EXCHANGE RATE DYNAMICS AND SPECULATIVE EFFICIENCY

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CONTENTS

TABLES AND ILLUSTRATIONS

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KEY TO SYMBOLS IN

CHAPTERS 6 AND 7

w = log of nominal wealth
m = log of the domestic money stock
b = log of the stock of domestic bonds
b^* = log of the stock of foreign bonds
S = spot exchange rate
F = forward exchange rate
f = forward premium = $\ln(1 + (F-S)/S)$
y = log of real output
r = domestic interest rate
r^* = foreign interest rate
d = log of real aggregate demand for domestic output
p = log of domestic price level
p^* = log of foreign price level

$E(.)$ = expectations operator

$\dot{x}$ = time derivative of variable x

$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ are parameters of the model
$\beta_1, \beta_2, \beta_3$
$\gamma_1, \gamma_2, \gamma_3$
$\pi, \sigma, \phi_1, \phi_2$

Other symbols used are explained where appropriate in the text.

SUMMARY

This study provides a new test of the hypothesis that speculative efficiency holds in the forward market for foreign exchange. Speculative efficiency is said to hold in the forward market if expectations are formed rationally and speculators are risk-neutral. The forward rate will then be an unbiased predictor of the future spot rate. Speculative efficiency has important implications for the theory of exchange rate determination, the conduct of exchange rate policy and the management of exchange rate exposure. However, previous tests of the hypothesis have been inconclusive. This paper firstly provides a critical review of tests of the speculative efficiency hypothesis in the existing literature, secondly, derives new tests based on a more rigorous examination of forward market behaviour and, thirdly, presents the findings. Previous research has mostly concentrated on the statistical properties of the forward rate as a predictor of the future spot rate. There has been little attempt to explicitly model forward market behaviour. The first part of this study reviews the theory of forward rate determination within a partial equilibrium setting. Building on this, the joint determination of spot and forward exchange rates within a general equilibrium framework is considered. The original contribution of this study is then to examine the adjustment paths of spot and forward exchange rates under alternative assumptions about risk-averse behaviour in the forward market. Model simulations demonstrate that, following a monetary disturbance, the variance of the spot rate around its long-run equilibrium path greatly exceeds the variance of the forward rate as the role of speculative activity increases in the forward market. These model simulations provide an alternative to the null hypothesis of speculative efficiency in tests based on the relative variance of spot and forward exchange rates. Evidence is presented to demonstrate that the high observed variance of the forward rate relative to the variance of the spot rate is inconsistent with speculative efficiency.

Chapter 1

Introduction

The aim of this study is to provide new evidence as to whether "speculative efficiency" exists in the forward market for foreign exchange. Necessary conditions for speculative efficiency to hold are that expectations are formed rationally and that speculators are risk-neutral. The forward rate will then be an unbiased predictor of the future spot rate. In addition, it can easily be demonstrated that the variance of the spot rate will exceed the variance of the forward rate. This paper firstly provides a critical review of tests of the speculative efficiency hypothesis in the existing literature, secondly, derives new tests based on a more rigorous examination of forward market behaviour and, thirdly, presents the findings. The original contribution of this study is to examine the dynamic adjustment paths of spot and forward exchange rates within a general equilibrium framework under alternative assumptions about risk averse behaviour in the forward market. Evidence is presented to demonstrate that the high observed variance of the forward rate relative to the variance of the spot rate is inconsistent with speculative efficiency.

Testing the null hypothesis of speculative efficiency is of interest firstly because it is an important element of several well known theoretical models including, for example, Dornbusch (26), Mussa (83), and Bilson (11) and secondly, because it has implications for the effectivenes of government policy in determining the level of domestic interest rates and the exchange rate. Thus if expectations are formed rationally and speculators are risk-neutral, intervention in the foreign exchange market will be ineffective and changes in domestic asset supplies will not affect the level of domestic interest rates (see Eaton and Turnovsky (30)). However, several observed facts cast doubt on the empirical validity of speculative efficiency. In particular, the close contemporaneous correlation between spot and forward rates, low variance of forward premia relative to the variance of actual spot rate changes and the presence of continuous discounts or premia over prolonged intervals of currency appreciation or depreciation all suggest that the forward rate is not an unbiased predictor of the future spot rate (see Figures 1.1 - 1.6 in Appendix to this chapter).

