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THE FORWARD MARKET FOR FOREIGN EXCHANGE: CHARACTERISTICS AND EFFICIENCY

A DISSERTATION

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THE FORWARD MARKET FOR FOREIGN EXCHANGE:

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THE FORWARD MARKET FOR FOREIGN EXCHANGE:

CHARACTERISTICS AND EFFICIENCY

CHAPTER I

INTRODUCTION

The foreign exchange and forward exchange markets are quite similar to other financial markets. The activity in any financial market represents the allocation and reallocation of financial claims against real assets. Foreign exchange transactions are one step removed from the typical financial market, however. Foreign exchange transactions are in two national currencies. Rather than a claim against specific real assets, the claims reallocated in foreign exchange trading (national currencies) are claims against the real assets of national economic systems. The forward market for foreign exchange differs from the foreign exchange market only by the timing of the exchange of assets. While the foreign exchange transaction takes place at the present time, a forward transaction is a present agreement for a future exchange of currencies.

With the movement, in 1973, from the fixed exchange rates of the Bretton Woods Agreement of the International Monetary Fund to the present "managed floating rates" system, the forward market for forward exchange has gained volume and prominence. Organizations doing business in more than one currency now face greater risks of loss from exchange rate changes and greater need to offset those risks.[1] Speculators now have the opportunity to earn greater profits (or suffer greater losses) through foreign currency speculation. Both have found the forward exchange market a useful vehicle through which their respective objectives may be accomplished.

I. The Importance of Forward Market Efficiency

The forward market, then, is one which has important implications for the allocation of scarce resources on an international basis. Any contribution to the body of knowledge concerning the forward market is of consequence, but analytical work on the efficiency and characteristics of this market seems of primary importance. Efficiency does not imply that paperwork is handled smoothly; it implies the current price of forward exchange reflects all that is knowable about the currency and maturity.

The implications of efficiency are twofold. If forward markets are efficient, speculators can earn extraordinary profits from them only by discovering new and unique methods of currency valuation; and business organizations, using forward markets to eliminate exchange rate risks, will pay the forward premium which fully reflects all information. In both cases, the efficient forward premium will result in a more optimal allocation of resources worldwide.

II. The Purpose of the Study

This dissertation is an examination of the efficiency of the forward market for foreign exchange and the characteristics of forward market premia. Specifically, the appropriate rate of return on forward transactions is defined and the actual rate of return on these transactions calculated. The study then tests the hypothesis that these time series offer no information that is not incorporated in the forward rate.

A second area of speculative activity, speculating between forward contracts of different maturities, or the intertemporal profitability condition, is also defined and examined. The condition itself is measured and tests are performed to see if this is a profitable substitute for other techniques in either forward exchange market speculation or foreign exchange risk reduction.

Finally, this study examines the term structure of forward premia. Through measurement and frequency analysis, the shape of a curve representing relative forward premia is identified. Since speculators and business organizations often can choose among several forward maturities, the relationship of different maturities is of importance. No work has been published specifying this relationship and the determination of such relationships forms an important part of the overall contribution of this paper.

III. Organization of the Study

This study begins with a detailed survey of the literature of: efficient markets theories and analysis in Chapter II; theories of the forward market for foreign exchange in Chapter III; and tests of market efficiency on foreign exchange and forward exchange markets in Chapter IV. The broad treatment of the literature in Chapters II to IV is necessary to show this is an original work and to establish its place in the economic and financial areas.

Chapter V presents the theories, hypotheses, and statistical techniques used to test the efficiency of the forward market. These tests include nonparametric tests as well as other, quite sophisticated, time series techniques.

Chapter VI describes the exchange rate data used and examines its statistical characteristics. In the real world, many economic time series do not come from normal distributions. The data used in this study is examined to see if it more closely approximates a normal distribution or a stable Paretian distribution. Analysis here draws heavily on the statistical work others have prepared to examine the distributions found in other economic time series such as the rate of return on common equities.

The time series analysis and the results of the hypothesis testing are summarized in Chapter VII. The tests employed include nonparametric sign and runs tests. Box-Jenkins time series analysis is also utilized in this chapter.

Chapter VIII presents the relative market premia and a typical or "normal" curve for the premia of different forward maturities. The condition for intertemporal profitability is estimated here and evaluated relative to other forward market techniques.

Chapter IX, the final chapter, offers a summary and the conclusions of the study as well as some implications of the results.

FOOTNOTES TO CHAPTER I

1. According to Frank Knight, Risk, Uncertainty and Profit (Boston: Houghton Mifflin, 1921) risk and uncertainty refer to different states of nature. Risk can be estimated through the use of actuarial tables, but uncertainty cannot. In the strict sense of Knight's definitions, what is commonly called foreign exchange risk is actually uncertainty, but for purposes of this paper, foreign exchange risk and foreign exchange uncertainty will be used as synonyms since the two are often used interchangeably in this area.

CHAPTER II

EFFICIENT MARKET ANALYSIS: A SURVEY OF THE LITERATURE

While the study of speculative price patterns began in 1900 with the work of Louis Bachelier,[1] the idea that capital markets are efficient has been developed and generally accepted by academicians during the past twenty years. Brief mention of some early work is necessary, however, if only to illustrate the evolutionary development of the efficient market concept.

I. The Early Works, Weak Form Tests

Louis Bachelier, writing in France, included in his dissertation a theoretical development of the probability distribution for a continuous stochastic process with independent increments. His work further included derivation of bond option prices assuming a profit-maximizing investor and the existence of such a process in the options market. His empirical testing revealed that the prices he predicted closely approached the actual prices, supporting the hypothesis of independent price changes.

In 1934, Holbrook Working[2] applied his efforts to pricing in the commodity markets and observed a random pattern of time-series price changes. He also noted the resemblance of price levels to the summation of random numbers. This distinction between the level of prices and changes in prices is more clearly developed in the work of Harry V. Roberts.[3]

Roberts, writing in the United States, expanded the work of M. G. Kendall,[4] a British statistician. Using the "chance model" as representative of stock market patterns, Roberts illustrated patterns similar to the U.S. stock market. When he switched to price differences, he was able to eliminate the regularities in stock price time series.

Published in the same year as Roberts' work was an article by M.F.M Osborne.[5] He compared the movements of stock prices to the movements of small particles suspended in liquid solution, the "Brownian motion" of physics. His results indicated a high degree of similarity between the two and statistical independence of stock price changes.

Empirical work in the period following took one of two forms. First, there were tests of serial correlation between successive stock price changes. Arnold B. Moore,[6] Granger and Morgenstern,[7] Godfrey,[8] Fama,[9] and others examined the serial correlation of stock price changes. Their findings supported the earlier studies; they found little or no serial correlation in stock price changes. Fama tested to see if runs persisted in the sign of price changes. Here, also, no trend was established.

While this empirical work was convincing to the academic community, the financial community largely rejcted it. These articles were quite mathematical and were published in professional journals rather than trade publications. To quote Adam Smith, "The random-walk people are university professors in business schools and economics departments. They have had a lot of advanced mathematics and they delight in using it, and in fact, most random-walk papers by these academics must be arcane and filled with symbols so that their colleagues will be impressed."[10]

The second form of testing approached a fair game model testing various trading rules. Sidney S. Alexander attempted to construct trading rules which would yield superior profits. His initial work, using filter rules, appeared successful.[11] As prices move up from a low by X%, using Alexander's filter rule model, one must buy. As the price falls from a high by Y%, the model dictates one sell and go short. By varying X and Y between 1 and 50 percent, Alexander claimed returns well above average. After criticisms and corrections, Alexander later concluded no filter rules could earn returns superior to a naive buy and hold strategy.[12] Fama and Blume[13] support this finding. While these studies do indicate a small margin of profitability on filters of less than 1%, commissions would more than eliminate this return. In the rigorous definition of the random walk, these studies show stock price changes to be non-random. But these studies do not show inefficiency in the market.

II. Development of the Theory

All the works cited above can be described as empirical tests of loosely stated theories.[14] The overwhelming evidence that successive common stock price changes are independent and, therefore, trading rules based on past prices could not earn above average returns was "a large body of empirical results in search of a theory."[15] Paul Samuelson[16] and Benoit Mandelbrot[17] are credited with the first rigorous treatments of fair game-expected return models and the relationship of such models to the theory of efficient markets. They specified efficient markets, the conditions necessary for efficient markets, and the relationship between an efficient market and the random price series of things traded in that market.

They indicated an efficient market, one in which prices "fully reflect" all available information, will exist under the following conditions: zero transactions costs; all information is available at zero cost; and all market participants have homogeneous expectations and time horizons. Under these ideal conditions, the price of the asset traded will reflect its "intrinsic" value. Changes in that intrinsic value will be instantaneously reflected in the price, and, since changes in the intrinsic value appear randomly, the price changes will be random.

Of course, the ideal conditions do not exist, but the important question is do the real world market conditions approximate the ideal to the extent that superior returns cannot be obtained from the use of new information. If the actual conditions do not adequately conform to the ideal, successive price changes will move toward newly perceived intrinsic values over some period of time. This would allow those participants with either earlier access to information or superior interpretation of that information to earn above average returns.

Since "a market in which prices 'fully reflect' all available information" is an untestable phenomenon, the empirical models have been stated in the form of expected return or fair game models.

Fama[18] represents the expected return model symbolically as:

$$E\,(\hat{P}_{j,\ t+1} \mid \emptyset) = 1 + E\,(\hat{r}_{j,\ t+1} \mid \emptyset)\ P_{j,t} \qquad (1)$$

$$r_{j,\ t+1} = (P_{j,\ t+1} - P_{j,t}) / P_{j,t} \qquad (2)$$

Where E = expected value operator

$(P_{j,\ t+1})$ = price of security j at time t + 1

$r_{j,\ t+1}$ = percentage return on j over 1 period t to t=1

$\hat{}$ = random variable symbol

$\emptyset$ = information set

Then if $\emptyset$, the information set, is incorporated in the price, the model becomes a fair game:

$$E\ (\hat{P}_{j,\ t+1} \mid \emptyset) = P_{j,\ t+1} \tag{3}$$

and

$$E\ (r_{j,\ t+1} \mid \emptyset) = r_{j,\ t+1} \tag{4}$$

and there is no profitability in $\emptyset$ or in market strategies using $\emptyset$.

This formulation of the expected value model led to tests of efficiency based on the information set $\emptyset$. Following Fama's[19] summary article, when $\emptyset$ represents past prices, the level is referred to as the weak form. This describes the previously mentioned tests. Let $\emptyset$ reflect all public information, and we have the semi-strong form. Finally, when $\emptyset$ represents all knowable information, the classification is the strong form. Tests and results differ for each form, but the evidence presented to date supports the efficiency of capital markets at the weak and semi-strong levels. Tests are inconclusive regarding the strong form. A brief review of important work in the semi-strong and strong forms will complete our summary of the state of the art and present the methodology of efficient market analysis.

The Semi-Strong Form

By far the most cited study of semi-strong efficiency was performed by Fama, Fisher, Jensen and Roll[20] (FFJR). Their study is as important for its method as for its results. In an examination of the effects of stock splits on stock price, they used the market model (developed by Markowitz, Sharpe and other)[21] to focus on only deviations between actual prices and those predicted using the market model. The use of a predictive model and examination of deviations from that model has become the standard method of analysis for the semi-strong form.

FFJR examined all New York Stock Exchange (NYSE) stock splits of 5 for 4 or greater during the period January, 1927 to December, 1959. Using monthly prices for each security as the dependent variable and a market index computed from returns on all NYSE securities, they first estimated parameters for the market model for each stock. In order to abstract from the effects of the split and related factors, observations 15 months prior and 15 months after the split were excluded when estimating the market model.

If there were no "abnormal" effects during the period excluded, the expected value of the difference or residual between the predicted and actual price, during that period, should be zero. They found the residuals had a positive expected value during the 15 months prior to the split and a zero expected value after the split.

By putting all stock splits in a common time frame, the average and cumulative average residuals were calculated from time t = -15 months to t = 15 months (t = 0 represents the split date). This average residual is the mean residual of the entire sample for month t. The cumulative average residual is the sum of monthly average residuals from the first month considered (0-15) to t. The cumulative average residuals are represented graphically in Exhibit II-1, on page 22.

Since the announcement of a stock split is typically two to four months prior to the split, the positive residuals cannot be attributed to the splits. They concluded that splits follow a time of both increased earnings and price performance.

The hypothesis of efficiency could not be rejected. The authors found no evidence that any profitable trading rule existed utilizing stock split announcements.

Other significant tests of the semi-strong form were performed by Scholes[22] on secondary distributions and Ball and Brown[23] on announced annual earnings. These also supported the efficient hypothesis. Other applications of the semi-strong efficient market methodology are found in the works of Green and Segall[24] and Brown and Niedergoffer[25] dealing with quarterly earnings announcements. These support market efficiency given transactions costs.

The Strong Form

The strong form tests have applied different methodology. The highest level of efficient market analysis, the strong form, is the most difficult to test. The information set, all knowable information, must be distinguished from all public information, the information set for the semi-strong level. In other words, the testing of strong form efficiency implies testing the profitability of non-public information. Rather than test this hard to identify information directly, the primary studies in this area have tested the performance of selected groups of market performers. The rationale for this approach is as follows: if information is present but not public, which groups of market participants are most likely to possess this information? By examination of the performance of the portfolios of these specified groups one can infer the value of information available to group members but unknown to the market as a whole.

In testing for strong form efficiency, the capital asset pricing model (CAPM) of Sharpe[26] and Lintner[27] has been utilized. Superior performance requires not only higher returns but higher returns than the (CAPM) would predict for that level of risk.

Scholes'[28] model, which did support semi-strong efficiency, had conflicting evidence at the strong level. While his examination of all secondary distributions revealed no profitability from the distribution announcement, his findings were interesting when he analyzed the groups making the distributions. Corporate officers and corporations were shown to make a secondary distribution after a period of extraordinary price increases (relative to the market model) and just prior to extraordinary price declines. Individuals making secondary distributions did so after exceptional price increases and just before a return to more normal price/market relationships. Both groups would seem to possess information not available to the market as a whole, and both groups are shown to make returns above the expected returns. This supports the hypothesis of inefficiency at the strong level.

Several studies directed their attentions to the mutual fund managers. As the most visible and as generators of the largest volume of transactions, this group was likely to possess superior information. Any costs of obtaining information would be allocated to each of a large number of shares. On a per share basis, the information costs would be quite low for the mutual funds. One of the earliest such studies, by Friend[29], was done at the direction of the Securities Exchange Commission (SEC). Based on rates of return and adjusting for risk only with portfolio composition, Friend could find no evidence of superior performance on the part of the mutual funds.

Sharpe[30] later examined the funds using the CAPM.

He found, assuming administrative and transaction expenses are zero, that 19 of the 34 mutual funds tested exhibited performance superior to the Dow Jones Industrial Index. When expenses were included, that number of superior performances fell to 11. The study indicated the mutual fund performance was not superior and that the market was not inefficient based on information available only to mutual fund managers.

The most comprehensive mutual fund study is that by Jensen.[31] He developed the appropriate model against which to test portfolio performance. While similar to Sharpe's model, Jensen made slight modifications[32] which eliminated statistical impurities in the application of the CAPM. His work, which is consistent with Friend, Sharp and several others,[33] supports the strong form efficiency of information available to mutual fund managers.

More recent work in the areas of market efficiency has been directed toward other markets. Some work has been done on Treasury Bills, commodities, and foreign exchange. Since the efficiency of any financial market affects the overall allocation of capital and worldwide well being, application of the efficient markets analysis and methodology to these other areas is appropriate. Examination of the application of these techniques to the area of foreign exchange and forward exchange and a review of Forward Exchange Theory are presented in the following two chapters.

FOOTNOTES TO CHAPTER II

1. Louis B. Bachelier, "A thesis presented to the Faculty of Sciences of the Academy of Paris" on March 29, 1900, for the Degree, Docteur es Sciences Mathematiques. Originally published in Ann. Sci. Ecole Norm. Sup. (3), No. 1018 (Paris, Gauthier-Villars, 1900). Reprinted in The Random Character of Stock Market Prices, ed. Paul H. Cootner (Cambridge, Mass: MIT Press, 1964): 17-78.

2. Holbrook Working, "A Random-Difference Series for Use in the Analysis of Time Series," Journal of the American Statistical Association 29 (1934).

3. Harry V. Roberts, "Stock Market 'Patterns' and Financial Analysis: Methodological Suggestions," Journal of Finance 14 no. 1 (March 1959): 1-10.

4. Maurice G. Kendall, "The Analysis of Time Series," Journal of the Royal Statistical Society ser. B, 116 (1953): 11-25.

5. M.F.M. Osborne, "Brownian Motion in the Stock Market," Operations Research 7 (March-April 1959): 145-73.

6. Arnold B. Moore, "Some Characteristics of Changes in Common Stock Prices," in The Random Character of Stock Market Prices ed. Paul H. Cootner (Cambridge, Mass: MIT Press, 1964): 139-61.

7. Clive W. J. Granger and Oskar Morgenstern, "Spectral Analysis of New York Stock Market Prices," Kyklos 16 (1963): 1-27.

8. Michael Godfrey, C. W. J. Granger, and O. Morgenstern, "The Random Walk Hypothesis of Stock Market Behavior," Kyklos 17 (1964): 1-30.

9. Eugene F. Fama, "The Behavior of Stock Market Prices," Journal of Business 38 (January 1971): 34-105.

10. Adam Smith, The Money Game (New York: Random House, Inc., 1967): 147.

11. Signey S. Alexander, "Price Movements in Speculative Markets: Trends or Random Walks," Industrial Management Review 2 (May 1961): 7-26.

12. Sidney G. Alexander, "Price Movements in Specu-

lative Markets: Trends or Random Walks, No. 2," in The Random Character of Stock Market Prices, ed. Paul H. Cootner, (Cambridge, Mass: MIT Press, 1964): 338-72.

13. Eugene F. Fama and Marshall Blume, "Filter Rules and Stock Market Trading Profits," Journal of Business 39 (Special Supplement, January 1966): 266-41.

14. Fama presents quotations from some of these works illustrating the lack of rigor in the theoretical explanations. A common error was that of concluding a random walk existed when no significant dependence between price changes could be detected. As Fama points out, the requirements for a random walk include independence between the random variables of the series and identical density functions for all observations of the series.

Eugene F. Fama, "Efficient Capital Markets: A Review of Theory and Empirical Work," Journal of Finance 25 no. 2 (May 1970): 383-417.

15. Ibid.

16. Paul A. Samuelson, "Proof that Properly Anticipated Prices Fluctuate Randomly," Industrial Management Review 6 (Spring 1965): 41-49.

17. Benoit Mandelbrot, "Forecasts of Future Prices, Unbiases Markets, and Martingale Models," Journal of Business, Security Prices: A Supplement 39, part 2 (January 1966): 242-55.

18. Fama, "Efficient Capital Markets", p. 385.

19. Ibid.

20. Eugene F. Fama, et al., "The Adjustment of Stock Prices to New Information," International Economic Review 10, no. 1 (February 1969): 1-21.

21. Harry M. Markowitz, "Portfolio Selection," Journal of Finance 7, no. 1 (March 1952): 77-91.

William F. Sharpe, "A Simplified Model for Portfolio Analysis," Management Science 9, no. 2 (January 1963): 277-93.

William F. Sharpe, "Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk," Journal of Finance 19 (September 1964): 429-442.

22. Myron S. Scholes, "The Market for Securities: Substitution Versus Price Pressure and the Effects of Information on Share Prices," <u>Journal of Business</u> 45, no. 2 (April 1972).

23. Ray Ball and Philip Brown, "An Empirical Evaluation of Accounting Income Numbers," <u>Journal of Accounting Research</u> 6 (Autumn 1968): 159-78.

24. D. Green and J. Segall, "The Predictive Power of First Quarter Earnings Reports," <u>Journal of Accounting Research IV Suppl. Empirical Research in Accounting: Selected Studies, 1966</u> (1967): 21-36.

25. P. Brown and V. Niederhoffer, "The Predictive Content of Quarterly Earnings," <u>The Journal of Business</u> 43 (January 1970): 60-62.

26. William F. Sharp, "Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk," <u>Journal of Finance</u> 19 (September 1964): 429-442.

27. John Lintner, "The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets," <u>Review of Economics and Statistics</u> 47 (February 1965): 13-37.

28. Myron S. Scholes, "The Market for Securities: Substitution Versus Price Pressure and the Effects of Information on Share Prices," <u>Journal of Business</u> 45, no. 2 (April 1972).

29. Irwin Friend, F. W. Brown, Edward S. Herman, and Douglass Vickers, <u>A Study of Mutual Funds</u>, (Washington, D. C.: U. S. Government Printing Office, 1962).

30. Sharpe, "Mutual Fund Performance," <u>Journal of Business</u> 39, part 2 (January 1966): 277-293.

31. Michael C. Jensen, "The Performance of Mutual Funds in the Period 1945-64," <u>Journal of Finance</u> 23, no. 2 (May 1968): 389-416.

32. The Sharpe model $r_{jt} = a_j + b_j I_t + u_{jt}$

where r_j = return on security$_j$

a and b are parameters for a linear regression

I = market return index

u + residual

can be shown to have $E(u_{jt}) \neq 0$ since u_{jt} is contained in I_t. Therefore, Jensen specifies the market model:

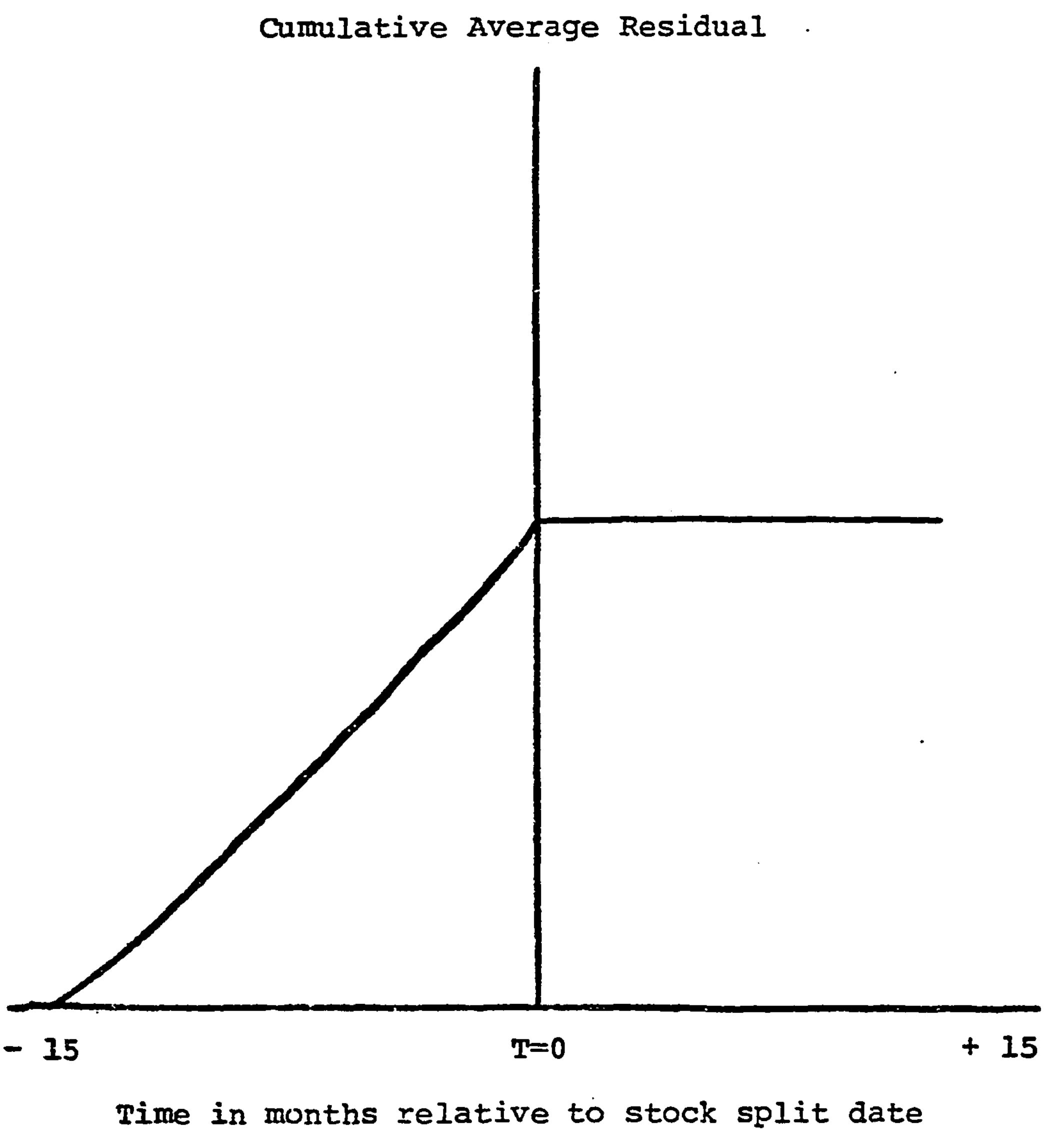
$$r_{jt} = E(r_{jt}) + b_j\pi_t + e_{jt}$$

where π is "an unobservable 'market factor' which to some extent affects the returns on all securities".

