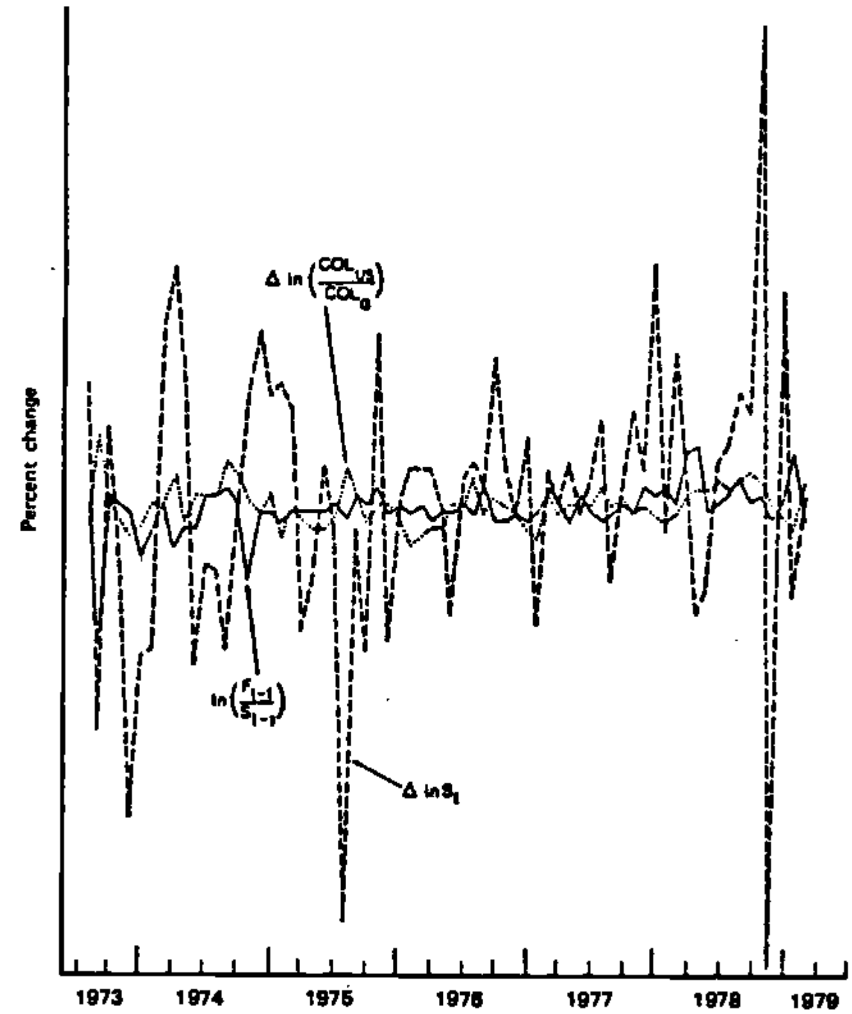
MONTHLY AVERAGE OF DAILY EXCHANGE RATES



Source: Economic Report of the President, January 1979, p. 153.

FIGURE 5

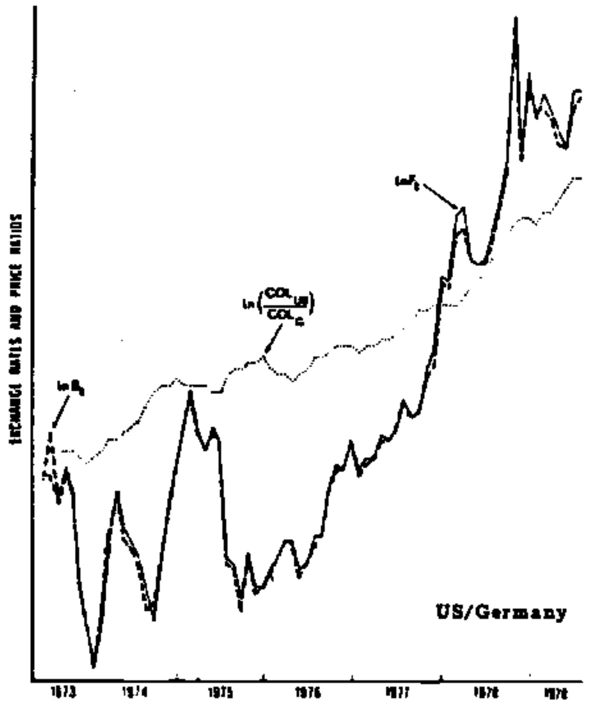
MONTHLY PERCENTAGE CHANGES OF THE U.S. AND GERMAN CONSUMER PRICE INDEXES (COL U.S. AND COL G, RESPECTIVELY), OF THE $/DM EXCHANGE RATE, AND THE MONTHLY FORWARD PREMIUM



Source: Frenkel and Mussa, "The Efficiency of Foreign Exchange Markets and Measures of Turbulence," *American Economic Review*, May 1980, p. 376.