Previous tests of the speculative efficiency hypothesis have been based on the statistical properties of the forward rate as a predictor of the future spot rate. The tests seek to establish firstly, whether the forward rate is an accurate predictor of the future spot rate, secondly, whether there is evidence of consistent bias in the implicit forecast contained in the forward rate and, thirdly, whether it is possible to outperform the forward market by learning from the past behaviour of forecast errors. Early tests of speculative efficiency, often based on poor statistical analysis, were inconclusive. More recently, tests based on more robust statistical techniques have rejected speculative efficiency (see, for example, Geweke and Feige (43), Hakkio (50), Hansen and Hodrick (51)). However, previous tests which reject the null hypothesis have failed to specify an alternative hypothesis and have therefore not sought to explain its rejection.

In this study, tests compare the relative variance of spot and forward rates under the null hypothesis of speculative efficiency with behaviour predicted from a general equilibrium model in which there is risk aversion in the forward market. This provides a more powerful test of speculative efficiency since rejection of the null hypothesis might be explained in terms of an alternative. The paper is divided into three parts. Part One (Chapters 2-4) considers the determination of the forward exchange rate within a partial equlibrium framework. The aim is to derive demand and supply schedules for forward foreign exchange and to investigate the role of arbitrage and speculative activity in the forward market. Part Two (Chapters 5 and 6) examines the simultaneous determination of spot and forward exchange rates within a general equilibrium model. The dynamic adjustment of spot and forward exchange rates is compared under firstly, the joint assumption of perfect capital mobility and speculative efficiency in the forward market and, secondly, under the assumption of risk averse behaviour by forward speculators. Part Three (Chapters 7-9) details simulations of spot and forward exchange rate behaviour within a portfolio balance general equilibrium model and considers some empirical tests of the speculative efficiency hypothesis. The relative variance of spot and forward exchange rates is compared under alternative assumptions about the elasticities of the arbitrage and speculation schedules in the forward market. Empirical evidence is presented to suggest that the observed high volatility of forward rates relative to the variance of spot rates is consistent with risk aversion in the forward market.

In Chapter 2 a brief discussion of early work on forward exchange markets, limited in the main to Keynes (62) (63) and Einzig (31), provides an introduction to "interest parity theory". The Modern Theory (MT) of forward exchange, developed in the late 1950s by Jasay (57), Tsiang (104) and Reading (91) is then examined in detail. The MT model identifies demand and supply schedules for forward exchange and provides a formal framework for analysing the relationship between spot and forward exchange rates. The equilibrium forward rate results where the supply of forward foreign currency by interest arbitrageurs is equal to the demand for forward foreign currency by speculators. The key prediction of the MT model is that if the arbitrage and speculation schedules have finite elasticities then the forward rate will be a weighted average of the interest parity forward rate and the expected future spot rate. The arbitrage and speculation schedules are examined in more detail in Chapters 3 and 4. The partial equilibrium framework of the MT model outlined in Chapter 2 is incorporated later into a general equilibrium model in Chapter 6.

Chapter 3 re-examines the role of the forward exchange market in international arbitrage operations. The aim is to provide an empirical measure of the elasticity of the arbitrage schedule. Interest rate parity theory states that, in an efficient market, the free movement of capital will ensure that the covered differential between similar assets belonging to the same risk class will be zero. In other words, the supply of arbitrage funds is infinitely elastic at the interest parity forward rate. The presence of either transactions costs or an upward sloping arbitrage schedule is necessary for deviations from interest rate parity to exist. An upward sloping arbitrage schedule may result from market imperfections or different non-price risk characteristics of assets under comparison. Chapter 3 cites evidence that interest rate parity appears to hold for a broad class of assets. A significant proportion of deviations from parity can be explained through allowance for transactions costs and the impact of exchange controls (see Frenkel and Levich (40) and Johnston (58)). The conclusion of Chapter 3 is that the arbitrage schedule is likely to have a very high -if not infinite- elasticity. Thus in terms of the MT framework the forward rate would be a biased predictor of the future spot rate unless the expected future spot rate was equal to the interest parity forward rate.