Jensen Ibid, 391.

33. Ira Horwitz, "A Model for Mutual Fund Evaluation," Industrial Management Review 6 (Spring 1965): 81-92.

Exhibit II-1


Cumulative Average Residual
- 15
T=0
+ 15
Time in months relative to stock split date

CHAPTER III

THE THEORY OF THE FORWARD MARKET: A SURVEY OF THE LITERATURE

The development of forward foreign exchange theory is a history of many contributors and many theories. Paul Einzig, certainly the most prolific writer on the subject of foreign exchange, has traced its evolution from its beginnings through the early sixties.[1] His treatment has been a guide to the early work and is summarized in the following pages. During the years since Einzig's volume, much new work has been published. This, too, is presented below. The intent is not to present an abstract of each work, but to identify the major theories of forward foreign exchange and the major contributors of each.

The forward market for foreign exchange is not a separate market but rather "an integral part of the Foreign Exchange Market"[2] and an extension of national money markets. Einzig places its origin in the early 1300's.[3]

I. Interest Parity Theory

In spite of its early beginnings, economists displayed little interest in the forward market prior to the first World War. John Maynard Keynes, writing first in the Manchester Guardian[4] and with more detail in his Tract on Monetary Reform,[5] presented the initial theory. The relationship between forward exchange rates, spot exchange rates, and interest rates that Keynes detailed, was labeled,"Inter-Parities" by Einzig[6]. Keynes' theory became the Interest Parity Theory (IPT) of forward foreign exchange.

According to Keynes, the single most important influence on forward exchange rates was the differential between the short-term interest rates in the two countries. Specifically, the percentage by which the forward rate differs from the spot rate should tend to equal the percentage difference between short-term rates in the two countries.

Keynes recognized certain circumstances such as political uncertainty, limited arbitrage capital, or collusion between foreign exchange brokers may cause actual forward rates to differ from interest parity conditions.

Interest parity has served as the basis of foreign exchange theory since Keynes' original presentation in 1922. As it has developed, the theory is one of arbitrage between two markets with different rates of return. Interest arbitrage occurs when an individual simultaneously borrows at the lower rate of return and lends at the higher rate of return. With the two markets denominated in different national currencies, two foreign exchange transactions are necessitated.

For the individual who borrows in one currency and simultaneously lends in another, one foreign exchange transaction must take place simultaneously with the money market transactions. When the two offsetting financial instruments mature, the second foreign exchange transaction must be consumated. To prevent losses due to exchange rate changes, the second exchange can be made simultaneously with the first by using the forward market. So long as the difference between the forward and spot rates does not eliminate the gain on interest differentials, it will be profitable.

To illustrate, let:

F = Forward exchange rate; A currency in terms of B currency

S = Spot exchange rate; A currency in terms of B currency

Ia = Short term rate in country A

Ib = Short term rate in country B

p = The % difference in the spot and forward rate.

$$p = \frac{F - S}{S}$$

Assume Ia - Ib > 0,

then it is profitable to borrow in country B at Ib, and lend in country A at Ia, provided forward exchange rate costs are not too great. If the following condition holds, the above circumstances are profitable:

$$S\ (1 + Ia) > F\ (1 + Ib). \qquad (1)$$

When all four rates are considered, the conditions for profitability become, $S\ (1 + Ia) \neq F\ (1 + Ib)$. Alternatively, when $S\ (1 + Ia) = F\ (1 + Ib)$, the opportunity for profitable arbitrage no longer exists. The forward rate which brings about equality is the interest parity rate: (F_{ip}). Solving for the forward premium or discount:

$$S\ (1 + Ia) = F\ (1 + Ib) \qquad (2)$$

$$\frac{(1 + Ia)}{(1 + Ib)} = F/S \qquad (3)$$

since $1 + P = F/S$

$$(1 + Ia) = (1 + P)\ (1 + Ib)$$
$$(1 + Ia) = (1 + P + PIb + Ib) \qquad (4)$$

$$Ia - Ib = P + IbP \qquad (5)$$

$$\frac{Ia - Ib}{1 + Ib} = P \qquad (6)$$

$$Ia - Ib \doteq P \qquad (7)$$

While equation (6) is mathematically correct, the approximation given in equation (7) is actually the expression used for interest parity. In practice the numerical difference between (6) and (7) has been viewed as insignificant (a viewpoint which may be invalid with today's higher interest rates).

II. Fisherian Theory, Purchasing Power Parity

An alternative theory of forward exchange has come to be called the Fisherian Theory[7]. According to Einzig[8], this theory was first presented in 1936 by W. W. Syrett[9], a banker. In an attempt to explain deviations from interest parity, Syrett argued that relative price levels, purchasing power parity (PPP) determine equilibrium spot rates. Furthermore, when governments intervene in the spot market and cause spot rates to deviate from purchasing power parity rates, the forward rates adjust to the purchasing power parity conditions.

Einzig's original[10] and revised texts on foreign exchange effectively incorporate Syrett's work as "actually complimentary to the interest parity theory."[11] Einzig argues that a spot rate which deviates from the purchasing power parity rate, gives rise to forward rates "which tend to move between their Interest Parities and the Purchasing Power Parities."[12] A spot rate above PPP will have a corresponding forward rate below its interest parity rate. Conversely, a spot rate under-valued relative to PPP yields a forward rate over-valued relative to the interest parity.

A spot rate which is at a premium relative to PPP results in a forward discount for the following reasons:

1. Interest rates in a centre with a overvalued currency tend to rise, especially if the currency is defended by raising the Bank rate and imposing credit restrictions, of if the adverse pressure caused by the overvaluation leads to an outflow of gold as a result of official supporting operations.

2. Flight of capital, national or foreign, and transfers of funds through outward Interest arbitrage causes a contraction of liquid resources. Interest arbitrage therefore is unable to take full advantage of the intrinsic discount, and is thus unable to cancel it out, or even counteract its widening tendency.

3. The trade balance of a country with an overvalued currency tends to become adverse, and consequently, forward selling of the national currency on commercial account tends to exceed forward buying on commercial account.

4. Apart from any import surplus created by the overvaluation of the currency, commercial forward selling may exceed commercial forward buying owing to the operation of leads and lags.

5. Hedging against risk on assets in a country with an overvalued currency increases.

6. Speculative anticipation of devaluation or depreciation of an overvalued currency causes a widening of the forward discount.[13]

Since the other country will face opposite conditions, the same reasoning explains why a spot exchange rate below PPP should have a forward premium.

Analysis along the lines of purchasing power parity was not re-directed to the forward market until 1972 when Pippenger introduced a restatement of the theory based on expected changes in relative prices.[14] Pippenger adopts the Fisherian distinction between real and nominal rates of interest, and this becomes the basis of his theory. Since he gives no references to Syrett or Einzig, he appears to be unaware of their less rigorous statements of this theory before him.

Pippenger believes purchasing power parity and interest parity are compatible. He argues that IPT is a partial equilibrium theory which assumes a given interest differential. Fisherian theory is more general, according to Pippenger, since "Given the assumptions of competition and zero transactions costs both the interest rate differential and the premium or discount on forward exchange are determined by the difference in the expected rates of inflation."[15]

A crucial assumption of the Fisherian model is the equality of real rates of interest resulting from capital flows. Thus the difference in nominal rates is a result of differences in inflationary expectations. Using the notation introduced earlier:

$$(1 + Ia) = (1 + R_a)\ (1 + e_a) \tag{8}$$

$$(1 + Ib) = (1 + R_b)\ (1 + e_b) \tag{9}$$

$$\frac{1 + Ia}{1 + Ib} = \frac{(1 + R_a)\ (1 + e_a)}{(1 + R_b)\ (1 + e_b)} \tag{10}$$

$$\frac{1 + Ia}{1 + Ib} = \frac{1 + e_a}{1 + e_b} \tag{11}$$

Where R = the real rate of return, e = expected inflation rates, subscripts refer to countries and $R_a = R_b$.

Substituting in equation (3), the interest differential is now determined only by different expectations of inflation rates.

$$\frac{1 + e_a}{1 + e_b} = F/S \tag{12}$$

Pippenger goes on to argue that the equilibrium spot rate is equal to the ratio of prices for identical baskets of goods, equation 13.

$$S = \frac{P_A \cdot Q_A}{P_B \cdot Q_B} \tag{13}$$

Where P is a price index, Q is a basket of goods.

Furthermore, the forward rate is nothing more than the ratio of the futures prices of this basket of goods, equation 14.

$$F = \frac{E(P_A) \cdot Q_A}{E(P_B) \cdot Q_B} \tag{14}$$

But $E(P_A)$ is only P_A adjusted for expected price changes (assuming no transactions costs).

So $E(P_j) = P_j(1 + e_j)$. Substituting into equation (3).

$$\frac{1 + Ia}{1 + Ib} = \frac{\dfrac{P_A(1 + e_a)}{P_B(1 + e_b)}}{\dfrac{P_A}{P_B}} = \frac{1 + e_a}{1 + e_b} \tag{15}$$

proving that the premium is determined by expected price level changes.

Fisherian Theory argues the forward premium equals the interest parity rate, but that both are determined independently and as a function of expected price level changes.

Pippenger concludes this simultaneous and independent determination of the forward premium and interest differential make arbitrage and speculation unnecessary for interest parity to hold. John J. Van Belle[16] has shown this conclusion to be false. Without arbitrage, the crucial assumption of equal real rates of return is violated. As

Collins has previously shown,[17] arbitrage in either goods or capital is necessary for PPP to explain the equality in the interest differential and forward premim. Arbitragers and speculators form the link which move the Fisherian model to equilibrium.

III. The Modern Theory

Both the Interest Parity Theory and the Fisherian Theory predict the forward rate will differ from the spot rate by a percentage equal to the short-term interest differential between the two countries. But casual observation and empirical testing show this condition does not always hold. S. C. Tsiang, partially as a result of the deviations (he labeled these intrinsic premia or discounts) between actual forward rates and those predicted by (IPT), developed and published a Modern Theory (MT) in 1959, which he further clarified in 1973.[18]

Of course, the fact that actual forward rates do not always conform to interest parity was noted by Keynes in his original treatment of the subject. Einzig, Syrett, and the pre-World War II financial press also discussed this at length. The list of possible causes for this deviation has now become standardized in textbooks on International Economics.[9] One of the earliest theoretical developments, by Auten in 1961, used Tsiang's model to the conditions under which these deviations occur and explains the deviations from interest parity in the Pound/dollar rates during the late 1950's and early 1960's.[20]

Without dwelling on them, several conditions give rise to intrinsic premia or discounts. During periods of fixed exchange rates, the forward rate will not move from the pegged spot rate or band unless market participants feel very strongly that the fixed rate will change.

If the official rates are expected to prevail, interest parity outside the band cannot be achieved. This was the condition Auten found for the forward Pound. Other problems concern measurement: what interest rates should be used; exchange rates should be measured simultaneously but is this possible for researchers; and is a minimum interest arbitrage return necessary for arbitragers to enter the market?

Tsiang's contribution was much more than a list of dis-equilibrating conditions. It was a theory which described an equilibrium rate other than the interest parity rate. Tsiang, and others[21] following him, have separated participants in the forward exchange market into "pure" functional categories.

Arbitragers, those participants who enter the market whenever the conditions of interest parity do not hold (equation 2), comprise one group. Trader-Hedgers are those importers and exporters who use the market to offset foreign exchange risk. This group can be assumed to always purchase foreign exchange and thus not affect the exchange rate, or specified in such a manner that their actions are included in the speculative function.[22] The third group of forward market participants are speculators. They respond to differences between the forward exchange rate for delivery at a future date, f, and the spot exchange rate expected to prevail at f.

A two participant model (arbitragers and speculators) has resulted from this work and has become the standard treatment for the forward market. Let us briefly describe the net supply and demand characteristics of these two functional groups.

Arbitragers, of course, are the sole participants of consequence in the interest parity theory. That speculators have a role, at all, implies that arbitragers have a different net demand for forward exchange than earlier postulated. Arbitragers, in the theory of interest parity, have a perfectly elastic net demand for forward exchange at the interest parity rate. As illustrated in Exhibit III-1 on page 44, AA is the net demand for foreign exchange by arbitragers, IP is the interest parity rate, and S is the spot rate.

The modern theory assumes that the net demand schedule of arbitragers is not perfectly elastic for any of a variety of reasons.[23] The resulting net demand is presented in Exhibit III-2 on page 45, A'A' is the net demand schedule of arbitragers. If no other participants affect the rate, as the Fisherian Theory implies, this distinction would not matter--the forward rate would equal the interest parity rate.

Speculators, however, need not be passive participants in the foreign exchange market. Expectations of price changes result in speculative activity in most financial markets. In the case of the spot exchange rates, the resulting speculation takes place in the forward market. This is due to greater leverage opportunities and a corresponding reduction in opportunity cost. Most forward speculation requires only a ten percent (or less) cash margin, and the remainder is not financed since it is a futures contract.

Speculators' net supply of forward exchange, SS, is a function of their expected spot rate at time f, E (S)f and the forward rate for contracts maturing at f. Exhibit III-3 on page 46 indicates this net supply function.

The modern theory results in an equilibrium forward exchange rate at the intersection of the net demand of arbitragers and the net supply of speculators as presented in Exhibit III-4 on page 47.

IV. Synthesis of Forward Market Theories

Most of the empirical work, dealing with national money markets, shows the forward rate responds to changes in the interest rate differential by fifty to ninety percent.[24] A body of work testing the forward rate relative to interest differentials in the external currency markets, the so-called "Euro Currency" markets, shows no difference between the interest parity rate and the actual forward rate.[25] The latter findings support any of the forward market theories above and suggest a more comprehensive theory of the forward market is needed.

Synthesis Models

Two recent works attempt to unite the theories above into a single model. While there are similarities between the two, the theoretical differences warrant separate development and careful comparison.

The earlier of these studies, by Giddy,[26] is based upon four related theories. Each theory is named, discussed, and defined by its equilibrium equation below. The variables are converted to the standard notation of this manuscript for consistency.

Purchasing Power Parity: the theory that the spot exchange rate reflects the relative prices in the two countries and changes in prices must be reflected in changes in the exchange rate. II represents inflation.

$$\frac{S_{t+f} - S_t}{S_t} = II_a^f - II_b^f \qquad (16)$$

and

$$E\left[\frac{S_{t+f} - S_t}{S_t}\right] = E(II)_a^f - E(II)_b^f \qquad (17)$$

Interest Rate Parity: the IPT as discussed above.

$$\frac{F_t^f - S_t}{S_t} = I_a^f - I_b^f \qquad (18)$$

Interest Rate Theory of Exchange Rate Expectations: a theory which states that efficient financial markets are all related and therefore, the difference in interest rates will be equal to the expected percentage change in exchange rates.

$$E\left[\frac{S_t^f - S_t}{S_t}\right] = I_a^f - I_b^f \qquad (19)$$

The Forward Rate Theory of Exchange Rate Expectations: a theory which argues the forward rate is the best predictor of the expected spot rate.

$$\frac{F_t^f - S_t}{S_t} = E\left[\frac{S_{t+f} - S_t}{S_t}\right] \qquad (20)$$

or

$$F_t^f = E(S_{t+f}) \qquad (21)$$

Giddy uses the four theories, and the listed equations which represent their equilibrium conditions to conclude the:

> . . .best forecast of the future spot rate. ($\hat{S}_{t+n}$) is either the interest rate differential or the forward rate, since these two are identical. If the forward exchange market is efficient, then any empirical result that is inconsistent with the previous statement is probably based on incorrect combinations of interest rates or exchange rates, or the result of capital controls inhibiting arbitrage.[27]

Interestingly, he goes on to point out that according to the theoretical development, "after expected rates of inflation have been subtracted, interest rates in different currencies are equal". Thus he demonstrates the assumption of equal real rates of interest, which is necessary for the Fisherian Theory, must be true if the equilibrium conditions for the Fisherian Theory are given.

His major contribution to Forward Market Theory in this work is the demonstration of equality in the expected change in spot exchange rates, the forward premium, interest rates, and inflationary expectations. In effect, the Modern Theory, Fisherian or Purchasing Power Theory, and Interest Parity Theory are all equivalent, if properly measured. Exhibit III-5 on page 48 illustrates this graphically.

Hodgson's[28] model is more general than Giddy's; its theoretical development allows for risk or uncertainty while Giddy implicitly assumes away risk. While both models are comparative static models, Hodgson's discussion of the dynamic mechanisms of various models is an important contribution of the paper.

Hodgson develops a general statement of the Modern Theory. He then demonstrates the Interest Parity, Fisherian, and a more recent "Cambist"[29] are special cases of the MT. These special cases occur when certain variables are constrained to zero values. Giddy, in effect, denies the MT since F_{ip} always equals E(S).

Following Hodgson's work, the forward exchange rate is determined by arbitragers and speculators. The arbitrage net demand function depends on the expected return and perceived risk of the simultaneous undertaking of the four financial transactions necessary for covered interest arbitrage. The expected return, of course, is the difference in the current forward rate and the interest parity rate, $(F_{ip} - F)$.

He specifies[30] the following general function for risk based on the size of an arbitrager's position and his level of perceived default risk:

$$\lambda = T - g(Q_B) \qquad (22)$$

where

λ = a risk factor which measures the effect of default risk on the arbitrager's willingness to hold foreign assets.

T ranges from zero to infinity as the perceived probability of default ranges from 0 to 1.

$g(Q_B)$ reflects the relationship of risk aversion to the size of the position (Q_B).

This can be used to specify equation for the net demand schedule of covered interest arbitragers.

$$Q_A = 1 / \lambda \ (F_{ip} - F) \qquad (23)$$

So the IPT becomes a special case of the MT where $\lambda = 0$.

Hodgson's speculative function is given as one of proportionately, $Q_S = \alpha\ (F - E(S))$. Solving the two equations for F, the equilibrium forward rate:

$$1/\lambda\ F(_{ip} - F) = (F - E(S)) \qquad (24)$$

$$F = \frac{F_{ip}}{1-\lambda\alpha} + \frac{\lambda\alpha\ E(S)}{1-\lambda\alpha} \qquad (25)$$

Hodgson then separates nominal interest rates into three components: real rates of interest; inflationary expectations, and any other explanatory factors, X. The rate of interest for country j would be:

$$j = \alpha j + E(II)_j + Xj$$

and

$$F_{ip} = \left(S\ \frac{1 + I_a}{1 + I_b}\right) = S\left(\frac{1 + r_a + E(II)a + Xa}{1 + r_b + E(II)b + Xb}\right) \qquad (26)$$

If expectations concerning the spot rate to prevail in the future are purely a function of inflationary expectations, then $E(S) = S\ \frac{1 + E(II)a}{1 + E(II)b}$ (27)

Hodgson suggests there may be other factors present as well, Z. So the expected spot exchange rate is:

$$E(S) = S\left[\frac{1 + E(II)a + Z_a}{1 + E(II)b + Z_b}\right] \qquad (28)$$

and substituting (28) and (27) into equation (26) we have his specification of the equilibrium equation for the MT:

$$F = S\left(\frac{1}{1 + \lambda\alpha}\right)\left(\frac{1 + r_a + E(II)a + X_a}{1 + r_b + E(II)b + X_b}\right) + S\left(\frac{\lambda\alpha}{1+\lambda\alpha}\right)\left(\frac{1+E(II)a+Z_a}{1+E(II)b+Z_b}\right) \qquad (29)$$

He then shows that IPT is equation (20) with $\bar{\gamma} = 0$. The Fisherian Theory is equation (29) and $r_a = r_b$ = constant, and $x_a = x_b = x_a = z_b$ = zero. Finally he presents the Cambist Theory and demonstrates it as a restatement of the MT (in fact IPT) with the assumption $\bar{\gamma} = 0$.

Hodgson's model is a general statement of the modern theory of the forward exchange rate and serves well as a general model in the theoretical development of the following chapters.

FOOTNOTES TO CHAPTER III

1. Paul Einzig, A Dynamic Theory of Foreign Exchange, 2nd. ed. (London: Macmillan, 1966): 132-143.

2. Ibid., p. 18.

3. Ibid., p. 1

4. John Maynard Keynes, "The Forward Market in Foreign Exchanges," Manchester Guardian Reconstruction Supplement (April 20, 1922).

5. John Maynard Keynes, A Tract on Monetary Reform (London: Macmillan, 1923).

6. Paul Einzig, "Some Theoretical Aspects of Forward Exchanges," Economic Journal (September 1936).

7. The term "Fisherian approach" was first applied by John J. Pippenger, "Spot Rates, Forward Rates and Interest Differentials," Journal of Money Credit and Banking 4 (May 1972): 375-383.

The theory incorporates Irving Fisher's interest theory: nominal interest rates differ from real interest rates by the inflationary expectations of investors. Fisher presented no forward market theories.

8. Einzig, "Some Theoretical Aspects of Forward Exchanges," p. 205.

9. W. W. Syrett, "A Revision of the Theory of Forward Exchanges," The Banker (June 1936).

10. Einzig, The Theory of Forward Exchange, (London: Macmillan, 1937).

11. Einzig, A Dynamic Theory p. 205.

12. Ibid., p. 206.

13. Ibid.

14. Pippenger

15. Ibid., p. 378.

16. John J. Van Belle, "Spot Rates, Forward Rates and the Interest-Rate Differentials," Journal of Money Credit and Banking 5 (November 1973): 997-999.

17. J. Markham Collins, "The Purchasing-Power Parity Problem," unpublished manuscript presented in Seminar in International Economics, University of Oklahoma, Fall 1973.

18. S. C. Tsiang, "The Theory of Forward Exchange and Effects of Government Intervention on the Forward Exchange Market," International Monetary Fund Staff Papers (April 1959): 75-106. "Spot Speculation, Forward Speculation, and Arbitrage - A Clarification and Reply," American Economic Review (Winter 1973): 999-1003.

19. For example:
Herbert G. Grubel, Forward Exchange, Speculation and the International Flow of Capital, (Stanford: Stanford University Press, 1966).

20. John H. Auten, "Forward Exchange Rates and Interest-Rate Differentials" The Journal of Finance 17 (December 1963): 11-19.

21. Leland B. Yeager, International Monetary Relations: Theory, History, and Policy, 2nd ed. (New York: Harper & Row, 1976).

22. Egon Sohman, The Theory of Forward Exchange, no. 17 (Princeton: Princeton Studies in International Finance, 1966).

23. A most comprehensive list of these reasons is presented in: Lawrence H. Officer and Thomas D. Willet, "The Covered-Arbitrage Schedule: A Critical Survey of Recent Development," Journal of Money, Credit and Banking 2 (May 1970): 247-257.

Hans R. Stoll, "Causes of Deviation from Interest-Rate Parity, A Comment," Journal of Money, Credit and Banking 4 (February 1972).

24. J. L. Stein, "The Forward Rate and the Interest Rate," Review of Economic Studies (April 1965): 40-66.

Hans R. Stoll, "An Empirical Study of the Forward Rate Under Fixed and Flexible Exchange Rate Systems," Canadian Journal of Economics, (February 1968): 55-78.

25. Richard J. Herring and Richard C. Marston, "The Forward Market and Interest Rates in the Eurocurrency and National Money Markets," unpublished working paper, (Philadelphia: The Wharton School, University of Pennsylvania).

26. Ian H. Giddy, "An Integrated Theory of Exchange Rate Equilibrium," Journal of Financial and Quantitative Analysis, (December 1976): 883-892.

27. Ibid., p. 891.

28. John S. Hodgson, "Reconciling Alternative Theories of the Forward Exchange Market," unpublished manuscript, (Milwaukee: University of Wisconsin at Milwaukee).

29. The Cambist Theory is discussed in:
J. Spraos, "Speculation, Arbitrage and Sterling," Economic Journal 69 (1959): 1-21.

and advanced by:
Paul Coulbois and Pierre Prissert, "Forward Exchange, Short-Term Capital Flows and Monetary Policy," De Economist 122 no. 4 (1974): 283-308.