FIGURE 6

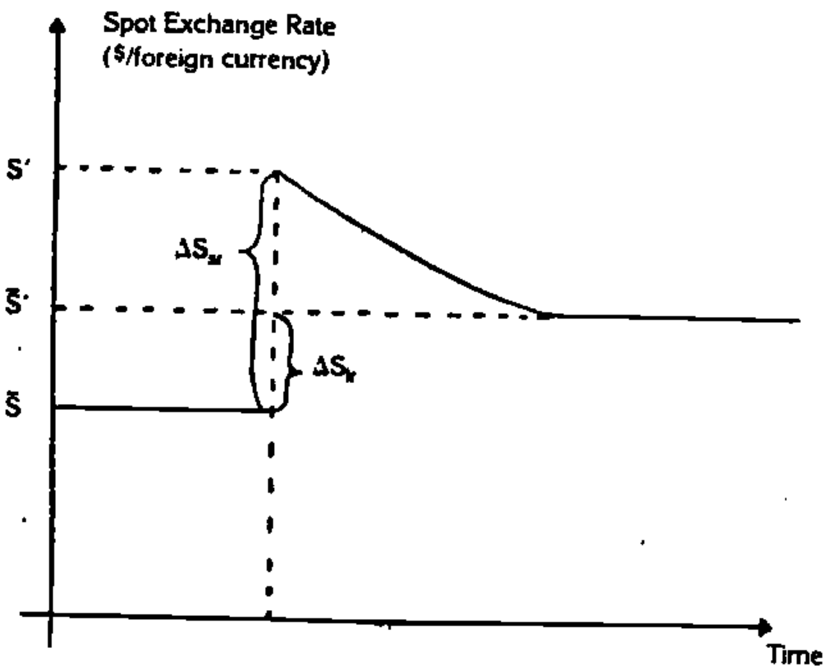
Consumer Price Ratios, the Spot Exchange Rate and Forward Premium, Monthly Observation, U.S./Germany, July 1973-February 19



Source: Frenkel (1981)

Figure 7

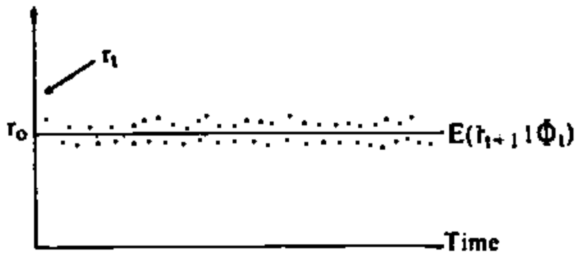
Exchange Rate Overshooting: Definition II



Source: Levich (1981c)

<u>FIGURE 8</u>:

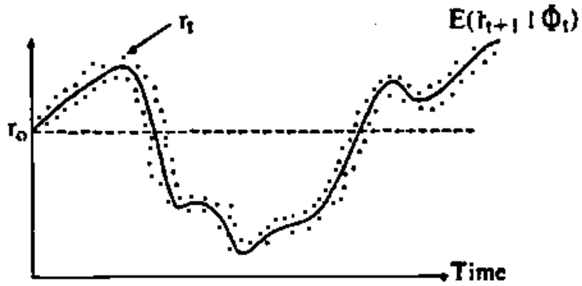
Source: Levich
(1979b)



Efficient Market Behavior with the Equilibrium Expected Return Constant.

<u>FIGURE 9</u>:

Source: Levich
(1979b)



Efficient Market Behavior Where the Equilibrium Expected Return Wanders Substantially.

REFERENCES

Adler, M. and Dumas, B. (1976), "Portfolio choice and the demand for forward exchange," American Economic Review, 66: 332-339.

Aliber, R. Z. (1973), "The interest rate parity theorem: a reinterpretation," Journal of Political Economy, 81: 1451-59.