Chapter 4 examines the speculation schedule in more detail and introduces the concept of "speculative efficiency". An efficient market is one in which prices "always fully reflect available information", (Fama (34), p. 133). The major implication of market efficiency is that if prices continuously, fully and correctly reflect the information set this will eliminate any profit opportunities over and above equilibrium expected returns. The speculative efficiency hypothesis states that in the absence of risk and transactions costs "the supply of speculative funds is infinitely elastic at the forward price that is equal to the expected future spot price" (Bilson (12) p. 436). This yields the testable hypothesis that the forward rate is an unbiased predictor of the future spot rate. A critical review of the existing literature on tests of the speculative efficiency hypothesis is conducted. This reveals that, although early tests of speculative efficiency were inconclusive, recent tests based on more robust econometric techniques have rejected the null hypothesis. However, such tests fail to explain the rejection of speculative efficiency. Chapter 4 concludes that a more fruitful approach may be to compare the behaviour of spot and forward exchange rates within a general equilibrium framework, under alternative assumptions of risk-averse and risk-neutral behaviour in the forward market.

Chapters 2-4 consider the determination of the forward exchange rate within a partial equilibrium setting. In Chapter 5, this framework is incorporated into a general equilibrium model. The chapter begins with a discussion of recent models of exchange rate determination developed by Bhandari (9), Dornbusch (25) and others which provide interesting scope for analysing the dynamic adjustment paths of spot and forward exchange rates under alternative assumptions about behaviour within the forward market. A key feature of these models is that, under perfect capital mobility and speculative efficiency in the forward market, a rich variety of adjustment paths can be obtained for the spot exchange rate. In all cases, however, the variance of the spot rate exceeds the variance of the forward rate as embodied in the fixed long-run equilibrium exchange rate. It is of interest to consider how this result may change if firstly, the assumption of risk-neutrality is relaxed and, secondly, the long-run equilibrium exchange rate is allowed to wander over time. The chapter concludes with a discussion of the model developed by Eaton and Turnovsky (30) which introduces risk-aversion in the forward market.

In Chapter 6, the forward market is integrated into a portfolio balance model which is set out along the lines of Eaton and Turnovsky (30). The short and long run properties of the model are examined following an increase in the supplies of money and domestic bonds. General expressions are derived for the variances of spot and forward exchange rates. In Chapter 7 plausible estimates of coefficients are employed to investigate the time paths of spot and forward rates under alternative assumptions about the role of risk aversion in the forward market. It is found that the variance of the spot rate increases relative to the variance of the forward rate, when both are measured around the long run equilibrium exchange rate, as the elasticity of the speculation schedule is increased relative to the elasticity of the arbitrage schedule. However, when risk aversion limits the role played by speculative activity in the forward market then the variance of the spot rate is similar to the variance of the forward rate. The model simulations performed in Chapter 7, under risk-averse behaviour in the forward market, provide an alternative to the null hypothesis of speculative efficiency.

Chapter 8 presents empirical evidence on the speculative efficiency hypothesis. A necessary, although not sufficient, condition of speculative efficiency is that the variance of the spot rate exceeds the variance of the forward rate. It is demonstrated that, under speculative efficiency, an increase in the variance of the spot rate relative to the variance of the forward rate ought to be witnessed in circumstances where the variance of forward prediction errors is increased. However, it is argued that high variance of prediction errors is likely to be associated with risk aversion and low elasticity of the speculation schedule. An alternative to the null hypothesis is then presented by the evidence of Chapter 7 which suggests that, in such circumstances, the variance of the spot rate will be similar to the variance of the forward rate. In Chapter 8 evidence is presented to show that, over the interval January 1976 to December 1984, forward prediction errors were increased for six exchange rate series when increasing the length to maturity of the forward contract from one month to twelve months. Secondly, prediction errors were increased when comparing five exchange rate series in terms of the US Dollar with the statistically more stable Swiss Franc/Deutsche Mark exchange rate. However, in two sets of tests, using alternative measures of a long run equilibrium exchange rate which wanders through time, no statistically significant pattern of relative variances of spot and forward rates could be found consistent with the speculative efficiency hypothesis.

Finally, Chapter 9 presents conclusions , considers some of the limitations of the analysis conducted in the paper and makes suggestions for further research. It is argued that the principal contribution of the paper is to provide new evidence against the existence of speculative efficiency in the forward market. The development of an alternative hypothesis, based on the predictions of a general equilibrium model with risk-averse behaviour in the forward market, is able to explain the rejection of the null. The limitations of the paper, considered briefly in Chapter 9, relate firstly to the restrictive nature of the model and secondly to the statistical analysis contained in

Chapter 8. Further research might seek to extend the empirical work to more exchange rate series and to develop further the model outlined in Chapter 6 which might permit explicit modeling of the determination of the forward exchange risk premium.