30. Hodgson, "Reconciling," p. 5.

Exhibit III-1

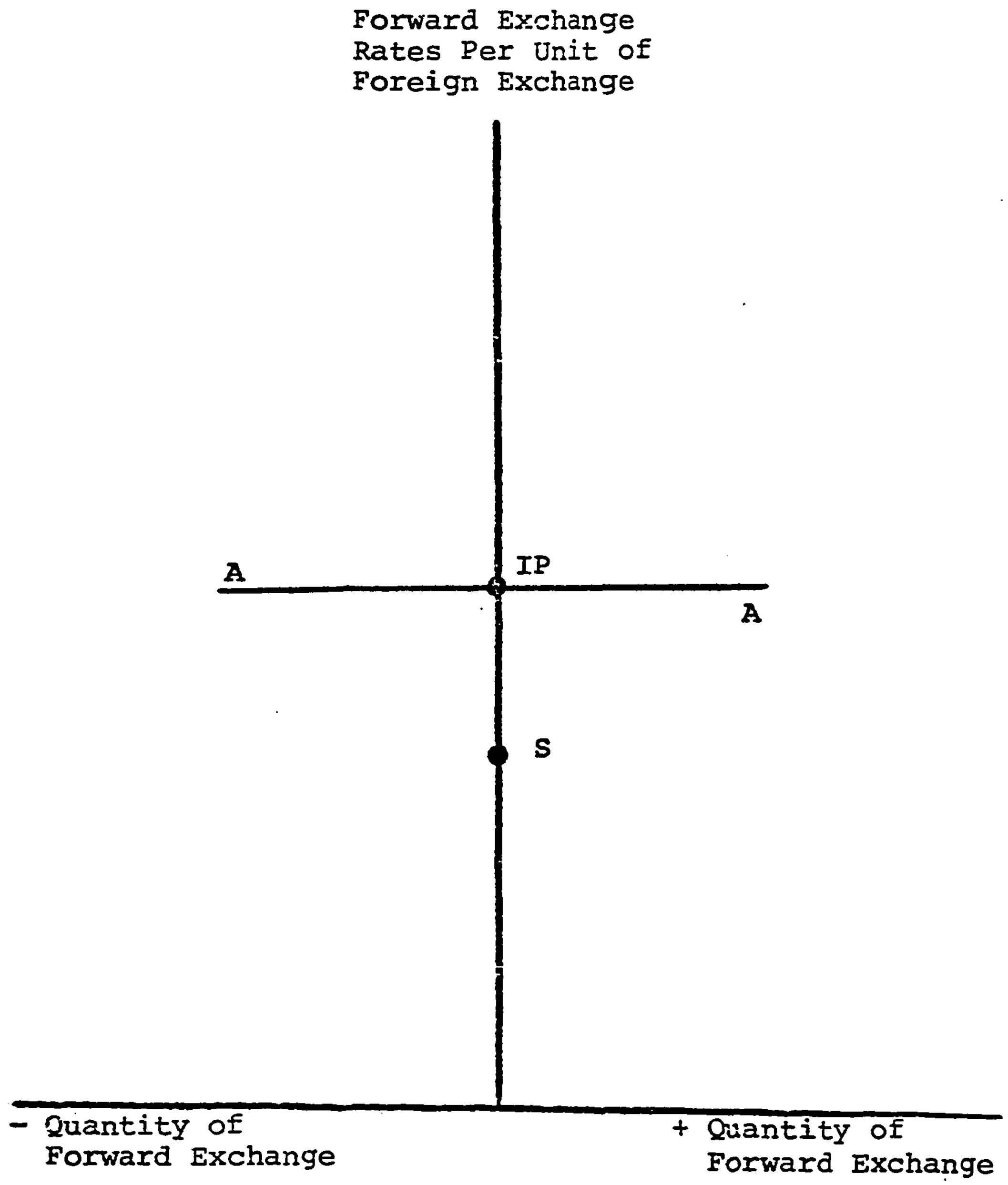
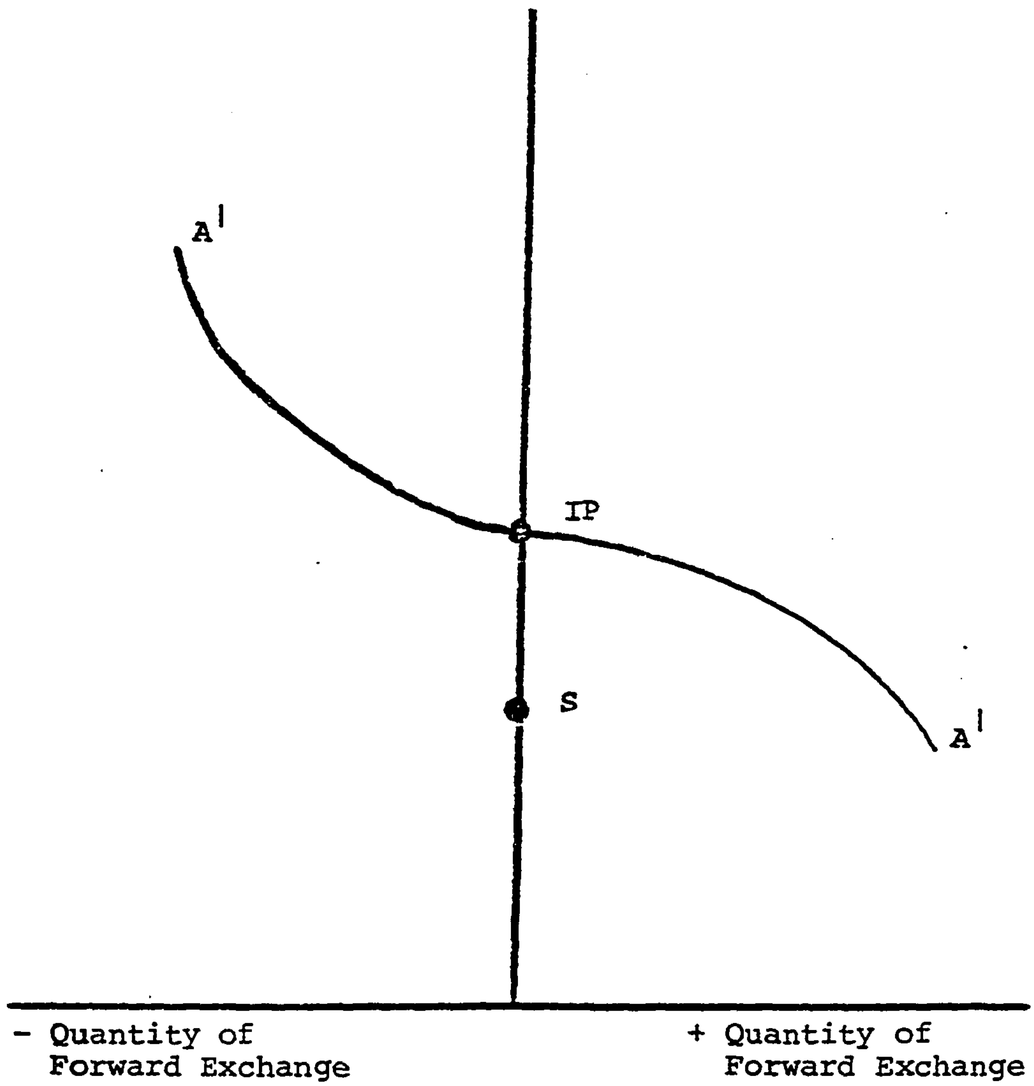


Exhibit III-2



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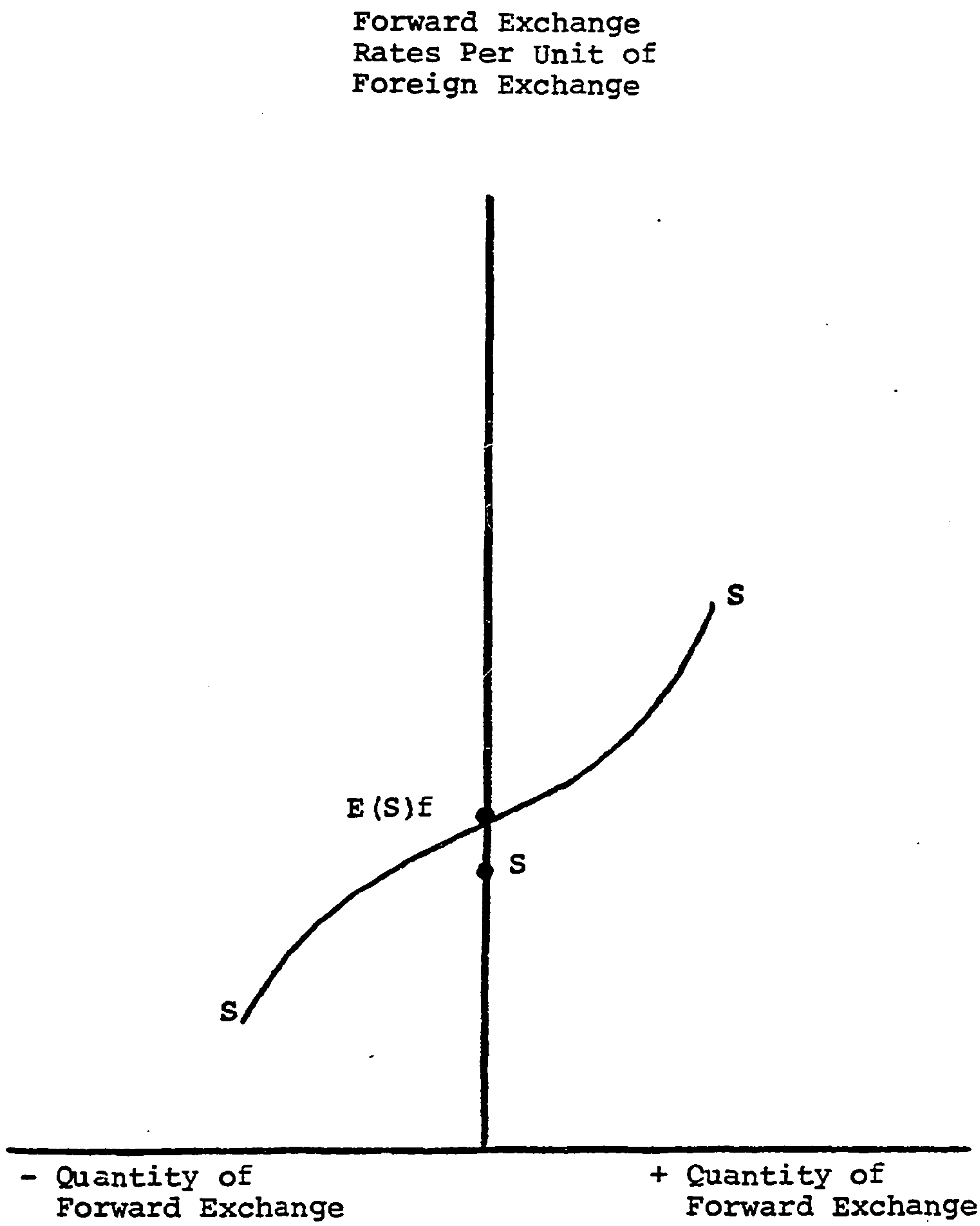

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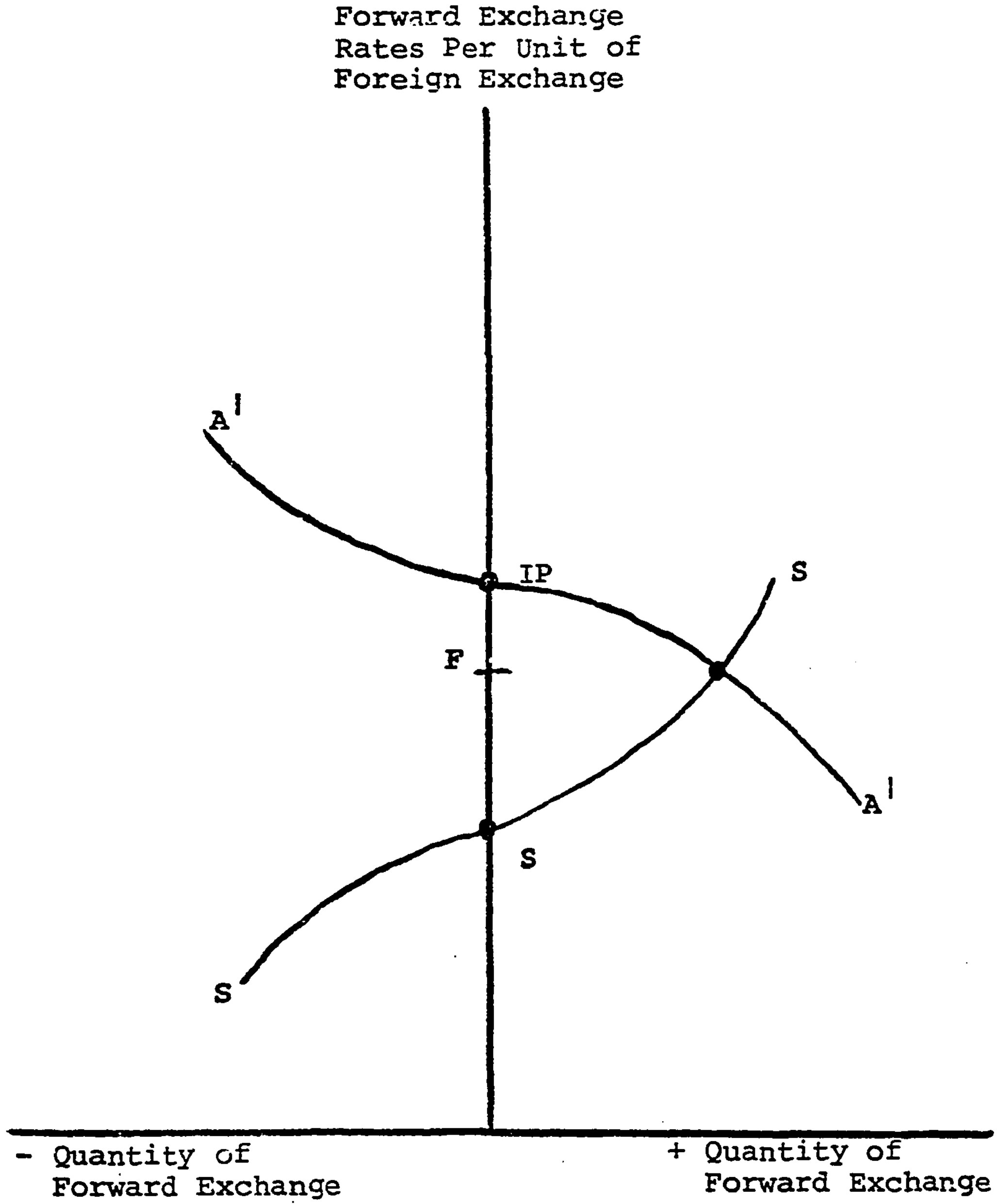
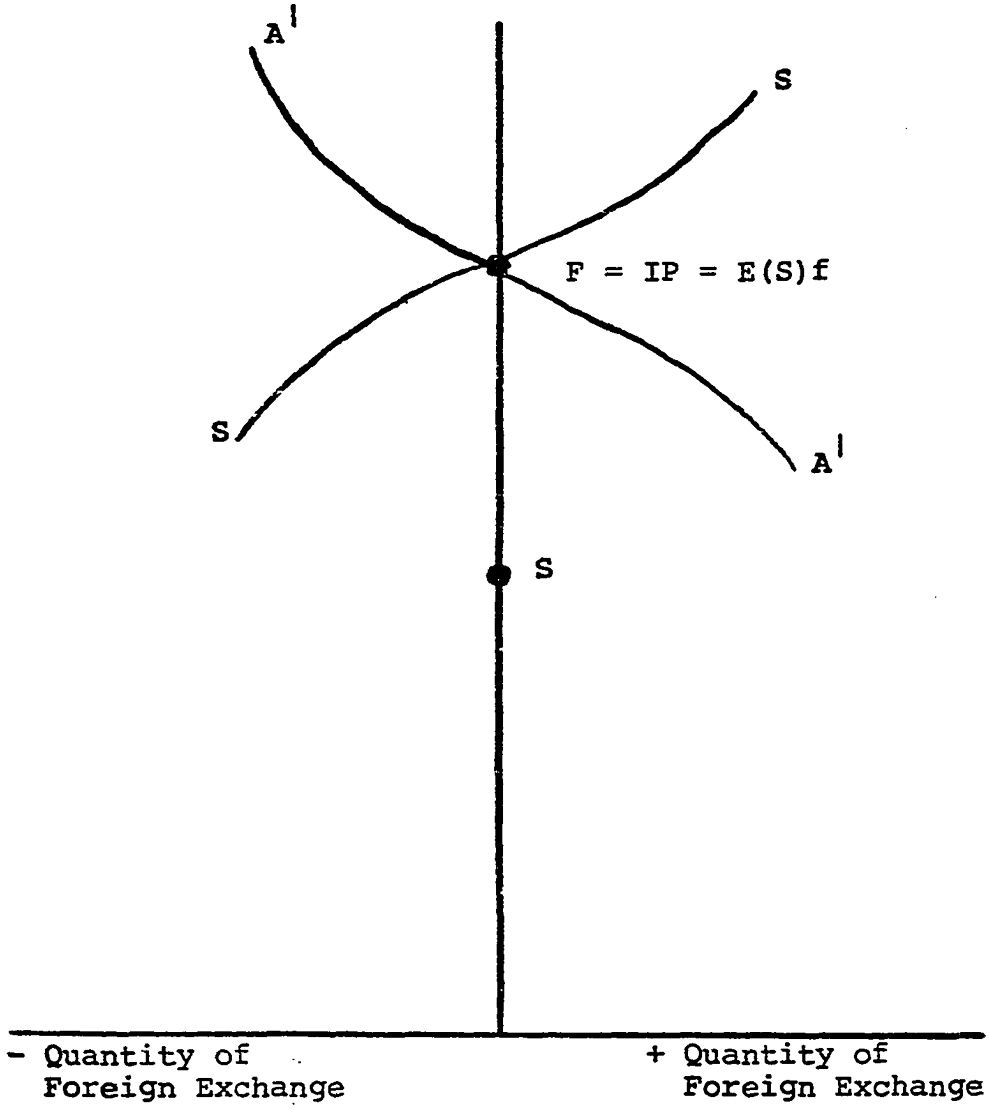


Exhibit III-5



CHAPTER IV

THE EFFICIENCY OF THE FORWARD MARKET: THEORIES AND TESTS

The application of the Efficient Markets Theory and Analysis to the foreign exchange markets has not been substantial, although several studies have been presented. This section summarizes some of the most important of these so that the originality of this dissertation's data set, theory, and tests may be established.

Herbert Grubel's[1] volume is one of the earliest published in this area. Although Grubel does not specifically state this, his work is a weak-form test of efficiency. He points out that a futures market, such as foreign exchange, must compare purchases price of a future contract to expected spot prices during the length of the forward contract.

Let

F^f = the thirty day forward rate

S_t = the spot rate (t = 1 to f)

such that

S_1 = spot rate the day the forward contract is initiated and

S_f = spot rate the day the forward contract matures.

Then, if $F^f < E(S_t)$ a forward exchange speculator should buy forward foreign exchange. He would expect to sell spot prior to maturity of the forward contract, hence profit from the transaction.

When $F^f > E(S_t)$, the speculator sells forward since conditions are reversed.

He tests three expectations models for the spot exchange rate between the U.S. dollar and British pound. For data, he uses daily and weekly exchange rates from July, 1955 through April, 1961. The models:

(i) E(Spot)t = $2.80 the parity rate

(ii) $E(\text{Spot})t = \sum_{t=1}^{50} \text{Spot}_i / 50$

(iii) ". . .spot rates often move in clearly discernible cycles with definite upper and lower bounds (the intervention points), resembling sine waves with rates of change slower the greater the proximity to the intervention points."[2]

Using these three expected value models, Grubel's hypothetical speculator will sell forward when $F^f > E(\text{Spot})_t$ and buy forward when $F^f < E(\text{Spot})_t$. Transaction costs are assumed zero, but a ten percent margin is required for forward contracts.

Three periods were tested:

(i) the entire period, July 1955 - April 1961.

(ii) only those periods when the forward rate did not conform to interest parity within 1/2 percent.

(iii) those periods left out of group (ii).

The quantity of forward exchange bought or sold can also vary. Grubel has two rules for this: (i) a constant amount, (ii) increasing amounts as the forward rate approached the 1% bands around the parity rate.

While all three expected value models are profitable for these periods, they are most profitable using the second quantity rule. This suggests his work may be invalid for a period of floating rates, but it does indicate past spot prices can be profitable information during a period of pegged exchange rates.

Poole[3] tests the spot exchange rate for randomness, a weak form test. His data is ten sets of daily exchange rates between the U.S. and the following countries over the dates indicated.

Country	Dates
Argentina	4/7/19 - 8/27/27
Belgium	4/7/19 - 8/29/25
Canada-1	4/7/19 - 6/28/24
Canada-2	10/4/50 - 5/2/62
France	4/7/19 - 12/4/26
Italy	4/7/19 - 8/1/25
Japan	4/7/19 - 11/23/29

Norway	4/7/19 - 4/28/28
Sweden	4/7/19 - 4/5/24
United Kingdom	4/7/19 - 5/2/25

Poole's contribution consists of three tests performed on the ten time series.

(i) Serial Correlation: If $d_t = \log S_t - \log S_{t-1}$, where St is the daily exchange rate at observation, then first serial correlation is a simple regression of d_t on d_{t-1}. Poole finds this correlation to be low but positive (except for Sweden which had negative correlation in the daily observations). All correlation coefficients are positive and slightly larger for the weekly changes. He finds "no doubt about the statistical significance of the serial dependence for most of the series."[4]

(ii) Variance - Time Function:

Let $d_{it} = \log S_t - \log S_{(t-1)}$. If D_{1t} series is serially independent, then Var d_{it} should equal i times Var d_{1t}, since $d_{it} = \sum_{k=0}^{i} d_1 (t-k)$, and the variance of a sum of independent random variables equals the sume of their variances.

For any i value, the expression $\text{Var}(d_{it/i})$ provides an estimate of the one period variance. Systematic change in this estimator as i changes indicates serial correlation. Poole tests the variance-time function, allowing i to be 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 non-overlapping day periods. In all cases, as i increases, the estimate of a one period variance increases. This indicates the independence assumption may be invalid and serial correlation present.

(iii) Filter Rules: The preceding are tests of randomness, while the filter rule comes much closer to a fair game test. Poole chooses a rule based on the following pattern: when the rate has risen X% from a trough, one should buy and hold until the rate has fallen by X% from a peak, then sell. His ten filters range from .1% to 2.0% except for Canada-2 which has a smaller variance. There the range is .1% to 1.0%. Relative to a strategy of buy and hold, Poole's filter rules indicate profitability. Poole averages a 17.5% return from a two percent filter rule with an annual average of 12.5 transactions. (Transactions cost, which he does not specify, might be responsible for the filter rules outperforming a buy and hold strategy.) Under the monetary system then in effect, the maximum change in an exchange rate (without a devaluation) was 2%.

To summarize, Poole finds floating exchange rates to be non-random and not in conformity with a fair game model when transactions costs are excluded. Although he does not test this, he suggests that the barrier to efficiency is the transactions costs and possibly a risk factor which he cannot quantify.

Roger G. Upson's[5] contribution is a random walk test of the forward exchange market. He applies spectral analysis to the three month forward market between the U.S. dollar and British pound sterling for the time period 1961-1967. His actual tests use weekly data and perform spectral analysis on the series of first difference between the forward rates quoted end-of-week.

Based on his spectral analysis, Upson finds frequencies or cycles of 32, 3.8, and 2.5 weeks. Since such cycles would not exist if the series was independent, he concludes the hypothesis of non-randomness is accepted. He shows this to be empirically significant at the .05 level.

In testing the distribution of the time series of first differences, he finds significant deviation from the normal distribution. Although symmetrical, the distribution is very leptokurtic relative to the normal distribution, and Upson demonstrates his data is significantly different from a normal distribution. More concerning the distribution of foreign exchange returns will be presented in Chapter VI.

Upson's important contribution is the application of spectral analysis to the foreign exchange market. To add several criticisms of his conclusions should not diminish the importance of the effort, but he incorrectly claims that the forward exchange market is inefficient if the forward rates are not independent through time. Since his spectral analysis indicates cycles in the time series of weekly rate differences, he argues the market for foreign exchange is inefficient.

The test for randomness is disproved but this cannot be introduced as proof of inefficiency in the market. Only if one can use past forward rates to earn a rate of return greater than the norm for this risk class can inefficiency be concluded. Upson offers no fair game test of efficiency. In an additional point, he mentions the inefficiency, or in this case non-randomness, of the spot market. Since this was a period of pegged exchange rates, the progression of spot rates was quite likely not random; therefore, the forward rate, determined in part by the spot rate, could not be expected to be random.

Giddy and Dufey[6] have prepared a true test of the fair game model in foreign exchange and forward exchange. They make a clear statement regarding profitability in a speculative market, ". . .opportunities for monetary gain require not only the availability of a superior forecasting model but also the exclusive use of such a model."[7] They test for the presence of the dual conditions using four hypotheses or forecasting models of the foreign exchange rate. Using daily exchange rates for France, the United Kingdom, and Canada with the United States during the periods of floating rates in the early twenties and the early seventies, their theoretical models are summarized on the following page.