Aliber, R. Z, (1974), "Attributes of national monies and the independence of national monetary policies," in R. Z. Aliber (ed). National monetary policies and the international system, (University of Chicago Press Chicago): 111-126.

Bagehot, W. (1971), "The only game in town," Financial Analysts Journal 27: No. 2, 12ff.

Bilson, J. F.O. (1976), "A monetary approach to the exchange rate," Unpublished Ph.D. dissertation, Unversity of Chicago.

Bilson, J. F.O. (1978a), "The monetary approach to the exchange rate: some empirical evidence, "Staff Papers 25: No. 1, 48-75.

Bilson, J. F.O. (1978b), "Rational expectations and the exchange rate," in J. Frenkel and H. Johnson (eds.), The economics of exchange rates (Addison-Wesley, Reading, Massachusetts).

Bilson, J. F.O. (1981), "The 'speculative efficiency' hypothesis," Journal of Business, 54: 435-51.

Bilson, J. F.O. (1982), "Exchange rate dynamics," Paper presented at NBER conference, Bellagio Italy.

Black F. (1972), "Capital market equilibrium with restricted borrowing," Journal of Business, 45: 444-45.

Black, F. and M. Scholes (1974), "From theory to a new financial product," Journal of Finance, 29: 399-412.

Brada, J., H. Ernest, and J. Van Tassel (1966), "The distribution of stock price differences: gaussian after all?" Operations Research, 14: 334-40.

Branson, W. H. (1968), Financial capital flows in the u.s. balance of payments (North Holland, Amsterdam).

Branson, W.H. (1977), "Asset markets and relative prices in exchange rate determination," Sozialwissenschaftliche Annalen, Vol. 1, 69-89.

Branson, W.H., H. Halttunenen and P. Masson (1977), "Exchange rates in the short run: the dollar deutschemark rate," European Economic Review, 10: 303-24.

Burt, John, R. Kaen and G. Booth (1977), "Foreign exchange market efficiency under flexible exchange rates," Journal of Finance, 32: 1325-30.

Calvo, G.A. and C. A. Rodriguez (1977), "A model of exchange rate determination with currency substitution and rational expectations," Journal of Political Economy, 85: 617-26.

Clendenning, E. W. (1970), The euro-dollar market (Clarendon Press: Oxford).

Cornell, B. (1977), "Spot rates, forward rates and exchange market efficiency," Journal of Financial Economics, 5: 55-65.

Cornell, B. and M. R. Reinganum (1981), "Forward and futures prices: evidence from the foreign exchange markets," Journal of Finance, 36: 1035-45.

Cumby, R. E. and M. Obstfeld (1981), "A note on exchange-rate expectations and nominal interest differentials: a test of the fisher hypothesis," Journal of Finance, 36: 697-703.

Cuneo, L. J. and W. H. Wagner (1975), "Reducing the cost of stock trading," Financial Analysts Journal, 32: No. 6, 35-44.

Cushman, D. O. (1983), "The effects of real exchange rate risk on international trade," Journal of International Economics, (forthcoming).

Deardorff, A. V. (1979), "One-way arbitrage and its implications for the foreign exchange markets," Journal of Political Economy, 87: 351-64.

Demsetz, H. (1968), "The cost of transacting," Quarterly Journal of Economics 82: 33-53.

Dooley, M. P. and P. Isard (1980), "Capital controls, political risk and deviations from interest rate parity," Journal of Political Economy 88: 370-84.

Dooley, M. P. and J. R. Shafer (1976), "Analysis of short-run exchange rate behavior: march 1973 to september, 1975," International Finance Discussion Papers, No. 76. Washington, D.C. Federal Reserve System.

Dooley, M. P. and J. R. Shafer (1982), Analysis of short-run exchange rate behavior: march, 1973 to november, 1981," International Monetary Fund, Departmental Memorandum, 82/22.

Dornbusch, R. (1976), "Expectations and exchange rate dynamics," Journal of Political Economy, 84: 1161-76.

Dornbusch, R, (1980), "Exchange rate economics: where do we stand?" Brookings Papers on Economic Activity, No. 1, 145-85.

Dornbusch, R. (1982), "Exchange rate risk and the macroeconomics of exchange rate determination," in: R. Hawkins, R. Levich and C. Wihlborg (eds.) Internationalization of Financial Markets and National Economic Policy (JAI Press, Greenwich, Conn.).