Hypothesis 1: Martingale

If the series of exchange rates can be represented by a martingale, then the probability of an exchange rate increase equals the probability of an exchange rate decrease, and both are fifty percent. The expected value of the exchange rate in the following period, knowing the information signified by Ø, is the same as the rate in this period.

$$E(S_{t+1} \mid \emptyset) = S_t \tag{1}$$

And the expected return from foreign exchange is zero.

$$\frac{E(S_{t+1} - S_t \mid \emptyset)}{S_t} = 0 \tag{2}$$

Hypothesis 2: Submartingale

The martingale model implies foreign exchange is held as non-interest-bearing demand deposits. The submartingale is an alternative model which takes into account potential returns form interest-bearing instruments. Here the equilibrium spot rate differs from the expected future spot rate by the difference in interest rates in the two countries. This model is quite similar to the familiar interest parity model, with one important difference: the expected spot rate, rather than the present forward rate, is used.

$$E(S_{t+1} \mid \emptyset) = S_t(I_a - I_b) \tag{3}$$

The authors construct a model which incorporates a risk premium in the submartingale model, but they do concede it is only one of many such models. When testing this model, they include no specification of risk. Indeed, Giddy argues against the existence of this risk in another article.[8] He questions the logic of a speculator receiving a risk premium for taking a position on currency A since the speculator who took the opposite position will receive a risk loss for taking risk. The obvious criticism of this line of argument can be found in the modern theory of the forward market. Participants other than speculators are present in the forward market. Hedgers and arbitragers may take the other side of the speculators' transaction.

So, hypothesis 2, the submartingale model, has no provision for a risk premium. This model, stated in terms of a rate of return:

$$E(R_{t+1} | \emptyset) = I_a - I_b \qquad (4)$$

Hypothesis 3: The Forward Rate as a Predictor of the Future Spot Rate

Under several models, the forward rate must equal the expected spot rate. This would be true if the Fisherian Theory holds or if Giddy's[9] integrative model is correct. It would also be the case under Hodgson's[10] reconciliation when the real rates of interest are equal and $X_a = X_b = Z_a = Z_b = 0$, so that nominal interest rates and expected spot rates are affected by only the present real rates and inflationary expectations. Hodgson's model also gives this result when default risk is very high, $\lambda \to \infty$, so that arbitragers do not enter the market.

This model, expressed as a rate of return:

$$E(R_{t+1}) = \frac{F^f - S_{t+1}}{S_t} \qquad (5)$$

Hypothesis 4: Time Series Forecasting

Since many time series display statistical dependence, the authors attempt to establish the form of this dependence and employ it to earn above normal returns. Two models were employed.

(a) Box-Jenkins

The general case of this linear combination model is a combination of autoregressive past observations and a weighted average of past error terms (ARMA). When the model considers differences in the series, the model is termed integrated and designated ARIMA (p, d, q) where p indicates the order of the autoregressive process, q indicates the order of the moving average, and d indicates the order of difference in the original series. Since the ARIMA method is based on past observations, it is a test of weak form efficiency.

(b) Although one can argue that exponential smoothing is subsumed by the ARIMA models, the authors test this model specifically by making twenty exponential smoothing forecasts of the Canadian dollar during the 1970's floating period. The forecasts were made using the Winter's Method.[11]

Giddy and Duffy subject their data set and models to three areas of testing. First, they use Box-Jenkins analysis on the daily exchange rate data to test for time series dependencies. Second, they compare the predictive power of the five forecasting models. And finally, they perform a statistical analysis of the variability and distributional characteristics of the daily exchange rate changes.

Their results show the following:

(i) Serial dependence is present in the exchange rate series during the period after WWI. The correlation is weak and unstable. Slight dependence is present in the rates during the 1970's period, but the correlation is even more unstable than the earlier period. When the series is divided into two periods and dependencies established in the earlier period are applied to the latter period, no profitable information is present.

(ii) The martingale and submartingale hypotheses consistently produce the best fit. Using the 1970's data, forecasts using all five methods above are constructed. A total of 860 forecasts are made. The results are then compared, based on the mean squared predictive error.[12]

The results show the forward rate is consistently inferior to the other four forecasting techniques. Box-Jenkins and exponential smoothing give very poor results when the forecast period is of any length. Some very short term forecasts were not significantly different from the martingale and submartingale.

One interesting fact was that no significant difference is present between the martingale and submartingale performance on an overall basis. One performs better in some cases but worse in others. The authors' conclusion regarding this is worth noting.

> Indeed, it is arguable on both theoretical and empirical grounds that the most accurate model might be one in which interest rate differences are taken into account in traders price-setting actions, but not to the full extent that would yield the parity relationship implied by (the IPT).[13]

This is certainly supportive of the MT and Hodgson's reconciliation of the various theories into special cases of the MT.

(iii) The statistical distribution of the daily exchange rate changes displays evidence of non-normality. In every case the distributions exhibit the elongated tails and exceptionally high peaks characteristic of leptokurtosis.

Fieleke[14] tests for efficiency by measuring the spread between bid and asked prices for foreign exchange as quoted in the interbank transactions. He views this markup as a proxy for the retail markup faced by bank customers making foreign exchange transactions.

The markup is a function of four factors, he argues. These are the volume of transactions, the degree of competition among banks, the governmental restrictions on international exchange, and the level of uncertainty regarding future exchange rate changes. The markup is inversely related to the first two factors and directly related to the latter two in Fieleke's theoretical presentation. Since his data covers only the calendar year of 1971, he eliminates the first two variables from his empirical work. Competition is unlikely to change greatly in such a short period, he argues, and volume data is simply not available. He suggests volume is not important, but he fails to explain this in detail.

The other variables are deemed important, but unavailable. He establishes proxy variables for these two: the size of the covered interest differential relative to the same variable during a normal period stands for both uncertainty and restrictions; the rate of change in the exchange rate is a proxy for risk; and announcements by public officials constitutes events which may affect expectations.

His results indicate the markup varies directly with the proxy variables and raises the question of what causes the proxy variables to change. His tests over 1971 do not indicate events such as those surrounding August 15, 1971, and the severance of the U.S. link to gold affect the proxy variables greatly. In effect, the study does not reach a conclusion about market efficiency in the terms of this paper. The effects of public announcements in 1971 would be examples of public information and be testable as a semi-strong form of the efficient market, but not during a period such as 1971. For half that year, the rates were pegged under the Bretton Woods agreement, and during the remainder, much interference by national central banks was in evidence.

Roll and Solnik[15] present an interesting application of the Capital Asset Pricing Model to the foreign exchange markets. Their model specifies that the interest differential between equivalent and financial assets in two countries is a biased predictor of the changes in the spot exchange rate over the period in question. The bias is a result of exchange rate risk and is a function of the "covariances between the spot exchange rate in question and the spot rates of all other countries."[16] So theirs is a portfolio model which is consistent with the MT and Hodgson's reconciliation in its framework.

Roll and Solnik develop a market index model using each currency traded (relative to a numeraire currency) as the assets and giving each currency equal weight.[17] This model expresses the interest differential in terms of the expected exchange rate change plus the measure of systematic risk times the market index:

$$Ib-Ia = P_{ba} + \beta a \sum_{j=1}^{n} w_j (I_b - I_a - P_{pj}) \text{ for } a=1 \text{ to } N \tag{6}$$

$$P_{bj} = E(S_{j,\ t+1} - S_{j,t}) \,/\, S_{j,t} \tag{7}$$

w_j = the weight of country j currency.

Of course the standard assumptions of market efficiency apply: perfect capital mobility and markets, zero transactions costs and taxes, continuous trading, and constant equilibrium.

The authors assume interest parity holds, allowing the interest parity equation to substitute for the interest differential and combining equations (6) and (7), we have:

$$E\left[(\hat{S}a,t+f - Fa^{f}_{,}t) \mid Sa,t\right] = \beta_a \sum_{j=1}^{n} W_j E\left[(\hat{S}_{j,t+f} - F^{f}_{j,t})\ S_{j,t}\right] \quad (8)$$

for a = 1 to n.

Given the model, returns on foreign exchange speculation can be divided into normal and extraordinary return with $\left((Fa^{f}_{,} - S_{a,t})/Sa,t\right)$ equal to the normal return and

$\left((S_{a,t+f} - Fa^{f},\ t)/Sa,t\right)$ equal to the extraordinary return.

The extraordinary return is a return on taking a risky position in country A currency. Let $R_{a,t}$ stand for this rate of return and equation (9) defines the linear model which Roll and Solnik "subject to empirical scrutiny".[18]

$$R_{a,t} = \alpha_a + \beta_a \sum_{j=1}^{N} W_j R_{j,t} + E_{j,t} \quad (9)$$

where $E_{j,t}$ is the error term.

If their model is correct, α should be zero for all currencies, and β should reflect the systematic risk of changes in currency as relative to all other currencies. The authors use monthly data for eight countries' observed exchange rates relative to the U.S. The results of the time series estimations on exchange rate indicate α values are not significantly different from zero in almost all cases. Slope coefficients, the β values, are significantly different from zero (Giddy's model, the Fisherian Theory, or the Cambists would all predict $\beta=0$.)

Using the time series estimates in cross sectional analyses the authors cannot draw any strong conclusions from the empirical data. They interpret the results as supporting their theory, but only from a qualitative perspective.

The portfolio model is interesting and is a very significant contribution to the foreign exchange literature. The model supports the use of some version of the MT of forward exchange. In general, their tests support efficiency in the spot market if the forward rate is used as the information set.

The area of forward exchange has been exposed to the efficient markets analyses and theories. Some support of weak form efficiency in floating periods has been established. However, much more analysis is warranted in this area.

Some tests cited above were performed during fixed exchange rate periods; this makes their results suspect as tests of market efficiency. Few tests use daily exchange rate data; this may affect the results since efficiency considers how quickly the market adjusts to new information. No tests use data other than exchange rates denominated in U.S. dollars; other exchange rate series may give different results. Finally, no tests of efficiency between forward rates of different duration have been presented; this is an area which could yield interesting results.

FOOTNOTES TO CHAPTER IV

1. Herbert G. Grubel, Forward Exchange, Speculation, and the International Flow of Capital (Stanford, California: Stanford University Press, 1966).

2. Ibid., p. 106.

3. William Poole, "Speculative Prices as Random Walks: An Analysis of Flexible Rates," Southern Economic Journal 33 (April 1967): 468-78.

4. Ibid., p. 471.

5. Roger B. Upson, "Random Walk and Forward Exchange Rates: A Spectral Analysis," Journal of Financial and Quantitative Analysis 7 (Sept. 1972): 1897-1906.

6. Ian H. Giddy and Gunter Duffy, "The Random Behavior of Flexible Exchange Rates: Implications for Forecasting," Journal of International Business Studies 6 (Sept. 1975): 1-32.

7. Ibid.

8. Giddy, "An Integrated Theory."

9. Ibid., p. 890.

10. Hodgson, "A Reconciliation."

11. P. R. Winters, "Forecasting Sales by Exponentially Weighted Moving Averages," Management Science 6 (1960): 324-342.

12. Since the R^2 of a random walk (martingale) model is zero, the Box-Jenkins produced better sample period R^2 values. The authors' concern is with predictive ability, however, and not with goodness-of-fit. Therefore, the mean squared predictive error is the more meaningful statistic for this purpose.

13. Giddy and Dufey, "Random Behavior," p. 27.

14. Norman S. Fieleke, "Exchange-Rate Flexibility and the Efficiency of the Foreign-Exchange Markets," Journal of Financial and Quantitative Analysis (Sept. 1975): 409-428.

15. Richard Roll and Bruno Solnik, "A Pure Foreign Exchange Asset Pricing Model," Journal of International Economics 7 (1977): 161-179.

16. Ibid., p. 163.

17. According to Solnik, the wj value should be the net value of country j capital owned by foreigners, as a percentage of world capital. This was unavailable and various proxies did not give significantly different results from equal weights. See Solnik, Bruno, European Capital Markets: Toward a general theory of international investment. (Lexington, Mass.: Lexington Books, 1973): 34-35.

18. Roll and Solnik, p. 165.

CHAPTER V

WEAK FORM EFFICIENCY AND INTERTEMPORAL ANALYSIS: THEORY AND HYPOTHESES

Unlike the market for common equities, and most financial assets, speculation in the foward market for foreign exchange requires separate transactions in two assets. In the stock market, an investor purchases (or sells short) an asset and later sells (or purchases) the same asset in the same market. Forward market speculators sell (buy) a currency in the forward market then buy (sell) the currency in the spot market when the forward contract matures.[1] The unique features of this market imply that weak form analysis of the forward market should consider the spot rate of exchange at the maturity date of the forward contract, as well as the forward rate. The first section of this chapter states the theory and develops the tests of weak form efficiency appropriate for the forward market as well as presenting the testable hypothesis for market efficiency.

An alternative method of completing a forward speculative transaction is to reverse the initial position with an opposite forward transaction subsequent to the initial transaction. For example, a speculator buying British Pound Sterling 90-days forward against the dollar (expecting an appreciation of Sterling above the existing forward rate) might sell Sterling 60-days forward during the first 30 days of the contract (if the speculator felt the profitability conditions appropriate). The results of these transactions guarantee neither a profit nor a loss, but they do enable the speculator to satisfy his delivery obligations relative to dollars and Sterling.

This technique, a type of activity labeled by Einzig[2] "time arbitrage" is discussed in the second section of this chapter and a testable hypothesis is presented. While weak form tests and analysis are important, the theoretical development and empirical tests of the time arbitrage conditions also stand as significant contributions of this dissertation.

The final section summarizes the contributions of the theories and tests presented in this chapter and indicates how these differ from previous work.

An Efficient Forward Market: Weak Form Efficiency

Market efficiency, as defined in Chapter II and in the financial literature, calls for the incorporation of all knowable information in the current price of a financial asset. The weak form of market efficiency, requiring only that the information contained in the past prices of the asset be incorporated in the current price, is a less restrictive level of market efficiency. Analysis dealing with weak form efficiency in the equity market has concentrated on time series analysis or trading rules.[3]

In considering either trading rules or time series in the equity market, one need consider only one asset, the equity itself. A speculator, attempting to earn above average returns utilizing information contained in past prices, must purchase, hold, and then sell shares of equity.[4]

Speculation in forward foreign exchange requires transactions in two markets and/or assets. The initial transaction, either a purchase or sale of foreign exchange, is a forward contract. The currency exchange will take place when the contract matures. Since secondary market transactions typically do not exist, the concluding transaction takes place in the spot market at the maturation of the forward contract. The speculator's profit (or loss) per unit is the difference between the contractual forward rate and the spot rate at maturity (equation 1 below).[5]

$$\text{Profit per unit} = S_n - F^n \qquad (1)$$

With two separate, but closely related transactions to consider, weak form analysis must include both forward rates and spot rates. This holds for both trading rules and time series analysis. One question does remain: which forward rate - spot rate pairing should one examine?

Given the time frame, a forward rate is determined. It is that forward rate which exists at the specified time for contracts which mature on a specified day. The question then concerns the spot rate. Conceivably a speculator could close or reverse his forward position at any time prior to the maturation of the forward contract. On a 30-day forward sale of foreign exchange, the speculator could purchase the foreign exchange needed to close his position in the spot market at any time between day zero and day thirty. On closer examination, the entire series of spot rates between initiation and consummation of a forward contract need not be considered. Pure speculation involves only those transactions which take place simultaneously with the maturation of the forward contract. All other possible dates constitute a combination of interest arbitrage and speculation in the spot and/or forward exchange markets. This is seen most clearly in the limiting case. Assume an individual enters a 30-day forward contract to sell forward exchange and purchases the required foreign exchange in the spot market at the same moment. Clearly this is identical to the foreign exchange transactions of an individual engaged in covered-interest-arbitrage.[6] The interest rates are opportunity costs which are implicit in this example.

The weak form analysis in this paper will be limited to the purely speculative model. The analysis will consider a series of pairings of forward rates existing at time (t) and maturing after a length of time (f), (F_t^f), with the actual spot rate at time (t+f), (S_{t+f}).

Time Series Analysis

The relevant time series to consider is the series of difference between the forward rate on day t and the spot rate on day t+f. This difference is labeled D_t^f and defined in equation (2) below.

$$F_t^f - S_{t+f} = D_t^f \tag{2}$$

An alternative variable which measures the rate of return on this speculative activity (ignoring both margin requirements and transactions costs) is given in equation (3) and in logarithmic form in equation (4).[7]

$$\frac{F_t^f - S_{t+f}}{F_t^f} = R_t^f, \text{ or} \tag{3}$$

$$R_t^f = \ln\left(\frac{F_t^f}{S_{t+f}}\right) \tag{4}$$

These variables, D_t^f and R_t^f, will be examined over the entire data set. The set of such variables will be called the D series for reference ease. At this state, no <u>a priori</u> theory is offered for D_t^f or R_t^f. Theories of the forward rate cannot be tested directly with this variable. Indirectly, however, certain values can support different forward market theories. For example, if the following martingale model should hold (equation 5), then the forward rate seems an excellent predictor of the spot rate. Since the Fisherian,

$$E(F_t^f - S_{t+f}) = 0 \tag{5}$$

$$\text{or } E(D_t^f) = 0; \; E(R_t^f) = 0$$

Cambist, and Giddy models all assume the forward rate equals the expected spot rate, this result would seem to support those models. However, this would not constitute an empirical test of any of these models, and the only conclusions one should draw from such a result concern the characteristics of the forward rate as a predictor of the spot rate.

The series of R_t^f, one could argue, is as likely to follow a submartingale as a martingale. Equation (6), expressing the conditions for a submartingale, would support the Interest Parity Theory, Modern Theory, or Hodgson's reconciliation model.

$$E\left(F_t^f - S_{t-f}/F_t^f\right) \neq 0 \tag{6}$$

Once again this will not directly test any forward market model.

Once the series D_t^f and R_t^f are measured, the next step is examination of these series for randomness, a sufficient but not necessary condition for weak form efficiency. Several tests for randomness are available. These include nonparametric tests such as sign tests as well as the more sophisticated time series models of Box-Jenkins analysis. These tests will be constructed to test the hypothesis that the series are not random. Rejection of the hypothesis will support (but not prove) weak form efficiency in the forward market.

Nonparametric tests.[8] Nonparametric tests make no assumptions about the population from which the sample is drawn. Three such tests are described below.

The sign test is a test which concerns the mean or median of a distribution. Observed values are compared to a hypothesized median, Mo, and categorized as either greater than (+) or less than (-) this value. Those observations equal to Mo are ignored. Using the normal approximation of the binomial distribution, one tests the hypothesis (Ho: $Mo - \bar{X} = 0$), the distribution mean ($\bar{X}$) equals the hypothesis median. Rejection of the null hypothesis indicates a series which is nonrandom.[9]

A sign reversal test can be used to examine the relationship between consecutive values of a time series such as the D series. When $R^f_{t+1} > R^f_t$; the sign is (+), when $R^f_{t+1} < R^f_t$, the sign is (-); all outcomes where $R^f_{t+1} = R^f_t$ are ignored. The hypothesis that $R^f_{t+1} - R^f_t = 0$ is tested using the normal approximation of the binomial. To reject (Ho: $R^f_{t+1} - R^f_t = 0$), indicates a nonrandom series where either (+) follows (+) too frequently or (-) follows (+) too frequently. Either of these implies a dependency between values in the series.[10]

The runs test examines series of observations on the same side of the mean, either above or below the mean value. Few runs indicates a nonrandom pattern with long series of observations above the mean followed by a long series below the mean. The runs test is tested using standardized normal tests, or Z scores, and a standard normal table.[11]

The nonparametric tests are not as strong as the more sophisticated tests described below, but they are easy to apply and certainly in the spirit of weak form analysis.

Box-Jenkins Time Series Analysis.[12] Due to the fact that most economic time series have some dependency (around a trend, seasonal tendencies, etc.), the Box-Jenkins techniques are often applicable. Several such tests are appropriate here. The mixed autoregressive-moving average (ARMA) model specifies a general class of linear dependent models. Two special cases of this class are the autoregressive (AR) and the moving average (MA).

The AR model is appropriate for a linear model where an observation can be expressed as a function of past observations and a randomly distributed error term. Equation (7) illustrates the AR model where α and Φi are fixed parameters.

$$R_t^n = \alpha + \Phi_1 R_{t-1}^n + \Phi_2 R_{t-2}^n + \ldots + e_{t-i}^n \qquad (7)$$

When $\Phi = 0$ for $i > p$, the AR model is specified as an autoregressive function of order p,AR(p). For a random process, E(p) = 0.

The MA model specifies a model which is a linear function of the present and past error terms (equation 8).

$$R_t^n = \pi + e_t^n + \theta_1 e_{t-1}^n + \theta_2 e_{t-2}^n + \ldots + \theta e_{t-i}^n \qquad (8)$$

Where π and θi are fixed parameters.

When $\theta i = o$ for $i > q$, the function is designated a moving average of order q or MA (q). If the series is random, E(q) = 0.

Both AR and MA together become the ARMA model of order pq or ARMA (p,q). This model may be modified to consider differences in the time series $R_t^n - R_{t-1}^n$ and the differences may be of any order (1,2,...).[13] Differencing makes this an integrated model ARIMA (p,d,q) where d is the degree of differencing. Non-linear regression techniques are applicable for the estimation of d. The time series is said to be random if, for ARIMA (p,d,q), E(p) = 0, E(q=0) for d = 1 to ∞. Here the hypothesis that any of these parameters is greater than zero,

(Ho: $E(p) \neq 0$: or $E(q) \neq 0$; for $d=1$ to ∞),

must be rejected to support the argument that forward markets are efficient.

Intertemporal Efficiency

Forward market speculation can be undertaken through a sequence of transactions more complex than the traditional route of forward then spot exchange transactions. This other technique can be called intertemporal speculation or time arbitrage. William Folks has aptly defined this activity as "the taking of a position in forward exchange which is balanced as to amount but mismatched in maturity."[14]

Intertemporal Speculation

While the intertemporal activities do constitute speculation, the technique results in a more limited range of possible profit or loss outcomes relative to the more traditional approach.[15] A brief example may serve to illustrate the sequence of transactions involved in intertemporal speculation. Assume a speculator purchases British Pounds Sterling 90-days forward and simultaneously sells an equal amount 30-days forward. At this point, he is balanced in amount (equal forward Pounds purchased and sold), but he is mismatched in maturities (one 30-days, the other 90-days). The speculator will close his position on the thirtieth day by making a spot purchase and selling Pounds 60-days forward. This last 60-day period is a time of pure arbitrage, and need not concern us in this work.

The traditional speculative model assumes the speculators act on differences between the expected spot rate at time t+n, and the n-day forward rate at time t.

$$E(S_{t+f}) - F_t^f \lessgtr 0 \qquad (9)$$

The difference between the actual spot rate at time t+n and the n-day forward rate at time t yields the realized profit or loss.

Such conditions are modified for the intertemporal speculator. Equation (10) illustrates his decision model.

$$E({}^{n-m}_{t+m} - S_{t+m}) - (F^{n}_{t} - F^{m}_{t}) \lesseqgtr 0 \qquad (10)$$

where n and m are two values of f, the length of time to forward maturity.

Here it is the expected differences between the n-m day forward rate, and the spot rate on day t+m relative to the difference in n-day and m-day forward rates which an intertemporal speculator considers. As an example, let the condition be greater than zero, let n=90, m=30, and t=0. Then an intertemporal speculator would purchase foreign exchange 90-days forward while simultaneously selling an equal amount of foreign exchange 30-days forward. on day 30, he would purchase foreign exchange spot and sell foreign exchange 60-days forward. His profit or loss can be shown as

$$\pi = (S_{90} - F_{0}^{90}) + (F^{30}_{0} - S_{30}) + (F^{60}_{30} - S_{90}) \qquad (11)$$

$$\pi = (F^{60}_{30} - S_{30}) - (F^{90}_{t} - F^{30}_{t}) \qquad (12)$$

or in a more general form

$$\pi = (F^{n-m}_{m} - S_{m}) - (F^{n}_{t} - F^{m}_{t}) \qquad (13)$$

Had his expectations been an inequality of less than zero, his actions would be reversed. Equation (10) can be considered a statement of the intertemporal speculative function and equation (13) is the intertemporal profitability condition.[16]

Intertemporal Analysis

No empirical work has been done on the intertemporal forward rates. Therefore, the two areas of analysis presented below are unique and an important part of any analysis of forward market efficiency.

First, the existence of the intertemporal profitability condition must be examined. If the condition does exist (and one would certainly expect it does during floating exchange rate periods), has it been random or have significant patterns existed? Would the existence of these patterns allow an intertemporal speculator to successfully profit from them?

The existence of the conditions is easily tested using two-tailed T tests, and tests for positive or negative tendencies can be performed using one-tailed T tests.[17] The hypothesis that intertemporal profitability is greater than zero, (Ho: $\pi > 0$), must be accepted as a necessary condition for this technique to be valuable to speculators. Rejection of the hypothesis supports market efficiency between forward maturities.

A second empirical area concerns the relationship of forward premia of different maturities. No extensive empirical studies have been directed to this area. If the premia are expressed as annualized percentage differences from the present spot rate they form a schedule similar to a yield-to-maturity curve. This schedule can be called the premia-maturity schedule. The shape of this function is unknown. An important contribution of this paper will be the determination of the "normal" shape of this schedule. The determination of the normal shape of the premia-maturity schedule is one of measurement. This will be presented in Chapter VIII along with the analysis of intertemporal speculative profitability. Should there be no significant difference in the annualzied premia of differing forward maturities, the expected premia of each maturity $E\left((F^f - S)/S\right)$ would be equal for all values of f. The hypothesis (Ho: $F^{90} = F^{60} = F^{30}$) must be rejected if the premia maturity schedule has any shape other than a horizontal line.

SUMMARY

This paper differs from previous work and makes a contribution to the field in the following ways:

Weak Form Efficiency

First the theoretical development of the correct rate of return on forward market transactions is presented. Then this variable, the D series, is subjected to hypothesis testing using daily data and data from non-U.S. (as well as U.S.) exchange rates. No previously published studies have used either daily data or non-U.S. data. Neither nonparametric nor Box-Jenkins tests have been applied to the forward market rate of return. Indirectly, the paper will also test forward market models as indicated below.

Intertemporal Efficiency

A model for intertemporal profitability is developed and appropriate daily exchange rate data has been obtained to measure intertemporal profitability. Although it has long been considered a profitable market strategy, the actual intertemporal profitability has not been measured or presented in previously published studies.

Empirical Analysis

Two aspects of the paper constitute more empirical than theoretical analysis, but both are appropriate research efforts and add to the body of knowledge. First, the paper will analyze the distribution of the rate of return on forward transactions as well as the spot and forward rates themselves. This will be presented in Chapter VI and differs from earlier works in two ways. It uses daily rates, and it considers the D series developed above, neither of which has been presented before.

Second, the shape of the premia maturity schedule is estimated. This relationship of annualized premia is of great interest and a source of great confusion to academicians and practicioners alike. This first empirical estimation of the shape of this curve should lead to further work in the future.

FOOTNOTES TO CHAPTER V

1. Technically the speculator can close the contract by taking the opposite position any time prior to maturity. The opposite position can be taken in the forward market by selling forward with a shorter maturity. This latter possibility will be developed in this chapter.

2. Paul Einzig, *A Dynamic Theory of Forward Exchange*, 2nd ed. (London: Macmillan, 1967): 248-257.

3. A summary of the important work is presented in Chapter II. For a more comprehensive summary, see Fama, "Efficient Capital Markets," pp. 383-417.

4. In the case of "short sales", the speculator will borrow, sell, and then later purchase to replace shares of common equity. Here, also, the same asset is both purchased and sold.

5. This distinction seems obvious, yet few scholars in this area have explicitly recognized this distinction between futures and equities. One exception is Grubel, *Forward Exchange*, pp. 101-103.

6. The discussion of covered-interest-arbitrage is contained in Chapter II.

7. The use of the logarithmic form of the equation is common in equity market analysis. It removes any effects of scale and approximates the rate of return for small differences between F_t^n and S_{t+n}.

$$\text{Let } R_t^n = (F_t^n - S_{t+n})/F_t^n = 1 - \frac{S_{t+n}}{F_t^n}$$

$$\text{Then } \ln F_t^n - \ln S_{t+n} = \ln (S_{t+n}/F_t^n)$$

$$= \ln (R_t^n - 1)$$

$$= R_t^n - 1/2\, R^{2}_{\substack{n\\t}} + 1/3\, R_t^{n2} - \ldots$$

(by a Taylor Series expansion)

$$\doteq R_t^n \text{ when } R_t^n \text{ is small.}$$

8. A thorough discussion of nonparametric tests is available in most statistics texts. A specific treatment of nonparametric methods is W. J. Conover, Practical Nonparametric Methods (New York: John Wiley & Sons, 1971).

9. Thomas R. Wonnacott and Ronald J. Wonnacott, Introductory Statistics for Business and Economics (New York: John Wiley & Sons, 1972): 398-402.

10. This application of the sign test is slightly different from the test usually applied to test for the distribution mean. More correctly this is a test for sign reversals and is more fully explained in: Victor Neiderhoffer and M.F.M. Osborne, "Market Making and Reversal on the Stock Exchange," Journal of the American Statistical Association 61 (December, 1966): 897-916.

11. Jean Dickinson Gibbons, Nonparametric Statistical Inference (New York: McGraw-Hill, 1971): 50-58.

12. This section is based on the time-series techniques developed by Box and Jenkins as presented in G.E.P. Box, and G. M. Jenkins, Time Series Analysis, Forecasting and Control (San Francisco: Holden-Day, 1970).

13. In many time series models differencing is necessary to achieve stationarity.

14. William R. Folks, Jr., "A New Look at Time Arbitrage," Center Paper 77-18, Working Papers on International Business (Columbia, South Carolina: University of South Carolina, 1977).

15. A popular text incorrectly argues that intertemporal speculation, or a "swap", reduces exchange rate risk to zero. Rita M. Rodriquez and E. Eugene Carter, International Financial Management (Englewood Cliffs, N.J.: Prentice Hall, 1976): 110-111.

16. Folks', "A New Look," has presented a similar equation calling it the time arbitrage criterion. He deals with the forward premium while this paper uses the actual rate. There is no other difference between his equation and the one used here. His article ends with the development of the equation and for this reason is not presented in Chapter II.

17. The hypothesis testing used is standard and can be found in any elementary text book. For a good treatment see: John E. Freund and Frank J. Williams, Elementary Basic Statistics, 2nd ed. (Englewood Cliffs, N.J.: Prentice Hall, 1972).

CHAPTER VI

EXAMINATION OF THE DATA

This chapter is divided into four sections. The first explains the data used in the paper and gives sources for that data.

The second section examines the data distributions and explains the preparation of the data for time series analysis. As in most time series of economic data, the distribution does not appear to be normal. Extensive statistical tests on the various series of spot and forward rates indicate these distributions are of the stable Paretian class with characteristic exponents of less than two (the exponent is two for a normal distribution).

The third section examines the D series, the actual difference between a forward rate and the spot rate of the day on which the forward contract matures. These distributions are also found to be other than normal; some are stable Paretians and others appear to be combinations of stable Paretians or possibly uniform distributions.

The final section attempts to summarize and explain the significance of the statistical testing done on these exchange rate series.

I. The Data

The data analyzed consists of daily spot and for ward exchange rates. Few research efforts have utilized daily rates due to the difficulty of obtaining them in a usable form. The paper also includes some exchange rates in which the United States dollar was not one of the traded currencies. Once again, the published research virtually ignores such rates. Overall this work deals with the following six exchange rate series:

United States Dollar per British Pound Sterling
Canadian Dollar per British Pound Sterling
German Mark per British Pound Sterling
United States Dollar per Canadian Dollar
United States Dollar per German Mark
United States Dollar per Swiss Franc

The three exchange rates expressed in terms of Sterling were obtained from The London Financial Times and taken from daily issues on microfilm at the University of Oklahoma, Norman, Oklahoma and Wright State University, Dayton, Ohio. Spot, 30-day forward, and 90-day forward rates were available. In each case the mid-point between bid and asked prices were taken. This data set, taken for all trading days between March 24, 1973, to January 30, 1976, yielded 729 observations.

The remaining observations were noon bank rates in New York City. These were collected and published in the annual International Monetary Market Yearbook for the periods 1973/1974 to 1975/1976.[2] Using the spot, 30-day forward, 60-day forward and 90-day forward rates over the period July 2, 1973, to June 30, 1976, yielded 739 observations. Once again, the mid-point between bid and asked prices was used.

In total, twenty-one time series and over fifteen thousand data points were collected for use in this study.

II. Data Distributions

The raw data consisting of daily quotes for both spot and forward rates was transformed into the series:

$$x_t = \left(Ln \frac{X_t}{X_{t-1}} \right) \qquad (1)$$

where X_t = the rate on day t

X_{t-1} = the previous day's rate

Ln = the natural logarithm

This form for daily changes has several advantages. First, it has been used in financial analysis in other financial markets including the stock market and the market for treasury bills.[3] It also eliminates the problem of unit size, and for percentage changes of less than fifteen percent, the log ratio is approximately equal to the percentage price change.[4]

An analysis of this variable was completed on each of the twenty-one series. Table 6-1 on page 98 , summarizes some of the important descriptive variables of these sample distributions. These sample statistics were computed using the CONDESCRIPTIVE subrouting of SPSS7.[5]

In observing this data, one should note the forward rates have lower mean values than the spot rates, indicat- smaller average rates of change over the period. At the same time forward rates have larger standard deviations than spot rates indicating greater volatility.

The skewness measure is a test for symmetry. If the distributions are symmetrical, one-half the observa- tions shoula be above the mean and one-half below the mean. The measure used[6] indicates none of the distributions is significantly skewed; the distributions are symmetrical.

The peakedness or flatness of the curve is given by its measure of kurtosis. As one can observe from Table 6-1, the kurtosis measure for these distributions range from 8.68 to 124.249. Using the formula from SPSS7[7], the expected value of kurtosis measure is (24/sample size) or a maximum of .033 for these 21 distributions. None of these distributions has a measure of kurtosis which is even close to three standard deviations from the kurtosis expected for a normal distribution. The preliminary indi- cation is that the distributions are leptokurtosic or have a high number of extreme cases and several cases clustered at the mean. Distributions of this type are sometimes des- cribed as having fat-fails and are accurate descriptions of stock price series and other financial time series. Pre- vious weekly data sets for foreign exchange have indicated the leptokurtosis of these distributions.[8]

Following the work by Fama and Roll,[9] these distributions were evaluated as members of the class of symmetric stable Paretian which is defined by the characteristic equation:

$$\text{Ln}Qx(t) = \left[e^{it\delta}\ F(x)\right]$$

$$= i\delta t - \gamma|t|^{\alpha} = i\delta t - |ct|^{\alpha} \qquad (2)$$

where: t is a real number,

x is a random variable,

i is the so called imaginary number $\sqrt{-1}$

and Ln is the symbol for the natural logarithm.

The distributions have three parameters;[10]

α, δ, and $C = \gamma^{1/2}$.

The first of these, α, is the characteristic exponent of the distribution. It measures the height of distribution and varies from $0<\alpha\leq 2$. As α approaches 2, the distribution approaches the normal distribution. Only the normal, of the entire class of stable symmetric Paretian distributions, has a variance or higher moments. For this class of distributions only those moments less than α exist. This implies that for time series which are best described by members of this class with characteristic exponents less than two, the variance is not a useful measure of risk.

The δ value is a measure of location and equals the mean of a normal distribution. Fama and Roll have shown that a truncated mean is a more accurate estimator of location than the sample mean when the exact form of the distribution is unknown.[11] Their estimator equals the interquartile average and is computed by sorting the series in ascending order and averaging the second and third 25 percent groups of the data[12]. This value can be labeled the point five mean or $\bar{x}_{.5}$.

The measure of disbursion, C, is similar to the standard deviation. Fama and Roll have shown it can best be estimated by the equation:

$$\hat{C} = \frac{1}{.827(2)} \left[\hat{x}(\alpha, .72) - \hat{x}(\alpha, .28)\right] \quad (3)$$

This can be found by arranging the data in ascending order and taking the 28th percentile observation from the 72nd percentile observation and dividing this by (2)•(.827).

Estimates of α are also available as a result of the work by Fama and Roll.[13] They have constructed tables and a model appropriate to the estimation of the characteristic exponent. This estimate, developed using Monte Carlo simulation, is computed by dividing the difference in the 95th percent observation and the 5 percent observation by the difference in the 72nd and 28th percent observations and multiplying the quotient by .827 to yield a "z" value. Equation (4) illustrates the z computations.

$$z = (.827)\left(\frac{x_{.95} - x_{.05}}{x_{.72} - x_{.28}}\right) \quad (4)$$

Estimates of α values are obtained from the tables representing the cumulative density functions of stable

Paretian distributions prepared and published by Fama and Roll.[14]

Estimates of the parameters for each of the twenty-one distributions are presented in Table 6-2 on page 99. The characteristic exponents are all well below 2, averaging between 1.3 and 1.4. This supports the hypothesis that the distributions are not normal; a hypothesis indicated by the high measure of kurtosis.

One property of stable distributions, by definition, is that they are invariant under addition. In other words, the sum of identically distributed stable Paretian variables should have the same distribution as the initial stable Paretian distributions. Drawing again from Fama and Roll[15], a test for stability was performed and summarized in Table 6-3 on page 100.

To test for stability, the series was ranked in ascending order and non-overlapping sums of 2, 5, and 10 observations were computed. The α values were then estimated for each of these and entered in Table 6-3 by N, the number of observations summed. In their work, Fama and Roll show this test will generate increasing values of α, approaching 2 as N is increased, if the distribution is normal. No such marked increase is present here. Westerfield[16] has similar results on weekly exchange rate data as does Treichmoeller[17] using stock prices.[18]

Finally a Chi-squared, goodness of fit was performed on each of the distributions. Each distribution was put in ascending order and converted to 10 percentile increments using $\bar{x}$.5 and C. The first and last deciles are divided into two equal cells to examine the tails. (Paretian distributions are characterized by fat tails.) The chi-squared results are presented in Table 6-4 on page 101.

The resulting chi-squared rejects the normal distribution. The minimum chi-squared value is for the spot German Mark and is 58.4. With nine degrees of freedom, the chi squared is greater than 27.88 less than .1 percent of the time if the distribution is normal. Therefore, in every case, the level of confidence exceeds .999 that these distributions are best described by a distribution other than normal.

III. The D. Series, Distributions

After examination of the original data, the series was transformed into a series of differences between the forward rate and the corresponding spot rate on the day that the forward contract matured (i.e., either 30, 60, or 90 days from the date the contract was initiated). In cases where the maturity date fell on a weekend or holiday, the rate in effect on the trading day preceding the maturity date was used. This follows the practice in the forward exchange market.[19]

There is one D series for each forward rate or a total of fifteen distributions. These distributions were converted to the form:

$$R_t^f = \text{Ln}\left(\frac{F^f{}_t}{St+f}\right) \times \left(\frac{360}{f}\right)$$

where f equals the length of the forward contract,
t equals the day the transaction was initiated
F equals the forward rate
S equals the spot rate
360/f makes the rate of return an annualized rate
and R equals the actual rate of return on forward contracts held to maturity expressed as an annual percentage rate.

General statistical characteristics of these distributions are tabulated in Table 6-5 on page . One generalization concerns the standard deviation of these distributions. As the time of the D series becomes longer, the standard deviation becomes smaller. Such a result implies that the variability of returns is greater in the shorter maturities and that is consistent with other financial markets in general. The shorter the length f time to maturity, the greater the variability of returns.

Skewness is not significantly different from zero indicating these distributions are symmetrical. The kurtosis values are much different here than for the distributions of spot and forward rates and are evenly divided between positive and negative values.

The kurtosis measure used indicates a peaked distribution if positive and a flat distribution if negative. The absolute value of these measures are much smaller than those presented in Table 6-1, but most are not within three standard deviations of zero, the measure for a normal distribution.

Although negative kurtosis is not consistent with members of the stable Paretian class, the parameters were estimated for all fifteen distributions. These are presented in Table 6-6 on page 103. As one can observe, the characteristic exponents are much higher than the series presented in Table 6-2. In most cases, where the kurtosis measure is negative, the estimate of the characteristic exponent is greater than two. This indicates a distribution other than stable Paretian since the Paretian has an α value less than or equal to two.

Examination of the goodness of fit, using the chi-squared test, reveals two things. First, one can see by the measures presented in Table 6-7 on page 104, that the normal distribution does not apply to all these distributions. Second, in examining the cells using the chi-squared technique discussed in Section II of this chapter, those distributions with α estimates greater than two have interesting features. While all the distributions of spot and forward rates which have exponents of less than two have high peaks with flat tails, the D series with α estimates greater than two have fewer observations near the mean and quite small tails. The U.S. dollar per Canadian dollar 60 and 90 day D series are bi-model.

Table 6-8 on page 105 classifies the D series into those which could possibly be described by the stable non-normal Paretian distribution, those which can possibly be described by the normal distribution, and those which can be described by neither. This is an area which should be pursued, but is outside the main thrust of this paper.

IV. Significance

Both the series analyzed in Part II and those analyzed in Part III present series of importance to speculators and traders in the foreign exchange market. As such, any information on the characteristics of these distributions is important.

Building on the work of Fama and Roll and the study by Westerfield, this chapter has both confirmed the conventional wisdom and raised some questions. Foreign exchange rates, spot and forward, are better described by non-normal stable Paretian distributions than normal distributions. This is consistent with other financial markets and Westerfield's weekly tests in the foreign exchange markets. Since there are no published works containing daily tests, this analysis is important and adds to the available knowledge of the foreign exchange market.

The D series, a very real speculative series, cannot be so easily categorized. The findings here call for further research into the series of differences. One would expect that further research cculd identify the general form of these distributions.

FOOTNOTES TO CHAPTER VI

1. The Financial Times (London) March 24, 1973 to February 1, 1976.

2. Chicago Board of Options Exchange, International Monetary Market Yearbook (Chicago, Ill.: Staff of the IMM, 1973/1974, 1974/1975, 1975/1976).

3. In the equities market see:

Michael C. Jensen, "The Performance of Mutual Funds in the Period 1945-64," The Journal of Finance XXIII no. 2 (May 1968): 389-416; and Eugene Fama, "The Behavior of Stock Market Prices," Journal of Business 38 (January 1971): 34-105.

In the treasury bill market:

Richard Roll, "The Efficient Market Model Applied to U. S. Treasury Bill Rates," (PhD Dissertation), Graduate School of Business, University of Chicago, 1968).

4. Footnote 7 of Chapter III develops the proof of the latter statement.

5. Norman H. Nie, et al., Statistical Package for the Social Sciences, 2nd ed. (New York: McGraw-Hill Book Co., Inc., 1975): 181-193.

6. The equation used in SPSS version 7 is:

$$\text{Skewness} = \frac{\left\{\left[\Sigma\, x_i^3 - 3\bar{x}(\Sigma_i^2) + 3\bar{x}^2\ (\Sigma x_i\right]\right\} - \bar{x}^3}{\left\{\left[(\Sigma x_i^2) - N\bar{x}^2\right] \ / \ (N-1)\right\}^{3/2}}$$

Ibid., p. 185.

7. The equation used in SPSS version 7 is:

Kurtosis =

$$\frac{\left\{\left[\Sigma x_i^4 - 4\bar{x}(\Sigma x_i^3) + 6\bar{x}^2(\Sigma x_i^2) - 4\bar{x}^3\ \Sigma x_i)\right] \ /N\right\} + \bar{x}^4}{\left\{\left[(\Sigma x_i^4) - N\bar{x}^2\right] \ / \ (N-1)\right\}^2} - 3$$

Ibid., p. 189.

8. Roger B. Upson, "Random Walk and Forward Exchage Rates: A Spectral Analysis," Journal of Financial and Quantitative Analysis 7 (September 1972): 1897-1906.

Janice M. Westerfield, "Empirical Properties of Foreign Exchange Rates Under Fixed and Floating Rate Regimes," Philadelphia Fed. Research Papers Research Paper No. 16 (Philadelphia, Pennsylvania: Department of Research, Federal Reserve Bank of Philadelphia, December 1975).

9. The remainder of this section draws heavily on Eugene Fama and Richard Roll, "Some Properties of Symmetric Stable Distributions." Journal of the American Statistical Association (September 1968): 817-836, and Westerfield, "Empirical Properties."

10. Fama and Roll, "Some Properties," p. 817.

11. Ibid., p. 823.

12. The files were put into ascending order using the SORT subroutine of SPSS version 7, Nie, SPSS, p. 167-166.

13. Fama and Roll, "Some Properties," p. 825.

14. Ibid., p. 822-823.

15. Eugene Fama and Richard Roll, "Parameter Estimates for Symmetrical Stable Distributions." Journal of the American Statistical Association (June 1971): 331-338.

16. Westerfield, "Empirical Properties."

17. John Teichnoeller, "A Note on the Distribution of Stock Price Changes," Journal of the American Statistical Association (June 1971): 282-285.

18. Fama and Roll, "Parameter Estimates," p.336, show the α values are biased downward when sample size is reduced below 100. Only the case where N=10 has less than 100 in its sample. A slight upward adjustment in α estimates would not change the results so they have been presented with no adjustment.

19. In order to match forward contracts with the spot rate on the maturity date, a series of FORTRAN programs were written. These programs, written by the author, are included as Appendix A of this dissertation.

TABLE 6-1

STATISTICAL CHARACTERISTICS: ORIGINAL DATA

Currencies	Mean	Standard Deviation	Skewness	Kurtosis
United States Dollar Per British Pound Sterling:				
Spot	-.000028	.008345	-.551	124.249
30 Day Forward	-.00029	.008487	-.593	118.468
90 Day Forward	-.000293	.008596	-.566	116.384
Canadian Dollar Per British Pound Sterling:				
Spot	-.000276	.005864	-.014	29.774
30 Day Forward	-.000274	.006020	-.075	28.102
90 Day Forward	-.000266	.006157	-.097	27.585
German Mark Per British Pound Sterling:				
Spot	-.00040	.01110	-.414	44.375
30 Day Forward	-.000382	.011158	-.421	44.078
90 Day Forward	-.000377	.011322	-.366	44.197
United States Dollar Per Canadian Dollar:				
Spot	.000414	.014253	-.044	3.139
30 Day Forward	.00034	.016863	.141	8.68
60 Day Forward	.000286	.019426	.894	27.66
90 Day Forward	.000234	.016962	.323	7.588
United States Dollar Per German Mark:				
Spot	-.000951	.069564	-.29	6.812
30 Day Forward	-.001008	.073949	.105	11.731
60 Day Forward	-.001017	.068886	-.113	6.196
90 Day Forward	-.001029	.070067	-.178	6.452
United States Dollar Per Swiss Franc:				
Spot	.001799	.081884	-.033	6.432
30 Day Forward	.00173	.082246	-.79	12.255
60 Day Forward	.001725	.132126	-.783	137.503
90 Day Forward	.001729	.083899	-.687	11.093

TABLE 6-2

STABLE PARETIAN PARAMETER ESTIMATES:

ORIGINAL DATA

Currency	Characteristic Exponent α	Location δ	Scale C
United States Dollar Per British Pound Sterling:			
Spot	1.29	-.000061	.0016548
30 Day Forward	1.26	-.000006	.0016741
90 Day Forward	1.25	-.000008	.0017291
Canadian Dollar Per British Pound Sterling:			
Spot	1.36	-.000133	.0019232
30 Day Forward	1.37	-.000074	.0019879
90 Day Forward	1.41	-.00008	.0020940
German Mark Per British Pound Sterling:			
Spot	1.22	-.000172	.0021530
30 Day Forward	1.30	-.000132	.0027158
90 Day Forward	1.31	-.000151	.1127697
United States Dollar Per Canadian Dollar:			
Spot	1.73	.0001407	.0078497
30 Day Forward	1.37	.000126	.007255
60 Day Forward	1.32	-.000056	.007255
90 Day Forward	1.43	-.000241	.0078597
United States Dollar Per German Mark:			
Spot	1.44	-.00035	.03265
30 Day Forward	1.32	-.001186	.03265
60 Day Forward	1.37	-.000538	.03205
90 Day Forward	1.35	-.000636	.03205
United States Dollar Per Swiss Franc:			
Spot	1.29	.002081	.03265
30 Day Forward	1.35	.00201	.03325
60 Day Forward	1.33	.002214	.03265
90 Day Forward	1.37	.001966	.03386

TABLE 6-3

CHARACTERISTIC EXPONENT: ORIGINAL SERIES

Currency	α N = 1	N = 2	N = 5	N = 10
United States Dollar Per British Pound Sterling:				
Spot	1.29	1.24	1.3	1.35
30 Day Forward	1.26	1.24	1.45	1.48
90 Day Forward	1.25	1.34	1.39	1.48
Canadian Dollar Per British Pound Sterling:				
Spot	1.36	1.42	1.34	1.49
30 Day Forward	1.37	1.38	1.32	1.33
90 Day Forward	1.41	1.30	1.46	1.46
German Mark Per British Pound Sterling:				
Spot	1.22	1.36	1.42	1.3
30 Day Forward	1.30	1.36	1.32	1.17
90 Day Forward	1.31	1.36	1.28	1.23
United States Dollar Per Canadian Dollar:				
Spot	1.73	1.68	1.73	1.62
30 Day Forward	1.37	1.61	1.54	1.63
60 Day Forward	1.32	1.54	1.45	1.56
90 Day Forward	1.43	1.54	1.33	1.38
United States Dollar Per German Mark:				
Spot	1.44	1.35	1.35	1.48
30 Day Forward	1.43	1.32	1.39	1.43
60 Day Forward	1.44	1.31	1.31	1.52
90 Day Forward	1.43	1.35	1.48	1.48
United States Dollar Per Swiss Franc:				
Spot	1.29	1.4	1.39	1.38
30 Day Forward	1.35	1.48	1.33	1.39
60 Day Forward	1.33	1.44	1.29	1.45
90 Day Forward	1.37	1.48	1.33	1.42