Driskill, R. A. (1981), "Exchange-rate dynamics: an empirical investigation," Journal of Political Economy 89: 357-71.

Dufey, G. and I. H. Giddy (1978), The international money market (Prentice-Hall, Englewood Cliffs, N.J.).

Fama, E. F. (1970), "Efficient capital markets: a review of theory and empirical work," Journal of Finance, 25: 383-417.

Fama, E. F. (1976), Foundations of Finance, (Basic Books, New York).

Fama, E. F. and A. Farber (1979), "Money, bonds and foreign exchange," American Economic Review, 69: 639-49.

Feiger, G. and B. Jacquillat (1979), "Currency option bonds, puts and calls on spot exchange and the hedging of contingent foreign earnings," Journal of Finance, 34: 1129-39.

Fieleke, N. S. (1975), "Exchange rate flexibility and the efficiency of the foreign exchange markets," Journal of Financial and Quantitative Analysis, 10: 409-26.

Frankel, J. A. (1979a), "The diversifiability of exchange risk," Journal of International Economics, 9: 379-93.

Frankel, J. A. (1979b), "On the mark: a theory of floating exchange rates based on real interest differentials," American Economic Review, 69: 610-22.

Frankel, J. A. (1982a), "The mystery of the multiplying marks: a modification of the monetary model." Review of Economics and Statistics, (forthcoming).

Frankel, J. A. (January 1982b), "In search of the exchange risk premium: a six-currency test assuming mean-variance optimization." Mimeographed, University of California, Berkeley.

Frankel, J. A. (1982c), "On the mark, pound, franc, yen and canadian Dollar," NBER Conference, Bellagio, Italy.

Frenkel, J. A. (1976), "A monetary approach to the exchange rate: doctrinal aspects and empirical evidence," Scandinavian Journal of Economics, 78: 200-224.

Frenkel, J. A. (1978), "Purchasing power parity: doctrinal perspectives and evidence from the 1920's," Journal of International Economics, 8: 161-91.

Frenkel, J. A. (1980), "Exchange rates, prices and money: lessons from the 1920's," American Economic Review, 70: 235-42.

Frenkel, J. A. (1981), "Flexible exchange rates, prices and the role of 'news': lessons from the 1970s," Journal of Political Economy, 89: 665-705.

Frenkel, J. A. and K. W. Clements (1981), "Exchange rates in the 1920s: a monetary approach," in: Flanders and Razin (eds.), Development in an inflationary world (Academic Press, New York) 283-318.

Frenkel, J. A. and R. M. Levich (1975), "Covered interest arbitrage: unexploited profits?" Journal of Political Economy, 83: 325-38.

Frenkel, J. A. and R. M. Levich (1977), "Transaction costs and interest arbitrage: tranquil versus turbulent periods," Journal of Political Economy, 86: 1209-26.

Frenkel, J. A. and M. L. Mussa (1980), "The efficiency of foreign exchange markets and measures of turbulence," American Economic Review, 70: 374-81.

Frenkel, J. A, and C. A. Rodriguez (1982), "Exchange rate dynamics and the overshooting hypothesis," Staff Papers, 29: 1-30.

Friedman, M.(1953), "The case for flexible exchange rates," in: M. Friedman, ed., Essays in positive economics (University of Chicago Press, Chicago).

Garbade, K. D, and W. L. Silber (1976), "Price dispersion in the government securities market," Journal of Political Economy, 84: 721-40.

Genberg, H. (1982), "Properties of innovations in spot and forward exchange rates and the role of the money supply process," paper presented at NBER conference, Bellagio Italy.

Giddy, I. H. (1979), "Measuring the world foreign exchange market," Columbia Journal of World Business, 14: No. 4, 36-48.

Giddy, I. H. and G. Dufey (1975), "The random behavior of flexible exchange rates," Journal of International Business Studies, 6: No. 1, 1-32.

Girton, L. and D. Roper (1976), "Theory and implications of currency substitution," International Finance Discussion Paper no. 86, Federal Reserve Board of Governors.

Goodman, S. (1981), "Technical analysis still beats econometrics," Euromoney, August: 48-60.

Grubel, H. G. (1966), Forward exchange speculation and the international flow of capital, (Stanford University Press, Stanford).