TABLE 6-4

CHI-SQUARED VALUES: ORIGINAL SERIES

Currency	χ^2
United States Dollar Per British Pound Sterling:	
Spot	120.51*
30 Day Forward	134.8
90 Day Forward	139.6
Canadian Dollar Per British Pound Sterling:	
Spot	63.8
30 Day Forward	84.4
90 Day Forward	98.13
German Mark Per British Pound Sterling:	
Spot	197.8
30 Day Forward	75.95
90 Day Forward	75.70
United States Dollar Per Canadian Dollar:	
Spot	63.11
30 Day Forward	128.77
60 Day Forward	118.84
90 Day Forward	76.84
United States Dollar Per German Mark:	
Spot	58.4
30 Day Forward	76.6
60 Day Forward	79.0
90 Day Forward	85.4
United States Dollar Per Swiss Franc:	
Spot	152.6
30 Day Forward	117.9
60 Day Forward	137.3
90 Day Forward	124.9

* $P(\chi^2(9df)>27.88) = .001$

TABLE 6-5

STATISTICAL CHARACTERISTICS: D SERIES

Currency	Mean	Standard Deviation	Skewness	Kurtosis
United States Dollar Per British Pound Sterling:				
30 Day D Series	-.0255	.27262	.172	2.919
90 Day D Series Annual Basis	-.0300	.18579	.367	-.28
Canadian Dollar Per British Pound Sterling:				
30 Day D Series	-.0152	.25566	.267	.881
90 Day D Series Annual Basis	-.0147	.18378	.045	-.746
German Mark Per British Pound Sterling:				
30 Day D Series	-.0228	.3792	-1.418	5.293
90 Day D Series Annual Basis	-.0156	.21913	-.966	1.171
United States Dollar Per Canadian Dollar:				
30 Day D Series	-.01265	.10252	.032	-.160
60 Day D Series	-.01160	.08205	.038	-.609
90 Day D Series Annual Basis	-.01112	.07507	.112	-1.093
United States Dollar Per German Mark:				
30 Day D Series	.0509	.378	.412	.179
60 Day D Series	.04906	.29494	-.004	-.332
90 Day D Series Annual Basis	.0468	.2547	-.029	-.000
United States Dollar Per Swiss Franc:				
30 Day D Series	-.03495	.3614	-.041	.481
60 Day D Series	-.02480	.2938	-.219	-.219
90 Day D Series	-.03129	.2559	.195	-.212

TABLE 6-6

STABLE PARETIAN PARAMETER ESTIMATES:

D SERIES

Currency	Characteristic Exponent α	Location δ	Scale C
United States Dollar Per British Pound Sterling:			
30 Day D Series	1.98	-.02367	.18588
90 Day D Series	1.81	-.04224	.12333
Canadian Dollar Per British Pound Sterling:			
30 Day D Series	1.89	-.01126	.16030
90 Day D Series	α 2	-.0261	.14631
German Mark Per British Pound Sterling:			
30 Day D Series	1.67	.01254	.19203
90 Day D Series	1.4	.00157	.11548
United States Dollar Per Canadian Dollar:			
30 Day D Series	$\alpha>2$	-.010041	.07618
60 Day D Series	$\alpha>2$	-.01064	.06893
90 Day D Series	$\alpha>2$	-.0067	.07134
United States Dollar Per German Mark:			
30 Day D Series	1.74	.029539	.20979
60 Day D Series	1.64	.048825	.18743
90 Day D Series	1.56	.049316	.14993
United States Dollar Per Swiss Franc:			
30 Day D Series	1.49	-.03846	.20979
60 Day D Series	1.46	-.02569	.16203
90 Day D Series	1.32	-.02836	.11850

TABLE 6-7

CHI-SQUARED VALUES: D SERIES

Currency	χ^2
United States Dollar Per British Pound Sterling:	
30 Day D Series	25.9
90 Day D Series	62.3
Canadian Dollar Per British Pound Sterling:	
30 Day D Series	31.3
90 Day D Series	61.9
German Mark Per British Pound Sterling:	
30 Day D Series	34.8
90 Day D Series	92.1
United States Dollar Per Canadian Dollar:	
30 Day D Series	15.1
60 Day D Series	94.8
90 Day D Series	183.8
United States Dollar Per German Mark:	
30 Day D Series	71.2
60 Day D Series	34.0
90 Day D Series	138.5
United States Dollar Per Swiss Franc:	
30 Day D Series	57.9
60 Day D Series	253.7
90 Day D Series	255.9

$P(\chi^2(9df)>27.88) = .001$

TABLE 6-8

CLASSIFICATION OF D SERIES DISTRIBUTIONS

Currency	χ^2
D Series Which Approach Normal Distribution	
U. S. Dollar per British Pound Sterling 30 Day	25.92
Canadian Dollar per British Pound Sterling 30 Day	31.3
U. S. Dollar per Canadian Dollar 30 Day	15.1
D Series Which Are Stable Paretian	
U. S. Dollar per British Pound Sterling 90 Day	62.3
German Mark per British Pound Sterling 30 Day	34.8
German Mark per British Pound Sterling 90 Day	92.1
U. S. Dollar per German Mark 30 Day	71.2
U. S. Dollar per German Mark 60 Day	34.0
U. S. Dollar per German Mark 90 Day	138.5
U. S. Dollar per Swiss Franc 30 Day	57.9
U. S. Dollar per Swiss Franc 60 Day	253.7
U. S. Dollar per Swiss Franc 90 Day	255.9
D Series Neither Normal Nor Non-Normal Stable Paretian	
Canadian Dollar per British Pound Sterling 90 Day	61.9
U. S. Dollar per Canadian Dollar 60 Day	94.8
U. S. Dollar per Canadian Dollar 90 Day	183.8

CHAPTER VII

TESTS OF WEAK FORM EFFICIENCY IN THE FORWARD MARKET FOR FOREIGN EXCHANGE

This chapter summarizes the results of performing the tests for randomness indicated in Chapter V on the data described in Chapter VI. Primary analysis is on the time series of rates of return on holding a forward contract to maturity, the D series defined in Chapter V. Where necesary, both the tests and the data are further illuminated in this chapter.

Two major sections comprise this chapter. The first considers the nonparametric tests and contains the results of those tests. The second section describes the Box-Jenkins time series analysis and the results of this analysis when applied to the D series data.

I. Nonparametric Tests

Each D series was subjected to three nonparametric tests: the sign test; the sign reversal test; and the runs test.

Sign Test

The sign test may be applied to time series data to test for a disproportionate number of observations above or below the mean; this tests the hypothesis that the sample mean, $\bar{X}$, is equal to the, unknown, population median, M or (Ho: $\bar{X} - M = 0$). An observation is classified as above $\bar{X}$, a plus observation (+), or below $\bar{X}$, a minus observation (-). These are summed, labeled n+ and n-, respectively, and presented for each D series in Table 7-1 on page 121.

To test the hypothesis that $\bar{X}$ equals M, one uses the normal approximations of the binominal distribution.[1] A large, symmetrical distribution is expected to have one half its observations above and one half below the median. The standard deviation of such a distribution is given in equation (1).[2] A Z value, estimating the number

$$\sigma = .5\sqrt{N} \tag{1}$$

where N is the number of observations

of standard deviations, is computed using equation (2)[3] and compared to a table of Areas Under the Normal Curve for the level of significance.[4]

Both the $$Z = \frac{(n+) - N/2}{.5\sqrt{N}} \tag{2}$$

score and the level of significance are entered in Table 7-1. Only levels of significance of .05 or greater are listed.

As Table 7-1 shows, four of the fifteen series have a mean significantly different from the median based on the sign test. Both German Mark per British Pound Sterling rates have a significantly high level of above mean (+) values. The United States to Canadian Dollar, 90-day rate has a significantly low number of (+) values as does the United States per German Mark, 90-day series. This suggests nonrandom, skewed series and possibly inefficiency. However, unless one can find a pattern of observations, the greater number of differences above (below) the mean is offset by the greater magnitude of differences below (above) the mean. Tests for patterns are presented below.

Sign Reversal Test

The sign reversal test examines the pattern of consecutive observations, D_0, D_1, D_2 ..., D_n. An increase in the observation, $D_{t+1} - D_t > 0$, is designated (+) a decrease, $D_{t+1} - D_t < 0$, is designated (-) and no change, $D_{t+1} - D_t = 0$, is ignored. Then the number of runs, sets of consecutive observations with the same sign, are computed. These are compared to the number of runs one would expect from a population described by the sums of (+) and (-) observations. Equation (3) is the expected number of runs and equation (4) is the estimated s andard deviation for such a population.[5]

$$E(R) = 2 \cdot N \cdot \frac{n+}{N} \cdot \frac{n-}{N} \quad (3)$$

$$\sigma = s\sqrt{N} \cdot \frac{(n+)}{N} \cdot \frac{(n-)}{N} \quad (4)$$

If R, the number of actual rans, is less than E(R), then there is a tendency for like signs to appear consecutively. In other words, a pattern such as (++) is more likely than (+-). Too many runs indicates that consecutive observattions are most likely of opposite sign (i.e., a (+-) pattern is more likely than a (++) pattern).

Table 7-2, Sign Reversal Runs Test on page 122 shows there is little evidence of nonrandomness in these series. Only two of the series are significantly different from what one would expect for a random series. Furthermore, the signs of the Z scores are evenly divided between positive and negative. This would indicate that neither the size nor the direction of the deviations are significant; an increased rate of return is as likely to be follwed with another increase as a decrease.

Runs Above and Below Mean

The final nonparametric test, runs above and below mean, shows significant nonrandomness at the .01 level for all series. The test is essentially the same as the sign reversal test except observations are classified (+) or (-) by their relationship to the distribution mean. Too few runs are indicative of long series of observations above or below the mean. Too many runs indicate a nonrandom pattern which oscillates about the mean at very frequent intervals.[6]

As one can see from Table 7-3, Runs Above and Below the Mean, (page), the level of runs is significantly low. The D series are nonrandom; long periods of above average returns are followed by long periods of below average returns. This results, in part, from the fact that definite trends exist in the series. This is more clearly discussed in the following section.

The nonrandom pattern does not suggest inefficiency here due to the short duration of these runs. To illustrate, the average run for the United States Dollar Per Canadian Dollar, 30-day series, is approximately fifteen days. Since a speculator needs to complete the speculation to determine the sign, he must look backward by at least f days (the length of the contract, here thirty days). To be in a fifteen day run does the speculator no good since at least another fifteen days must pass before the presence of a position or negative run is established.

Certainly the Sign Test and the Runs Test indicate a nonrandom time series. However, inefficiency implies the information of nonrandomness can be used to make above average profits for a given level of risk. To do this, a necessary condition is a predictable pattern in the time series which relates observations more than f days apart, where f is the length of the forward contract (30, 60 or 90 days). The existence of such patterns has not been shown by the nonparametric tests presented, but the sophisticated tests which follow will identify them if they exist.

II. Box-Jenkins Univariate Time Series Analysis

The fields of applied time series analysis and forecasting exists at its present state largely as a result of the work of G. E. P. Box and G. M. Jenkins.[7] They have combined the relevant information necesseary to understand and apply time series models of the general autoregressive, integrated, moving average class. For this reason, their method: identification; estimation; and forecasting; has come to be termed Box-Jenkins analysis and forms the standard textbook treatment.[8] This discussion, and the research presented below, follows the methodology of Box and Jenkins.

General time series analysis presumes the time series is generated by a stochastic process and, furthermore, that the stochastic process can be modeled. The models take one or both of two forms, autoregressive and/or moving average. Each model uses only the past observations of the single time series variable to explain the present value or predict the future values of the variable.

Autoregressive Models

Yule first introduced the autoregressive model in 1926.[9] The autoregressive process is one in which the current observation, x_t, is a function of a weighted average of past observations going back p periods plus a random disturbance in the current period. Equation (1) illustrates a general case of the autoregressive model, while equation (2) presents a first order autoregressive equation (p = 1). In each case, δ represents the series mean. The autoregressive model

$$x_t = \phi_1 x_{t-1} = \phi_2 x_{t-2} + \ldots + \phi_p x_{t-p} + \delta + e_t \qquad (1)$$

$$x_t = \phi_1 x_{t-1} + \delta + e_t \qquad (2)$$

is signified by the AR(p) where $\phi_{t-i} = 0$ if $(t-i) > p$.

The term, autoregressive, is derived from the fact that the model is simply a regression model where:

x_t = the dependent variable

x_{t-i} = the independent variable(s) when $(i \leq p)$

ϕ_i = the coefficients

δ = the constant term

e_t = the error term

Any series can be written in the form of equation (1), the current error term plus the weighted sum of all observations. Only if the number of nonzero terms is finite, if p is a finite number, is the series an autoregressive one.

Moving Average

The moving average models were introduced by Slutzky in 1937.[10] Moving average is actually a misnomer since the general class of models is, strictly speaking, neither an average nor a moving value. The term is the accepted one in the literature, however, and will be applied in this paper.

A moving average series or process is one in which the present observation is a function of a weighted average of past random disturbances going back q periods plus the present error term. The general case for a moving average model is illustrated by equation (3), and equation (4) is a first order moving average model. The general moving average

$$x_t = \delta + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \cdots - \theta_q e_{t-q} \quad (3)$$

$$x_t = \delta + e_t - \theta_1 e_{t-1} \quad (4)$$

where δ = the mean of x_t or t=1 to n, and the θ values may be either positive or negative.

model is designated MA(q) where $\theta_{t-1} = 0$ if $(t-1) > q$.

Just as any series can be written in the form of equation (1), so any equation can be written as equation (3), the current error term plus a weighted average of past errors. Only if q is finite, the number of nonzero terms is finite, is the series a moving average process.

Stability

A necessary condition for the application of either an autoregressive or a moving average time series model is the condition of stability. A model with "drift" or a definite tread will not be "invariant with respect to time."[11] It will be most difficult to represent such a series with fixed coefficients estimated using past data. Fortunately, most nonstationary time series may be made stationary with differencing of a low order (first or second differencing). In the Box-Jenkins techniques, this differencing is termed integration and is specified of order d or I(d). For example, a series which has been differenced two times is termed I(2). The general autoregressive, integrated, moving average model is specified as ARIMA (p,d,q). One which has second order autoregressive parameters (p=2), first difference integration (d=1), and third order moving average (q=3), would be written ARIMA (2,1,3). Empirical Approach: As mentioned above, the Box-Jenkins methodology is one of identification, estimation, and forecasting. This research follows this approach with the exception of forecasting. Rather than forecast future values, the values forecast were for known values with the emphasis on testing the model for significant explantory power. This step is included with the estimation step. The computer package used for the Box-Jenkins analysis was Computer Programs for the Analysis of Univariate Time Series Models and Single Input Transfer Function Models Using the Methods of Box and Jenkins, by David J. Pack of the Ohio State University.[12]

For purposes of analysis, each set of D series data (returns for holding a forward contract to maturity) were divided into two sets of 500 observations. (Other sets were examined with no significant difference in results.) To fully analyze these time series, thirty different D series were examined.

Identification

The identification state of Box-Jenkins analysis computes the autocorrelations between and/or observation of a variable, x_t, and previous observations of the same variable x_{t-1}, x_{t-2}, ..., x_{t-i}. No significant correlation between x_t and x_{t-i} for all i indicate a random series or a white noise series. An appropriate test for white noise is a chi-squared, χ^2, test for the appropriate degrees of freedom.

A pattern of slowly decreasing autocorrelation over a long period suggests a nonstable time series. Appendix B on page B-1 illustrates such a pattern for the first 500 observations of the United States Dollar per Canadian Dollar Thirty Day D Series. This pattern is typical of each of the thirty D series examined. Table 7-4 on page shows the χ^2 values for the residual values relative to a random series for both the original time series and the first difference of each series. The large values for each original series clearly point to a trend rather than a random series around a stationary mean.

Differencing each series one time produced stability in all cases. Appendix B on page B-2 shows the autocorrelations of first differences for the same series illustrated in Appendix B, page B-1. The absence of any autocorrelations greater than two standard errors indicates this model is neither autoregressive nor moving average.

(As Table 5-5 indicates, no significant parameters could be estimated for this series.)

Further reference to Table 7-5 indicates most series are not significantly different from white noise when the first difference is used. Of the thirty series examined, only nine have a χ^2 value above the critical value of 192.43 which is the ninety-five percent confidence interval.

Overall there is low autocorrelation for the Stable Series. For the eighteen series of U. S. Dollar X currency, only the last 500 observations of the Swiss Franc Ninety Day D Series is nonrandom. This clearly supports market efficiency. Of the twelve Y currency per British Pound Sterling rates, eight are significantly nonrandom at the ninety-five percent level.

To estimate the parameters of a time series model, one initially uses the autocorrelation pattern. As indicated above, one with no autocorrelation values above two standard errors has no significant parameters. One which has a few significant autocorrelations which slowly diminish is probably an autoregressive pattern, while one with significant autocorrelations which abruptly cease is most likely a moving average model. Preliminary estimates of the models and their parameters are necessary for the estimation procedure.

Estimation

Table 7-5 on page 125, containes the significant parameters produced by the estimation process. Although only nine series were nonrandom based on the χ^2 test, all were tested for parameter values which could reduce the χ^2 values. Of the series which were originally nonrandom, all were made random with a first or second order model. Table 7-6 on page 126 shows the χ^2 value computed with an ARIMA (0,1,0) model and with the significant parameters estimated. For those series which could not be classified nonrandom, the employment of significant parameters made little difference in the χ^2 value. For example, the United States Dollar per British Pound Sterling First 500 Observations Thirty Day D Series has a χ^2 value of 179.26 using ARIMA (0,1,0). Using a moving average model, ARIMA (0,1,1), the value changes to 130.97, only a slight improvement and not a significant one.

Overall Results

The series of returns on forward market speculation during this time period do follow definite trends. Once an adjustment is made for trend, the series exhibit low autocorrelation and the majority of autocorrelations are not significantly different from zero. Those series which are nonrandom can be made random with a low level time series model usually of a MA(1) type. These models themselves are not stable as one can see by inspection of Table 7-4.

A significant parameter value during the first period is either higher, lower, or insignificant during the second period of analysis.

Furthermore, the predictive power of these series is limited to a few days. A prediction of thirty days, sixty days, or ninety days or greater would be as inaccurate as a random guess.

Finally, while not investigating the exact series as Giddy and Dufey, the results appear consistent.[13] They find the appropriate models for the spot exchange rates to be of a moving average type and stable after first differencing has been applied. They also find the parameters change through time and a low predictive power for the spot exchange rate in the time series. This is exactly what is shown here.

FOOTNOTES TO CHAPTER VII

1. Wonnacott and Wonnacott, Introductory Statistics, p. 401.

2. Ibid., P. 401.

3. Ibid., p. 401.

4. Such as Herbert Arkin and Raymond R. Colton, Tables for Statisticians, 2nd ed. (New York: Barnes & Nobel, Inc., 1970): 121.

5. Gibbons, Nonparametric Statistical Inference, pp. 56-57.

6. Ibid., pp. 54-58.

7. George E. P. Box and Gwilym M. Jenkins, Time Series Analysis Forecasting and Control Revised Edition (San Francisco: Holden-Day, 1976).

8. The following are representative:

Spyros Makridakis and Steven C. Wheelwright, Forecasting Methods & Applications (Santa Barbara: Wiley/ Hamilton, 1978).

Charles R. Nelson, Applied Time Series Analysis (San Francisco: Holden-Day, 1973).

Robert S. Pindyck and Daniel Rubinfield, Econometric Models and Economic Forecasts (New York: McGraw-Hill, 1976).

9. G. U. Yule, "Shy Do We Sometimes Get Nonsense-Correlations Between Time Series? A Study of Sampling and the Nture of Time Series," Journal of the Royal Statistical Society 89 (March, 1926): 1-64.

10. E. Slutzky, "The Summation of Random Causes as the Source of Cyclic Processes," Econometrica 5 (January, 1937): 105-146.

11. Pindyke, Econometric Models, p. 435.

12. David J. Pack, Computer Programs for the Analysis of Univariate Time Series Models and Single Input Transfer Function Models Using the Methods of Box and Jenkins. The Data Center, College of Administrative Science, The Ohio State University, Columbus, 1974.

13. Giddy and Dufey, "Random Behavior of Flexible Exchange Rates," find that the spot rates have ARIMA (p,d, q) models with d=1, p=0, and q=1 to 10. They also find the parameter estimates vary over time and have fairly low explanatory power.

TABLE 7-1

SIGN TESTS ABOVE AND BELOW THE MEAN

Currency	Observations Above Mean (n+)	Observations Below Mean (n-)	Z*	Level of Significance
United States Dollar Per British Pound Sterling:				
30 Day	357	351	.22	-
90 Day	335	353	-.68	-
Canadian Dollar Per British Pound Sterling:				
30 Day	361	348	.31	-
90 Day	331	337	-.23	-
German Mark Per British Pound Sterling:				
30 Day	406	303	3.86	.01
90 Day	377	291	3.33	.01
United States Dollar Per Canadian Dollar:				
30 Day	339	378	-1.45	-
60 Day	341	356	- .57	-
90 Day	309	368	-2.27	.05
United States Dollar Per German Mark:				
30 Day	376	337	1.46	-
60 Day	357	336	.79	-
90 Day	303	369	-2.54	.01
United States Dollar Per Swiss Franc:				
30 Day	362	352	.37	-
60 Day	368	325	-1.63	-
90 Day	313	353	-1.77	-

$$* \; Z = \frac{((n+)) - N/2}{\sqrt{N\,(.5)(.5)}}$$

TABLE 7-2

SIGN REVERSAL RUNS TEST

Currency	(+) Changes (-) Positive (n+)	Negative (n-)	No. of Runs	Z* Value	Level of Significance
United States Dollar Per British Pound Sterling					
30 Day	365	343	360	.45	-
90 Day	343	325	309	-1.92	-
Canadian Dollar Per British Pound Sterling					
30 Day	363	344	351	-.26	-
90 Day	339	329	304	-2.32	.05
German Mark Per British Pound Sterling					
30 Day	371	338	373	1.38	-
90 Day	333	325	315	-1.47	-
Unites States Dollar Per Canadian Dollar					
30 Day	366	351	337	-1.59	-
60 Day	347	350	334	-1.10	-
90 Day	327	350	331	- .54	-
United States Dollar Per German Mark					
30 Day	343	370	378	1.65	-
60 Day	336	357	356	.75	-
90 Day	347	325	345	.72	-
United States Dollar Per Swiss Franc					
30 Day	361	353	389	2.16	.05
60 Day	332	361	362	1.22	-
90 Day	332	340	356	1.54	-

$$*: Z = \frac{\text{Runs} - 2(N)\left(\frac{n+}{N}\right)\left(\frac{n-}{N}\right)}{2\sqrt{N}\left(\frac{n+}{N}\right)\left(\frac{n-}{N}\right)}$$

TABLE 7-3

RUNS ABOVE AND BELOW MEAN

Currency	Above (+)	Below (-)	No. of Runs	Z Value	Level of Significance
United States Dollar Per British Pound Sterling					
30 Day	357	351	87	-20.1	.01
90 Day	335	353	41	-23.1	.01
Canadian Dollar Per British Pound Sterling					
30 Day	361	348	92	-19.7	.01
90 Day	331	337	21	-24.2	.01
German Mark Per British Pound Sterling					
30 Day	406	303	80	-20.5	.01
90 Day	377	291	52	-21.8	.01
United States Dollar Per Canadian Dollar					
30 Day	339	378	48	-23.18	.01
60 Day	341	356	16	24.1	.01
90 Day	309	368	18	24.6	.01
United States Dollar Per German Mark					
30 Day	376	337	40	-23.7	.01
60 Day	357	336	25	-24.4	.01
90 Day	303	369	49	-22.1	.01
United States Dollar Per Swiss Franc					
30 Day	362	352	83	-20.5	.01
60 Day	368	325	38	-23.4	.01
90 Day	313	359	44	-22.5	.01

TABLE 7-4

CHI-SQUARED VALUES ORIGINAL SERIES

AND FIRST DIFFERENCE SERIES

D-Series Currencies	χ^2 Original Series		χ^2 First Difference	
United States Dollar Per British Pound Sterling	First 500	Second 500	First 500	Second 500
30 Day	6101.3	11461.0	179.27	138.11
90 Day	12362.0	13370.0	228.89	138.17
Canadian Dollar Per British Pound Sterling				
30 Day	4789.9	6835.4	273.22	229.17
90 Day	10852.0	12984.0	229.99	239.32
German Mark Per British Pound Sterling				
30 Day	5510.3	8080.9	122.01	276.97
90 Day	12892.0	2937.4	206.57	232.34
United States Dollar Per Canadian Dollar				
30 Day	54521.0	10250.0	148.40	142.58
60 Day	11199.0	20144.0	106.94	123.97
90 Day	15491.0	22709.0	110.35	123.77
United States Dollar Per German Mark				
30 Day	5671.6	6716.1	147.36	176.37
60 Day	11370.0	13566.0	150.55	170.69
90 Day	14382.0	17617.0	152.75	148.30
United States Dollar Per Swiss Franc				
30 Day	3256.7	3825.3	150.66	123.62
60 Day	8971.1	7978.2	131.45	130.57
90 Day	12658.0	14035.0	178.01	211.77

TABLE 7-5

PARAMETER EXTIMATION

D-Series Currencies	Significant Parameters (.95) First 500	Second 500
United States Dollar Per British Pound Sterling		
30 Day	MA1 = .444	MA1 = .558, ARI=.337
90 Day	MA1 = .352	MA1 = .378
Canadian Dollar Per British Pound Sterling		
30 Day	MA1 = .398	MA1 = .426
90 Day	MA1 = .440	MA1 = .393
German Mark Per British Pound Sterling		
30 Day	MA1 = .397	MA1 = .479
90 Day	MA1 = .477	MA1 = .558
United States Dollar Per Canadian Dollar		
30 Day	None	None
60 Day	MA3 = .11	None
90 Day	None	None
United States Dollar Per German Mark		
30 Day	None	MA1 = .480
60 Day	None	None
90 Day	AR2 = -.115	AR2 = -.173
United States Dollar Per Swiss Franc		
30 Day	None	MA1 = .748, ARI=.664, AR2 = -.21
60 Day	None	MA1 = .581
90 Day	None	AR2 = -.137

TABLE 7-6

CHI-SQUARED VALUES OF FITTED MODELS

D-Series Currencies	χ^2 First Difference	χ^2 Significant Model
United States Dollar Per British Pound Sterling		
30 Day (First 500)	179.27	130.97
30 Day (Second 500)	138.11	129.57
90 Day (First 500)	228.89	169.86
90 Day (Second 500)	138.17	137.32
Canadian Dollar Per British Pound Sterling		
30 Day (First 500)	273.22	173.69
30 Day (Second 500)	229.17	143.85
90 Day (First 500)	229.99	179.91
90 Day (Second 500)	239.32	162.20
German Mark Per British Pound Sterling		
30 Day (First 500)	122.01	122.54
30 Day (Second 500)	276.97	118.28
90 Day (First 500)	206.57	148.19
90 Day (Second 500)	232.34	161.29
United States Dollar Per Canadian Dollar		
60 Day (First 500)	106.94	109.27
United States Dollar Per German Mark		
30 Day (Second 500)	176.37	145.41
90 Day (First 500)	152.75	160.09
90 Day (Second 500)	148.32	136.20
United States Dollar Per Swiss Franc		
30 Day (Second 500)	123.62	76.93
60 Day (Second 500)	130.57	85.59
90 Day (Second 500)	211.77	191.04

CHAPTER VIII

THE INTERTEMPORAL PROFITABILITY CONDITIONS AND THE SHAPE OF THE PREMIA-MATURITY SCHEDULE

This chapter considers the intertemporal characteristics of the forward market for foreign exchange. In the first section, the existence of intertemporal profitability is examined and its relevance discussed. The second section examines the relationship of annualized premia or discounts for thirty, sixty and ninety day forward rates of exchange. From this analysis, a normal or typical premia-maturity schedule is developed. Possible explanations for the shape of this curve, along with practical implications, are presented as well.

I. Intertemporal Profitability Conditions

As stated in Chapter V, the forward market speculator must make transactions in two markets, the spot market and the forward market.[1] For the pure speculator, one who does not engage in convered-interest-arbitrage, there are two ways to complete these transactions. First, one can hold the forward contract to maturity and complete the speculation in the spot market at that time. An alternative is to reverse the first forward transaction, prior to its maturation, with an opposite forward contract having the same date of maturity as the first. For example, a ninety day forward purchase could be reversed with a thirty day forward sale in sixty days.

Intertemporal Speculation

A more complex, but less risky, speculation is the intertemporal speculative model developed in Chapter V. Here, a speculator both buys and sells a currency for different maturities. Upon the maturation of the contract of shortest duration, the two initial positions are reversed with a spot and forward transaction. To illustrate, suppose a speculator purchased British Pound Sterling ninety days forward while simultaneously selling Sterling thirty days forward. On the thirtieth day, the speculator could close the positions by purchasing spot (to meet the thirty day contract) and selling sixty days forward (to match the ninety day contract).

In considering an action, the intertemporal speculator considers the decision model presented in Chapter V, equation (10):

$$E((F^{n-m}_{t+m}) - (S_{t+m}) - (F^n_t - F^m_t)) = o$$

where superscripts represent the length of time a forward contract is held and subscripts represent the time at which a contract is entered.

When the expression is an equality, no action is taken. When the inequality is greater than, the speculator should purchase the currency on the longer forward contract (n days) while selling the currency forward on a shorter (m day) contract. In m days, an intermediate point, he completes the contracts by purchasing spot to satisfy the m day contract and selling an (m-n) day contract to satisfy the original n day forward purchase.

The return from the sequence above was termed the intertemporal profitability condition and defined as:

$$\pi = (F_m^{n-m} - S_m) - (F_o^n - F_o^m)$$

in equation (13), Chapter V. Note that this equals the expected return only if $E(F_m^{n-m} - S_m) = (F_m^{n-m} - S_m)$, the expected n-m day forward premium is realized.[2] Here, a speculator is estimating the size of the forward premium at a future time while the traditional forward speculator estimates the future spot rate.

Intertemporal Profitability

Using the three exchange rates for which thirty, sixty and ninety day forward rates were available, the actual intertemporal profitability condition was calculated and various statistical measures were prepared using the CONDESCRIPTIVE routine of SPSS.[3]

Table 8-1, Characteristics of Intertemporal Profitability, lists for each series, the mean, standard error, standard deviation, and indicates at what level of significance the mean differs from zero. The table, found on page 136 , gives each series by the m date, the date at which the speculation effectively ends. As the table shows, the intertemporal profitability differs significantly from zero in only three of six cases, both United States Dollar per Canadian Dollar series and the United States Dollar per Swiss Franc thirty day series.

Table 8-2, Intertemporal Profitability Frequency, shows the percentage of observations yielding negative, zero, and positive returns, respectively. As one can observe from the table on page 137, only the two United States Dollar per Swiss Franc series differ significantly from the frequencies one would expect from a normal distribution with zero mean.

In the three cases where intertemporal profitability differs significantly from zero, the speculator would have profited by selling the appreciating currency ninety days forward and taking the other intertemporal transactions which correspond.

On page 138, Table 8-3, Annualized Rates of Return on Intertemporal Speculation, considers the rate of return per United States Dollar contract for each of the six series. The highest annual rate of return is on the Swiss

Franc thirty day series, .703 percent. An individual who consistently sold Swiss Francs ninety days forward while purchasing them thirty days forward, waited the thirty days and then sold spot while making a sixty day forward purchase would have earned slightly more than seven-tenths of one percent on his total position.[4] Overall, one must conclude that intertemporal profitability is well below the required rate of return for its level of risk and the presence of nonzero mean values does not indicate that forward markets display intertemporal inefficiency.

II. The Premia-Maturity Function

The relationship of forward premia is one which is of interest for several reasons. Since little work has been done in this area, any knowledge of these interrelationships should aid international financial management.[5] If differences do exist between the premia of different forward maturities, traders may be able to profit from this knowledge by lowering their cost of using forward cover.

Annual percentage premia for each forward rate were calculated by taking the logarithm of the ratio of the forward rate to the spot rate. These were then put on an annual basis, and all currencies were adjusted to reflect forward premia.[6]

Table 8-5, Forward Exchange Rate Premia, summarizes the nine forward premia on page 140. For each currency, as the time to maturity increases, the mean value of the premium decreases. These differences are all significant at the .05 level and most are significant at the .01 level as indicated in the table. The variability also decreases at the time to maturity increases in all cases. This can be seen by the decreasing standard errors and standard deviations. All mean values are significantly different from zero at the .01 level. This evidence strongly suggests a downward sloping premia-maturity schedule.

Further analysis of the premia-maturity schedule involved the frequency of different configuations of premia. Rather than an average, this analysis centered on a case-by-case examination and used the FREQUENCIES program of SPSS.[7] Each forward rate was stated as an annual forward premia, and all possible combinations of premia were defined. Excluding any case where the annual premia are equal, the six possible combinations are listed below:

1. $P_{30} < P_{60} < P_{90}$
2. $P_{30} < P_{90} < P_{60}$
3. $P_{90} < P_{30} < P_{60}$
4. $P_{30} > P_{60} > P_{90}$
5. $P_{30} > P_{90} > P_{60}$
6. $P_{90} > P_{30} > P_{60}$

where P_{30}, P_{60}, and P_{90} represent the annual percentage premium for the thirty, sixty, and ninety day forward rates, respectively.

The results of the frequencies analysis are summarized in Tables 8-5, A to C, Premia-Maturity Frequencies, found on page 140. Case 4, $P_{30} > P_{60} > P_{90}$ is the most frequent case for each currency. This is consistent with the mean analysis presented above. A chi-squared test for each currency shows a significant difference between these outcomes and the uniform distribution one would expect with a random pattern. The table value for chi-squared at .01, and 5 degrees of freedom is 15.086. The lowest computed value is 259 for the German Mark.

Finally, the slopes between the premia of differing maturities were calculated. These are summarized in Table 8-6, Slope Between Forward Premia on page 143. For each currency, the slope is less steep between the sixty and ninety day values than between thirty and sixty days. In two cases, these differences are statistically significant at the .01 level; in the case of the Swiss Franc, the difference is not significant statistically.

The overall evidence indicates a premia-maturity schedule which is downward sloping but decreasing at a decreasing rate. Exhibit VIII-1 illustrates the typical premia-maturity schedule.

Since all theories of the forward market include interest rate differentials in their explanation of forward rates (either as a determinant or an equivalent difference), it is possible that interest rate differentials could explain the pattern of the forward premia. Daily interest rate for the countries and time period were not available for this study and so this line of research has not been pursued. Possibly the lower risk in holding longer contracts, as indicated by the decreasing standard deviations as time to maturity increases in the D series (Table 6-5), is the determining factor. Future work should be directed to this question.

Applications

The determination of a normal premia-maturity schedule and the analysis of the intertemporal speculation have implications for business managers and speculators.

First, a business person using the forward market to cover business transactions will find it profitable to use longer contracts. The rate is lower, on an annual basis, and the variability is less. If one considers the cost of forward cover to be the difference in the forward rate and the spot rate at the time of maturity, Table 6-5 clearly shows the ninety day rate to be cheaper to use than the thirty or sixty day rate.

Forward speculators will find the intertemporal area an inferior investment strategy. Using alternative maturities involves a risk-return tradeoff, since longer contracts have both lower returns and variability (when put on a comparable holding period). Realization of this should help speculators and increase market efficiency.

FOOTNOTES TO CHAPTER VIII

1. See Chapter V, Section II, Intertemporal Efficiency, for the development of this concept.

2. This distinction seems obvious, but has been overlooked in the literature. See Rita M. Rodriquez and E. Eugene Carter, International Financial Management (Englewood Cliffs, N.J.: Prentice-Hall, 1979): 138-142.

3. SPSS, op cit., pp. 186-191.

4. This analysis ignores transactions costs and margin requirements. The basic ten percent margin requirement would increase the return to seven percent, and transactions costs would reduce it somewhat. Even at six to seven percent, the United States Treasury bill rate would be higher with less risk.

5. Rodriquez and Carter, International Financial Management, implicitly assume the annual premia are all equal for all rates under one year. This is reflected throughout their text but specifically in all examples in Chapter 5, "An Introduction to the Foreign Exchange Market," pp. 119-178.

6. The United States Dollar per Canadian Dollar was at a discount during theis period. The rate was rewritten as Canadian Dollar per United States Dollar so forward rates were stated as a premium.

7. SPSS, op cit., pp. 194-202.

TABLE 8-1

CHARACTERISTICS OF INTERTEMPORAL PROFITABILITY

Currency/ Day of Completion	Mean	Standard Error	Standard Deviation	Level of Significance
30 Day	-.00041	.00010	.00272	.01
60 Day	-.00035	.00009	.00226	.01
Actual Returns				
United States Dollar Per German Mark:				
30 Day	.00006	.00006	.00158	-
60 Day	.000001	.00006	.00157	-
Actual Returns				
United States Dollar Per Swiss Franc:				
30 Day	.00023	.00011	.00287	.01
60 Day	.00011	.00006	.00148	-
Actual Returns				

TABLE 8-2

INTERTEMPORAL PROFITABILITY FREQUENCY

Currency/ Day of Completion	Negative Percentage	Zero Percentage	Positive Percentage
United States Dollar Per Canadian Dollar:			
30 Day	59.6	1.1	39.1
60 Day	58.2	1.1	40.7
United States Dollar Per German Mark:			
30 Day	49.9	1.4	48.7
60 Day	54.7	2.2	43.1
United States Dollar Per Swiss Franc:			
30 Day	33.4	1.4	65.2
60 Day	27.8	1.3	70.9

TABLE 8-3

ANNUALIZED RATES OF RETURN

ON INTERTEMPORAL SPECULATION

Currency/ Day of Completion	Mean	Standard Error	Standard Deviation	Level of Significance
United States Dollar Per Canadian Dollar:				
30 Day	-.00526	.00122	.03260	.01
60 Day	-.00206	.00051	.01357	.01
United States Dollar Per German Mark:				
30 Day	-.00188	.00185	.04941	-
60 Day	.00010	.00009	.02433	-
United States Dollar Per Swiss Franc:				
30 Day	.00703	.00360	.09723	.05
60 Day	.00331	.00190	.04999	-

TABLE 8-4

FORWARD EXCHANGE RATE PREMIA

ANNUAL PERCENTAGE

Currency/ Forward Period	Mean	Standard Error	Standard Deiation	Level of Significance Mean	Level of Significance Between Means
United States Dollar Per Canadian Dollar:					
30 Day	2.0594	.07345	1.9967	.01	.01
60 Day	1.7435	.06265	1.7031	.01	.05
90 Day	1.5394	.05201	1.4140	.01	
United States Dollar Per German Mark:					
30 Day	3.2340	.15195	4.1194	-	.01
60 Day	2.6620	.07637	2.0704	-	-
90 Day	2.5777	.05699	1.5449	-	
United States Dollar Per Swiss Franc:					
30 Day	4.4129	.14824	4.0217	-	.05
60 Day	3.7840	.17333	4.7022	-	.01
90 Day	3.2999	.06842	1.8563	-	

TABLE 8-5A

PREMIA-MATURITY FREQUENCIES

FOR

CANADIAN DOLLAR PER UNITED STATES DOLLAR

	Outcome	Absolute Frequency	Relative Frequency Percentage
1.	$P_{30} < P_{60} < P_{90}$	67	9.1
2.	$P_{30} < P_{90} < P_{60}$	67	9.1
3.	$P_{90} < P_{30} < P_{60}$	44	6.0
4.	$P_{30} > P_{60} > P_{90}$	462	62.8
5.	$P_{30} > P_{90} > P_{60}$	73	9.9
6.	$P_{90} > P_{30} > P_{60}$	23	3.1
	Total	736	100.0

χ^2 value = 374

TABLE 8-5B

PREMIA-MATURITY FREQUENCIES

FOR

UNITED STATES DOLLAR PER GERMAN MARK

Outcome	Absolute Frequency	Relative Frequency Percentage
1. $P_{30} < P_{60} < P_{90}$	206	28.0
2. $P_{30} < P_{90} < P_{60}$	35	4.8
3. $P_{90} < P_{30} < P_{60}$	12	1.6
4. $P_{30} > P_{60} > P_{90}$	310	42.2
5. $P_{30} > P_{90} > P_{60}$	122	16.6
6. $P_{90} > P_{30} > P_{60}$	50	6.8
Total	735	100.0

χ^2 value = 259

TABLE 8-5C

PREMIA-MATURITY FREQUENCIES

FOR

UNITED STATES DOLLAR PER SWISS FRANC

Outcome	Absolute Frequency	Relative Frequency Percentage
1. $P_{30} < P_{60} < P_{90}$	98	13.3
2. $P_{30} < P_{90} < P_{60}$	64	8.7
3. $P_{90} < P_{30} < P_{60}$	52	7.1
4. $P_{30} > P_{60} > P_{90}$	390	53.0
5. $P_{30} > P_{90} > P_{60}$	95	12.9
6. $P_{90} > P_{30} > P_{60}$	37	5.0
Total	736	100.0

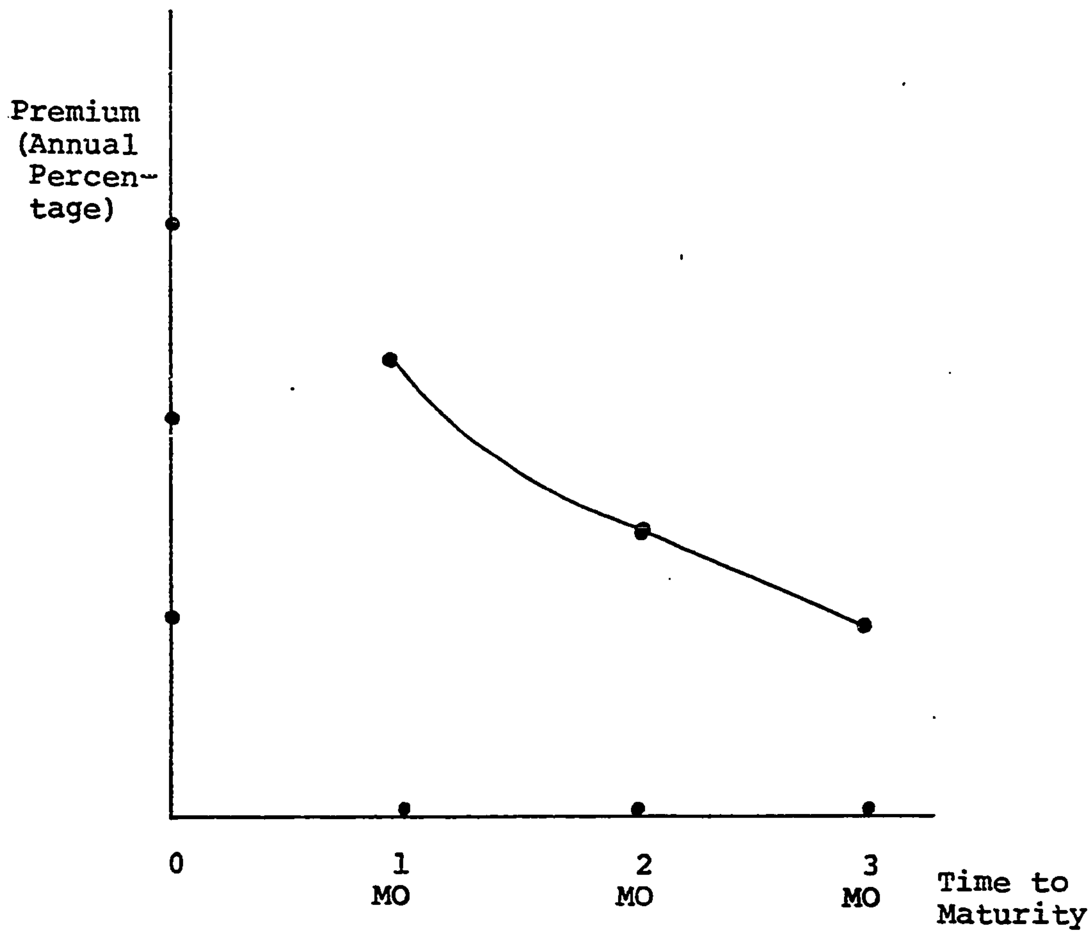
χ^2 value = 297

TABLE 8-6

SLOPE BETWEEN FORWARD PREMIA

Currency/ Range	Mean	Standard Error	Level of Significance Mean	Level of Significance Between Means
Canadian Dollar Per United States Dollar:				
30 to 60 Day	-.31598	.04222	.01	.05
60 to 90 Day	-.20402	.02716	.01	
United States Dollar Per German Mark:				
30 to 60 Day	-.57201	.11102	.01	.05
60 to 90 Day	-.08430	.03503	.05	
United States Dollar Per Swiss Franc:				
30 to 60 Day	-.62901	.17180	.01	-
60 to 90 Day	-.48398	.15493	.01	

EXHIBIT VIII-1



CHAPTER IX

SUMMARY, CONCLUSIONS, AND IMPLICATIONS

This study has been devoted to an examination of the characteristics and efficiency of the forward market for foreign exchange. This final chapter briefly outlines the study, states the conclusions drawn from examination of the data and the tests of hypotheses, and identifies the implications of these conclusions.

I. SUMMARY

A speculator must purchase (sell) a forward contract of f days in length and sell (purchase) the currency in the spot market on day f to complete his transaction. This necessary use of two financial markets distinguishes the forward market from most other financial markets.

The rate of return on forward speculation, R, is estimated by the logarithm of the ratio of the forward rate and the spot rate at maturity. The series of such rates is examined, along with spot and forward rates, for evidence of a non-normal distribution.

Rather than purchase a forward contract and sell spot upon maturity, a speculator may complete his transaction through a more complex procedure. By buying and selling different forward maturities and reversing both positions when the earliest contract matures, the speculator is performing time arbitrage or intertemporal speculation. The procedures and conditions of intertemporal speculation are detailed and examined in the paper.

The difference in a forward exchange rate and the existing spot exchange rate is called the forward premium (discount if negative). The relationship of the annualized premia for currencies was examined and normal curves representing the premia-maturity schedules were estimated.

II. Conclusions

Based on the analysis contained in this paper, several conclusions and implications may be stated concerning the forward market for foreign exchange. Speculators, business organizations, and students of the foreign exchange market should find these conclusions and implications of interest.

Distributions

The distributions of the spot, forward, and return on forward contract rates are non-normal. These distributions are characterized by distributions with high peaks around the mean and fat tails. A better fit is obtained when these distributions are described with a member of the stable Paretian family. The characteristic exponent of the distributions examined falls between 1.25 and 1.8 with an average of approximately 1.55. A normal distribution has a characterist exponent of 2.0.

A stable Paretian distribution has no moments higher than its characteristic exponent. The forward rate, spot rate, and the rate of return on forward contracts held to maturity all are stable Paretian with characteristic exponents of less than two; therefore, none of these distributions have finite variances. Some measure of distribution or variability other than variance or standard deviation must be employed when considering the riskiness of speculative activities using these markets.

The rate of return on holding forward rates to maturity was significantly different from zero as one might expect from the modern theory, the interest parity theory, or Hodgson's reconciliation theory. The mean return, on an annual basis, was also found to decrease as the length of the forward contract increased. And, smaller variability in returns accompanied the longer maturities.

Forward Market Efficiency

This paper demonstrates that the forward market for foreign exchange is nonrandom but cannot be proven inefficient at the weak form level based upon the tests employed in this study.

A nonrandom pattern tends to occur in the time series of the rate of return on forward contracts. This pattern is one of positive autocorrelation, but the level of correlation is low and length of patterns in the series is short. So, in a true fair game sense, the information would not allow an individual to profit; therefore, the paper supports efficiency in the forward market.

The fact that the series are nonrandom means that neither a random walk nor a martingale model is appropriate; however, these models are sufficient but not necessary conditions for an efficient market. Only if the information of a nonrandom pattern can be used to earn returns above the expected return for this risk class could inefficiency be claimed. Since there is no pattern which remains stable throughout the time period examined, and the memory of the pattern is short, the possibility for above average returns does not exist in the forward market.

Intertemporal Profitability

Various scholars and practitioners of the complex area of international finance have wondered about time arbitrage or intertemporal speculation. The development and measurement of the condition in this study should be of interest to these individuals.

The intertemporal profitability condition does exist; it is significantly different from zero in most cases. However, it is low, and, even with favorable margin requirements and zero transactions costs, the rate of return would be below the yield on United States Treasury Bills. With higher risks and lower returns than government securities, this technique does not indicate forward market inefficiency.

The Premia-Maturity Schedule

The shape of the normal premia-maturity schedule is a downward curve decreasing at a decreasing rate. The annualized premium for a thirty day premium exeeds the annualized sixty day premium and this exceeds the ninety day premium. The slope between the 30-day and 60-day premia is more steep than between 60 days and 90 days. This is not true each trading day, but is true in a significant majority of the cases.

Aside from adding to the general knowledge, this work on relative premia of forward rates has important implications for foreign exchange traders and business planners. These implications concern the risk and return of using forward markets.

For a business using the forward market to cover foreign exchange risks, the cost of using the forward market can be estimated in either of two ways. On an <u>ex ante</u> basis, the cost is the actual forward premium (F-S)/S. On an *ex post* basis, the cost is the difference between the forward rate and the spot rate on the day the forward rate matures.

Either calculation of the cost of using the forward market is reduced as the forward maturity is increased. This reduction in cost is accompanied by a reduction in variability. To business planners, there is a benefit to planning as far forward as possible to take advantage of the lower cost of using longer forward contracts. In addition, it is possible that some business policies, such as credit terms of sale, should be changed to reflect the benefit of lower premia at longer maturities.

III. Directions for Future Research

Research is an ongoing process and each step should indicate future steps. This dissertation follows work on market efficiency in capital markets and suggests research in several areas. Obviously, semi-strong and strong efficiency in foreign exchange and forward exchange markets should be tested. The premia-maturity schedule should be examined with the purpose of identifying the determinants of its shape. And, the relationship of a premia-maturity curve to the interest rate yield-to-maturity curves in the two countries deserves examination. This study represents a start in each of these areas as well as an in-depth analysis of the characteristics and efficiency of the forward market for foreign exchange.