Hakkio, C. S. (1980), "Expectations and the forward exchange rate," NBER Working Paper No. 439.

Hansen, L. P. and R. J. Hodrick (1980), "Forward exchange rates as optimal predictors of future spot rates: an econometric analysis," Journal of Political Economy, 88: 829-53.

Hernández-Catá, E., et. al (1978), "Monetary policy under alternative exchange-rate regimes: simulations with a multi-country model," in: Managed exchange-rate flexibility: the recent experience, Federal Reserve Bank of Boston, Conference Series NO. 20.

Hilley, J. R., C. R. Beidleman and J. A. Greenleaf (1981), "Why there is no long forward market in foreign exchange." Euromoney, January: 94-103.

Hoag, J. W. (1978), "An introduction to the valuation of commodity options," Columbia University Center for the Study of Futures Markets, Working Paper No. CSFM-19.

Hodjera, Z. (1973), "International short-term capital movements: a survey of theory and empirical analysis," Staff Papers, 20: 683-740.

Hooper, P. and S. W. Kohlhagen (1978), "The effect of exchange rate uncertainty on the prices and volume of international trade," Journal of International Economics, 8: 483-512.

Hooper, P. and J. Morton (1968), "Summary measures of the dollar's foreign exchange value," Federal Reserve Bulletin 64: 783-89.

Hsieh, D. A. (1982), "Tests of rational expectations and no risk premium in forward exchange markets," NBER Working Paper No. 843.

Huang, R. D. (1981), "The monetary approach to exchange rates in an efficient foreign exchange market: tests based on volatility," Journal of Finance, 36: 31-42.

Isard, P. (1977), "How far can we push the law of one price?" American Economic Review, 67: 942-48.

Isard, P. (1978), "Exchange rate determination: a survey of popular view and recent models," Princeton Studies in International Finance, No. 42.

Katseli-Papaefstratiou, L.T. (1979), "The reemergence of the purchasing power parity doctrine in the 1970s, "Princeton Special Papers in International Economics, No. 13.

Kohlhagen, S. W. (1978), The behavior of foreign exchange markets a critical survey of the empirical literature. New York University Monograph Series in Finance and Economics (Salomon Brothers Center) No. 3.

Kouri, P. J.K. (1976), "The exchange rate and the balance of payments in the short run and in the long run: a monetary approach," Scandinavian Journal of Economics, 78: 280-304.

Kouri, P. J.K. (1982), "The effect of risk on interest rates: a synthesis of the macroeconomic and financial views," in: R. Hawkins, R. Levich and C. Wihlborg (eds.), Internationalization of financial markets and national economic policy (JAI Press, Greenwich, Conn.).

Kouri, P. J.K. and M. G. Porter (1974), "International capital flows and portfolio equilibrium," Journal of Political Economy, 82: 443-67.

Krasker, W. S. (1980), "The 'peso problem' in testing the efficiency of forward exchange markets," Journal of Monetary Economics, 6: 269-76.

Kravis, I., Z. Kennessey, A. Heston, and R. Summers (1975), A system of international comparisons of gross product and purchasing power (Johns Hopkins University Press, Baltimore).

Kreinin, M. E. (1977), "The effect of exchange rate changes on the prices and volume of foreign trade," Staff papers, 24: 297-329.

Kubarych, R. M. (1978), Foreign exchange markets in the united states (Federal Reserve Bank of New York, New York).

Levi, M. D. (1977), "Taxation and 'abnormal' international capital flows," Journal of Political Economy, 85: 635-46.

Levich, R. M. (1978), "Further results on the efficiency of markets for foreign exchange," in: Managed exchange-rate flexibility: the recent experience, Federal Reserve Bank of Boston, Conference Series No. 20.

Levich, R. M. (1979a), The international money market: an assessment of forecasting techniques and market efficiency (JAI Press, Greenwich, Conn.).

Levich, R. M. (1979b), "On the efficiency of markets for foreign exchange," in: R. Dornbusch and J. Frenkel (eds.), International economic policy: an assessment of theory and evidence (Johns Hopkins University Press, Baltimore).

Levich, R. M. (1980), "Analyzing the accuracy of foreign exchange advisory services: theory and evidence," in: R. Levich and C. Wihlborg (eds.), Exchange risk and exposure (D.C. Heath and Co., Lexington, Mass.).

Levich, R. J. (1981a) "Maximizing the return on forex services," Euromoney currency report, February 11,page 3.

Levich, R. M. (1981b), "How to compare chance with forecasting expertise," Euromoney, August: 61-78.

Levich, R. M. (1981c), "An examination of overshooting behavior in the foreign exchange market," Group of Thirty Occasional Studies No. 3, New York.

Levich, R. M. (1981d), "Exchange rates and currency exposure," in: E. Altman (ed.), Financial handbook (John Wiley, New York) Chapter 12.

Levich, R. M. (1982), "Comment on sweeney," in: G. Haberler and T. Willett (eds.), The international monetary system under stress (American Enterprise Institute, Washington, D.C.).

Lintner, J. (1965), "The valuation of risky assets and the selection of risky investments in stock portfolio and capital budgets," Review of Economics and Statistics, 47: 13-37.

Logue, D. E. , R. J. Sweeney and T. D. Willett (1978), "Speculative behavior of foreign exchange rates during the current float," Journal of Business Research 6: 159-74.

Longworth, D. (1981), "Testing the efficiency of the canadian exchange market under the assumption of no risk premium," Journal of Finance 36: 43-50.

McCormick, F. (1979), "Covered interest arbitrage: unexploited profits?: comment," Journal of Political Economy, 87: 411-17.

McKinnon, R. I. (1979), Money in international exchange (Oxford University Press, New York).

Meese, R. and K. Rogoff (1981), "Empirical exchange rate models of the seventies: are any fit to survive?" International Finance Discussion Papers, No. 184, Board of Governors of the Federal Reserve System, Washington, D.C.

Meese, R. and K. Rogoff (1982), "The out-of-sample failure of empirical exchange rate models: sampling error or misspecification?" Mimeographed, Board of Governors of the Federal Reserve System, Washington, D.C.

Meese, R. A. and K. J. Singleton (1980), "Rational expectations, risk premia, and the market for forward exchange," International Finance Discussion Paper No. 165, Federal Reserve Board of Governors.

Melhem, M.F. (1982), "Money expectations and exchange rate dynamics." Unpublished Ph.D. dissertation, New York University.

Miles, M. (1978), "Currency substitution, flexible exchange rates and monetary independence," American Economic Review, 68: 428-36.

Mossin, J. (1966), "Equilibrium in a capital asset market," Econometrica, 34: 768-83.

Mussa, M. (1976), "The exchange rate, the balance of payments, and monetary policy under a regime of controlled floating, "Scandinavian Journal of Economics, 78: 229-48.

Officer, L. H., and T. D. Willet (1979), "The covered-arbitrage schedule: a critical survey of recent developments," Journal of Money, Credit and Banking, 2: 247-57.

Poole, W. (1966), "The canadian experiment with flexible exchange rates," Unpublished Ph.D. dissertation, Unversity of Chicago.

Poole, W. (1967), "Speculative prices as random walks: an analysis of ten time series of flexible exchange rates," Southern Economic Journal, 33: 468-78.

Rogalski, R. J. and J. D. Vinso (1978), "Empirical properties of foreign exchange rates," Journal of International Business Studies, 9: No. 2, 69-79.

Roll, R. (1977), "A critique of the asset pricing theory's tests," Journal of Financial Economics, 4: 129-176.

Sharpe, W. F. (1964), "Capital asset prices: a theory of market equilibrium under conditions of risk," Journal of Finance, 19: 425-42.

Solnik, B. H. (1973), European capital markets, (D.C. Heath, Lexington, Mass.).

Stockman, A.C. (1978), "Risk, information, and forward exchange rates," in: J. Frenkel and H. Johnson (eds.), The economics of exchange rates (Addison-Wesley, Reading Mass.).

Sweeney, R. J. (1982), "Intervention strategy: implications of purchasing power parity and tests of spot market efficiency," in: G. Haberler and T. Willett (eds.), The international monetary system under stress (American Enterprise Institute, Washington, D.C.).

Tryon, R. (1979), "Testing for rational expectations in foreign exchange markets," Board of Governors of the Federal Reserve System, International Finance Discussion Papers. No. 139.

Westerfield, J. M. (1977), "Empirical properties of foreign exchange rates under fixed and floating rate regimes," Journal of International Economics, 7: 181-200.

Wihlborg, C. G. (1978), "Currency risks in international financial markets," Princeton Studies in International Finance, No. 44.