APPENDIX A

A-1. Program to Assign Preceding Daily Rate to Non-Trading Days

A-2. Program to Pair Thirty Day Forward Rate With Spot Rate in Thirty Days

A-3. Program to Pair Sixty Day Forward Rate With Spot Rate in Sixty Days

A-4. Program to Pair Ninety Day Forward Rate With Spot Rate in Ninety Days

A-1

```
      PROGRAM DC
      THIS IS A PROGRAM TO FILL MISSING SPOT RATES.
      EACH WEEKEND DAY, HOLIDAY, OR NON-TRADING DAY IS
      FILLED WITH THE PREVIOUS DAY'S SPOT EXCHANGE RATE.
      INTEGER DA,MO,YR,SDA,SMO,SYR
      N=2
      SMO=7
      SYR=73
    1 READ(25,2,END=99)DA,MO,YR,SPOT,F30,F60,F90
    2 FORMAT(3I2,3X,4(F6.5,4X))
      IF(SMO.EQ.02)GO TO 77
      IF(SMO.EQ.06.OR.SMO.EQ.09)GO TO 78
      IF(SMO.EQ.04.OR.SMO.EQ.11)GO TO 78
      IF(N.GT.31)GO TO 79
      GO TO 54
   27 IF(YR.EQ.76)GO TO 777
      IF(N.GT.28)GO TO 79
      GO TO 54
  777 IF(N.GT.29)GO TO 79
      GO TO 54
   78 IF(N.GT.30)GO TO 79
      GO TO 54
   79 N=1
      IF(SMO.LT.12)GO TO 97
      SMO=1
      SYR=SYR+1
      GO TO 54
   97 SMO=SMO+1
   54 IF(DA.GT.N)GO TO 55
      SYR=YR
      SSPOT-SPOT
      SF30=F30
      SF60=F60
      SF90=F90
   55 WRITE(26,3)SMO,N,SYR,SSPOT,SF30,SF60,SF90
      N=N+1
      IF(DA.GT.N)GO TO 55
      IF(DA.EQ.N)GO TO 54
    3 FORMAT(1X,3I2,4X,4(F7.5,1X)
      GO TO 1
   99 STOP
      END
```

A-2

```
      PROGRAM GOGO
C     THIS PROGRAM LINKS A THIRTY DAY FORWARD
      EXCHANGE RATE WITH THE SPOT RATE WHICH
      EXISTS WHEN THE FORWARD RATE MATURES
      IN THIRTY DAYS.
      INTEGER DA,DDA,YR,SMO,SDA,SYR
    1 READ(25,111,END=99)DA,MO,YR,SPOT,F30,F60,F90
    2 READ(26,11,END=99)SMO,SDA,SYR,SS|F3,F6,F9
   11 FORMAT(1X,3I2,4X,4(F7.5,1X))
  111 FORMAT(3I2,3X,4(F6.5,4X))
      IF(MO.EQ.1)GO TO 26
   66 CONTINUE
      IF(MO.EQ.4.OR.MO.EQ.6.OR.MO.EQ.9.OR.MO.EQ.11)GO TO22
      IF(MO.NE.2)GO TO 21
   22 CONTINUE
      IF(MO.EQ.02)GO TO 23
      DDA=DA
    3 CONTINUE
      IF(SDA.NE.DDA)GO TO 2
      WRITE(27,12)MO,DA,YR,SPOT,F30,F60,F90,SS,F3,F6,F9
   12 FORMAT(3I2,8F10.5)
      WRITE(6,33)DA,MO,YR,SMO,SDA,SYR
   33 FORMAT(6(2X,I2))
      GO TO 1
   21 DDA=DA-1
      IF(DDA.NE.0)GO TO 3
      DDA=31
      GO TO 3
   23 DDA=DA+2
      GO TO 3
   26 IF(DA.LE.29)GO TO 21
      DDA=DA+1-30
      GO TO 3
   99 STOP
      END
```

A-3

```
      PROGRAM SIXTY
C     THIS PROGRAM LINKS THE SIXTY DAY FORWARD EXCHANGE
C     RATE TO THE SPOT RATE IN EXISTENCE UPON MATURITY
C     IN SIXTY DAYS
      INTEGER DA,DDA,YR,SMO,SDA,SYR
111   CONTINUE
      READ(26,11)SMO,SDA,SYR,SS,F3,F6,F9
      IF(SMO.LT.8)GO TO 111
    1 READ(25,1111,END=99)DA,MO,YR,SPOT,F30,F60,F90
    2 READ(26,11,END=99)SMO,SDA,SYR,SS,F3,F6,F9
   11 FORMAT(1X,3I2,4X,4(F7.5,1X))
1111  FORMAT(3I2,3X,4(F6.5,4X))
      IF(MO.EQ.03.OR.MO.EQ.05)GO TO 21
      IF(MO.EQ.08.OR.MO.EQ.10)GO TO 21
      IF(MO.EQ.04.OR.MO.EQ.06)GO TO 24
      IF(MO.EQ.09.OR.MO.EQ.11)GO TO 24
      IF(MO.EQ.12.AND.DA.EQ.31)GO TO 255
      IF(MO.EQ.07.OR.MO.EQ.12)GO TO 25
      IF(MO.EQ.01.OR.MO.EQ.02)GO TO 23
   22 CONTINUE
      DDA=DA-1
    3 CONTINUE
      IF(SDA.NE.DDA)GO TO 2
      WRITE(6,66)DA,MO,YR,SDA,SMO,SYR
   66 FORMAT('0'),6(2X,I2))
      WRITE (27,12)MO,DA,YR,SPOT,F30,F60,F90,SS,F3,F6,F9
   12 FORMAT(3I2,8F10.5)
      GO TO 1
   21 IF(DA.GT.01)GO TO 22
      DDA=30
      GO TO 3
   24 IF(DA.GT.01)GO TO 22
      DDA=31
      GO TO 3
   23 DDA=DA+1
      IF(DA.LT.31)GO TO 3
      DDA=1
      GO TO 3
   25 IF(DA.GT.02)GO TO 26
      IF(DA.EQ.01)GO TO 27
      DDA=31
      GO TO 3
   27 DDA=30
      GO TO 3
  225 DDA=1
      GO TO 3
   26 DDA=DA-2
      GO TO 3
   99 STOP
      END
```

A-4

```
      PROGRAM DODO
C     THIS PROGRAM LINKS THE NINTY DAY FORWARD RATE
C     WITH THE SPOT RATE IN EXISTENCE WHEN THE FORWARD
C     CONTRACT MATURES IN NINTY DAYS.
      INTEGER DA,DDA,YR,SMO,SDA,SYR
  111 CONTINUE
      READ(26,11)SMO,SDA,SYR,SS,F3,F6,F9
      IF(SMO.LT.9)GO TO 111
    1 READ(25,1111,END=99)DA,MO,YR,SPOT,F30,F60,F90
    2 READ(26,11,END=99)SMO,SDA,SYR,SS,F3,F6,F9
   11 FORMAT(1X,3I2,4X,4(F7.5,1X)
 1111 FORMAT(3I2,3X,4(F6.5,4X))
      IF(MO.EQ.10)GO TO 27
      IF(MO.EQ.7.AND.DA.EQ.1)GO TO 44
      IF(MO.EQ.7.AND.DA.EQ.2)GO TO 29
      IF(MO.EQ.7)GO TO 27
      IF(MO.EQ.1.OR.MO.EQ.12)GO TO 22
      IF(MO.EQ.3.OR.MO.EQ.5.OR.MO.EQ.6)GO TO 27
      IF(MO.EQ.8.OR.MO.EQ.11)GO TO 27
      IF(MO.EQ.2)GO TO 23
      IF(MO.EQ.9.OR.MO.EQ.4)GO TO 21
   22 CONTINUE
      IF(MO.EQ.1.AND.DA.EQ.31)GO TO 45
      DDA=DA
    3 CONTINUE
      IF(SDA.NE.DDA)GO TO 2
      WRITE(6,66)DA,MO,YR,SDA,SMO,SYR
   66 FORMAT('0',6(2X,I2))
      WRITE(27,12)MO,DA,YR,SPOT,F30,F60,F90,SS,F3,F6,F9
   12 FORMAT(3I2,8F10.5)
      GO TO 1
   21 DDA=DA-1
   25 IF(DDA.GT.0)GO TO 3
      DDA=30
      GO TO 3
   27 DDA=DA-2
      IF(DDA.GT.0)GO TO 3
      IF(DA.EQ.1)GO TO 29
      DDA=31
      GO TO 3
   29 DDA=30
      GO TO 3
   23 DDA=DA+1
      GO TO 3
   44 DDA=29
      GO TO 3
   45 DDA=1
      GO TO 3
   99 STOP
      END
```

APPENDIX B

AUTOCORRELATION FUNCTION

DATA = COOL 30 DAY D SERIES FIRST 500 — 500 OBSERVATIONS

DIFFERENCING = ORIGINAL SERIES IS YOUR DATA.

DIFFERENCES BELOW ARE OF ORDER 1

ORIGINAL SERIES
MEAN OF THE SERIES = .22626E 02
ST. DEV. OF SERIES = .92797E 02
NUMBER OF OBSERVATIONS = 500

1- 10	.96	.92	.89	.86	.82	.79	.76	.72	.69	.65
ST.E.	.04	.08	.10	.11	.12	.13	.14	.15	.16	.16
11- 20	.61	.57	.53	.49	.44	.40	.36	.32	.28	.25
ST.E.	.17	.17	.18	.18	.18	.18	.19	.19	.19	.19
21- 30	.23	.22	.21	.21	.20	.18	.17	.16	.15	.14
ST.E.	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19
31- 40	.13	.13	.13	.14	.15	.16	.16	.17	.17	.18
ST.E.	.19	.19	.19	.19	.19	.19	.20	.20	.20	.20
41- 50	.18	.18	.18	.17	.17	.18	.19	.20	.21	.21
ST.E.	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
51- 60	.22	.22	.22	.22	.21	.20	.19	.19	.19	.19
ST.E.	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
61- 70	.20	.20	.20	.20	.21	.21	.21	.20	.19	.19
ST.E.	.20	.20	.20	.21	.21	.21	.21	.21	.21	.21
71- 80	.19	.19	.19	.18	.18	.17	.16	.15	.14	.11
ST.E.	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21
81- 90	.09	.07	.04	.02	-.00	-.03	-.05	-.06	-.08	-.10
ST.E.	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21
91-100	-.12	-.14	-.15	-.16	-.17	-.18	-.19	-.19	-.19	-.19
ST.E.	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21
101-110	-.18	-.18	-.17	-.16	-.15	-.15	-.14	-.13	-.12	-.12
ST.E.	.21	.21	.21	.21	.21	.21	.22	.22	.22	.22
111-120	-.11	-.11	-.10	-.09	-.08	-.07	-.07	-.06	-.06	-.06
ST.E.	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22
121-130	-.06	-.07	-.08	-.08	-.08	-.08	-.09	-.09	-.09	-.09
ST.E.	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22
131-140	-.09	-.10	-.11	-.12	-.12	-.13	-.13	-.12	-.12	-.11
ST.E.	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22
141-150	-.10	-.08	-.07	-.06	-.05	-.04	-.03	-.02	-.01	.00
ST.E.	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22

MEAN DIVIDED BY ST. ERROR = .54521E 01

TO TEST WHETHER THIS SERIES IS WHITE NOISE, THE VALUE .57147E 04
SHOULD BE COMPARED WITH A CHI-SQUARE VARIABLE WITH 150 DEGREES OF FREEDOM

DIFFERENCE 1
MEAN OF THE SERIES = .77875E-01
ST. DEV. OF SERIES = .26374E 02
NUMBER OF OBSERVATIONS = 499

1- 10	-.06	-.04	.02	-.02	.04	-.02	.01	-.01	.05	-.01
ST.E.	.04	.04	.05	.05	.05	.05	.05	.05	.05	.05
11- 20	.03	.06	-.00	.02	-.07	.00	.01	-.08	-.06	-.14
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
21- 30	-.09	-.04	-.00	.02	.06	.02	-.06	.02	-.04	-.06
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
31- 40	-.02	-.01	-.08	-.05	-.01	.04	.05	-.02	-.01	.03
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
41- 50	.03	.03	.04	-.05	-.07	-.06	-.01	-.01	.04	.04
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
51- 60	.05	-.01	.05	.04	.03	-.07	-.02	-.03	-.05	.02
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
61- 70	-.01	-.02	-.05	.03	.05	.02	.10	-.02	-.09	-.01
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
71- 80	.00	.01	.01	.07	-.04	.10	-.02	.08	.09	-.01
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
81- 90	-.00	.00	.04	-.01	.01	-.02	-.12	.05	-.04	.07
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
91-100	.01	-.06	-.04	-.09	.08	-.08	-.02	.01	-.07	-.05
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
101-110	-.02	.03	-.02	-.02	.02	-.05	.05	.02	-.01	.00
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
111-120	.02	-.06	-.03	.05	.01	-.01	.01	.01	.05	.06
ST.E.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
121-130	.02	-.01	-.01	-.05	.06	-.02	.00	-.03	.02	.02
ST.E.	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
131-140	.03	-.01	.03	-.02	-.04	-.03	-.03	-.04	-.04	-.07
ST.E.	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
141-150	-.02	.01	.03	-.00	.01	.03	-.07	.08	-.06	.03
ST.E.	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06

MEAN DIVIDED BY ST. ERROR = .65959E-01

TO TEST WHETHER THIS SERIES IS WHITE NOISE, THE VALUE .14840E 03
SHOULD BE COMPARED WITH A CHI-SQUARE VARIABLE WITH 150 DEGREES OF FREEDOM

BIBLIOGRAPHY

Alexander, Sidney. "Price Movements in Speculative Markets: Trends or Random Walks." Industrial Management Review 2 (May, 1961), 7-26.

____________. "Price Movements in Speculative Assets: Trends or Random Walks, No. 2." in The Random Character of Stock Market Prices. Ed. Paul H. Cootner. Cambridge, Mass: MIT Press, 1964, 17-78.

Bachelier, Louis. "A Thesis presented to the Faculty of Sciences of the Academy of Paris." in The Random Character of Stock Market Prices. Ed. Paul H. Cootner. Cambridge, Mass: MIT Press, 1964, 17-78.

Ball, Ray and Philip Brown. "An Empirical Evaluation of Accounting Income Numbers." Journal of Accounting Research 6 (Autumn 1968), 159-178.

Box, G. E. P. and G. M. Jenkins. Time Series Analysis, Forecasting and Control. San Francisco: Holden-Day, 1970.

____________. Time Series Analysis, Forecasting and Control, Revised Edition. San Francisco: Holden-Day, 1976.

Brown, P. and V. Niederhoffer. "The Predictive Content of Quarterly Earnings." The Journal of Business 43 (January 1970), 60-62.

Chicago Board of Options Exchange. International Monetary Market Yearbook. Chicago: Staff of the IMM, 1973/74, 1974/75, 1975/76.

Collins, J. Markham. "The Purchasing Power Parity Problem." Unpublished manuscript, presented in Seminar in International Finance. Norman, Oklahoma, Fall 1973.

Conover, W. J. Practical Nonparametric Methods. New York: John Wiley, 1971.

Coulbois, Paul and Pierre Prissert. "Forward Exchange, Short-Term Capital Flows and Monetary Policy." De Economist 122, No. 4 (1974): 283-308.

Einzig, Paul. "Some Theoretical Aspects of Forward Exchanges." Economic Journal (September 1936).

____________. A Dynamic Theory of Foreign Exchange, 2nd ed. London: MacMillan, 1966.

Fama, Eugene F. and Marshall Blume. "Filter Rules and Stock Market Trading Profits." Journal of Business 39 (Special Supplement, January, 1966), 166-241.

____________ and Richard Roll. "Some Properties of Symmetric Stable Distributions." Journal of the Ameri- Statistical Association (September 1968): 817-836.

____________, et al., "The Adjustment of Stock Prices to New Information." International Economic Review 10, No. 1 (February 1969), 1-21.

____________. "Efficient Capital Markets: A Review of Theory and Empirical Work." Journal of Finance 25, No. 2, (May, 1970), 383-417.

____________. "The Behavior of Stock Market Prices." Journal of Business 38 (January 1971): 34-105.

Fieleke, Norman. "Exchange Rate Flexibility and the Efficiency of the Foreign-Exchange Markets." Journal of Financial and Quantitative Analysis 10 (Sept. 1975): 409-428.

The Financial Times. London, March 24, 1973 to February 1, 1976.

Folks, William R. Jr. "A New Look at Time Arbitrage." Unpublished working paper. Columbus, S.C.: University of South Carolina, 1977).

Freund, John E. and Frank J. Williams. Elementary Basic Statistics, 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, 1972.

Friend, Irwin, et al. A Study of Mutual Funds. Washington, D. C.: U. S. Government Printing Office, 1962.

Gibbons, Jean Dickinson. Nonparametric Statistical Inference. New York: McGraw-Hill, 1971.

Giddy, Ian H. and Gunter Dufey. "The Random Behavior of Flexible Exchange Rates: Implications for Forecasting." Journal of International Business Studies 6 (Spring, 1975): 1-32.

____________. "An Integrated Theory of Exchange Rate Equilibrium." Journal of Financial and Quantitative Analysis 11 (Dec. 1976): 883-892.

Godfrey, Michael, C. Granger, and Oskar Morgenstern. "The Random Walk Hypothesis of Stock Market Behavior." Kyklos 17 (1964): 1-30.

Granger, Clive and Oskar Morgenstern. "Spectral Analysis of New York Stock Market Prices." Kyklos 16 (1963): 1-27.

Green, D. and J. Segall. "The predictive Power of First-Quarter Earning Reports." Journal of Accounting Research IV Suppl. Empirical Research in Accounting: Selected Studies, 1966 (1967), 21-36.

Grubel, Herbert G. Forward Exchange Speculation and the International Flow of Capital. Stanford: Stanford University Press, 1966.

Herring, Richard J. and Richard C. Marston. "The Forward Market and Interest Rates in the Eurocurrency and National Money Markets." Unpublished working paper. Philadelphia: The Wharton School, Univ. of Penn., 1974.

Hodgson, John S. "Reconciling Alternate Theories of the Foreign Exchange Market." Unpublished manuscript. Milwaukee: University of Wisconsin at Milwaukee, 1977.

Horwitz, Ira. "A Model for Mutual Fund Evaluation." Industrial Management Review 6 (Spring 1965): 81-92.

Jensen, Michael C. "The Performance of Mutual Funds in the Period 1945-64." Journal of Finance 23, No. 2 (May 1968): 389-416.

Kendall, Maurice G. "The Analysis of Time Series I." Journal of the Royal Statistical Society Ser. B. 116 (1975), 11-25.

Keynes, John Maynard. "The Forward Market in Foreign Exchanges." Manchester Guardian Reconstruction Supplement, April 20, 1922.

____________. A Tract on Monetary Reform. London: Macmilian, 1923.

Knight, Frank. Risk, Uncertainty and Profit. Boston: Houghton-Mifflin, 1921.

Lintner, John. "The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets." Review of Economics and Statistics 47 (Feb. 1965), 13-37.

Makridakis, Spyros and Stephen C. Wheelwrite. Forecasting Methods & Applications. Santa Barbara, CA: Wiley/ Hamilton, 1978.

Mandelbrot, Benoit. "Forecasting of Future Prices, Unbiased Markets, and Martingale Models." Journal of Business 39 part 2 (Special Supplement, January 1966), 242-255.

Markowitz, Harry M. "Portfolio Selection." Journal of Finance 7, No. 1 (March 1952), 77-91.

Moore, Arnold. "Some Characteristics of Changes in Common Stock Prices." In The Random Character of Stock Market Prices. Ed. Paul H. Cootner. Cambridge, Mass: MIT Press, 1964, 139-161.

Nelson, Charles R. Applied Time Series Analysis. San Francisco: Holden-Day, 1973).

Nie, Norman, et al. Statistical Package for the Social Sciences, 2nd ed. New York: McGraw-Hill, 1975.

Niederhoffer, Victor and M.F.M. Osborne. "Market Making and Reversal on the Stock Exchange." Journal of the American Statistical Association, 61 (Dec. 1970): 897-916.

Officer, Lawrence H. and Thomas D. Willett. "The Covered-Arbitrage Schedule: A Critical Survey of Recent Development." Journal of Money, Credit and Banking (May 1970): 247-257.

Osborne, M.F.M. "Brownian Motion in the Stock Market." Operations Research 7 (March-April, 1959), 145-173.

Pindyck, Robert S. and Daniel Rubinfeld. Econometric Models and Economic Forecasts. New York: McGraw-Hill, 1976.

Pippenger, John J. "Spot Rates, Forward Rates, and Interest Differentials." Journal of Money, Credit, and Banking, 4 (May 1972): 375-383.

Poole, William. "Speculative Prices As Random Walks: An Analysis of Ten Time Series of Flexible Exchange Rates." Southern Economic Journal 33 (April 1967): 468-478.

Roberts, Harry V. "Stock Market "Patterns' and Financial Analysis: Methodological Suggestions." Journal of Finance 14, No. 1 (March, 1959), 1-10.

Rodriquez, Rita M. and E. Eugene Carter. International Financial Management. Englewood Cliffs, N.J.: Prentice-Hall, 1976.

Roll, Richard. "The Efficient Market Model Applied to U. S. Treasury Bill Rates." Diss. Univ. of Chicago, 1968.

____________ and Bruno Solnik, "A Pure Foreign Exchange Asset Pricing Model." Journal of International Economics 7 (1977): 161-179.

Samuelson, Paul A. "Proof that Properly Anticipated Prices Fluctuate Randomly." Industrial Management Review 6 (Spring, 1965): 41-49.

Scholes, Myron S. "The Market for Securities: Substitutions Versus Price Pressure and the Effects of Information on Share Prices." Journal of Business 45, No. 2 (April 1972).

Sharpe, William F. "A Simplified Model for Portfolio Analysis." Management Science 9, No. 2 (January 1963): 277-293.

____________."Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk." Journal of Finance 9 (Sept. 1964), 429-442.

____________. "Mutual Fund Performanc." Journal of Business 39 (Special Supplement part 2, Jan. 1966), 272-293.

Smith, Adam. The Money Game. New York: Random House, Inc., 1967.

Working, Holbrook. "A Random-Difference Series for Use in the Analysis of Time Series." Journal of the American Statistical Association 29 (1934).

Sohman, Egon. The Theory of Forward Exchange. No. 17. Princeton: Princeton Studies in International Finance, 1966.

Solnik, Bruno. European Capital Markets: Toward a General Theory of International Investment. Lexington, Mass.: Lexington Books, 1973.

Sparos, J. "Speculation, Arbitrage and Sterling." Economic Journal 69 (1959), 1-21.

Stein, J. L. "The Financial Rate and The Interest Rate." Review of Economic Studies (April 1965), 40-66.

Stoll, Hans. "An Empirical Study of the Forward Exchange Market Under Fixed and Flexible Exchange Rate Systems." Canadian Journal of Economics (Feb. 1968), 55-78.

____________. "Causes of Deviation from Interest-Rate Parity, A Comment." Journal of Money Credit and Banking (Feb. 1968), 55-78.

Syrett, W. W. "A Revision of the Theory of Forward Exchanges." The Banker (June 1936).

Tsiang, S. C. "The Theory of Forward Exchange and Effects of Government Intervention on the Forward Exchange Market." International Monetary Fund Staff Papers (April 1959), 75-106.

____________. "Spot Speculation, Forward Speculation, and Arbitrage; A Clarification and Reply." American Economic Review (Winter 1973), 999-1003.

Upson, Roger B. "Random Walk and Forward Exchange Rates: A Spectral Analysis." Journal of Financial and Quantitative Analysis, 7 (Sept. 1972), 1897-1906.

Van Belle, John J. "Spot Rates, Forward Rates and the Interest Rate Differentials." Journal of Money Credit and Banking, (Nov. 1973), 997-999.

Westerfield, Janice M. "Empirical Properties of Foreign Exchange Rates Under Fixed and Floating Rate Regimes." Philadelphia Fed. Research Papers, Research Paper No. 16, Philadelphia: Federal Reserve Bank of Philadelphia, 1975.

Winters, P. R. "Forecasting Sales by Exponentially Weighted Moving Averages." Management Science 6 (1960), 324-342.

Wonnacott, Thomas H. and Ronald J. Wonnacott. Introductory Statistics for Business and Economics. New York: John Wiley & Sons, 1972, 398-402.

Yeager, Leland B. International Monetary Relations: Theory, History and Practice. 2nd ed. New York: Harper & Row, 1976.

Yule, G. U. "Why Do We Sometimes Get Nonsense-Correlations Between Time Series? A Study of Sampling and the Nature of Time Series." Journal of the Royal Statistical Society 89 (1926), 1-64.