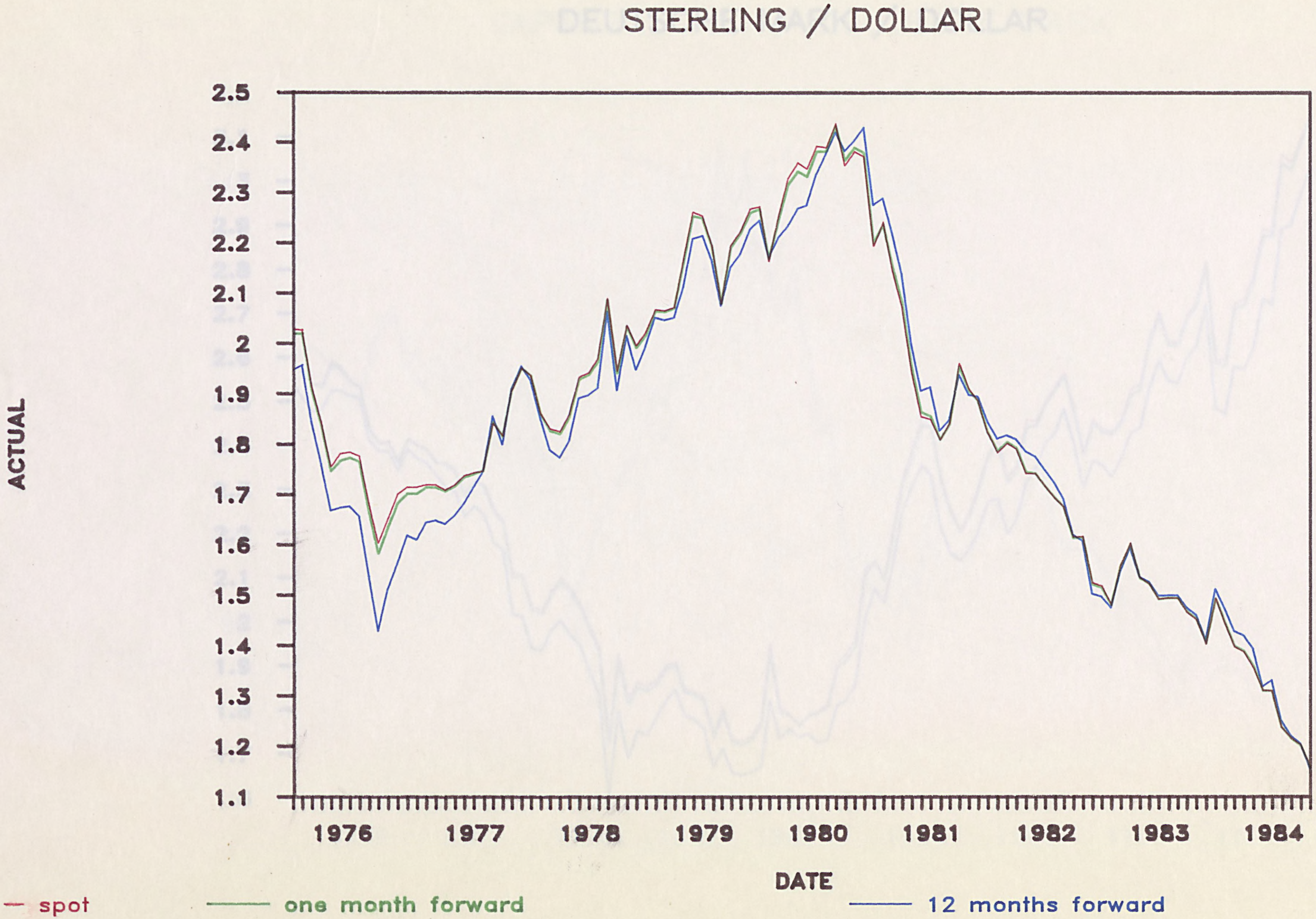


Figure 1.1

(Month end values. Source: Data Resources Incorporated)

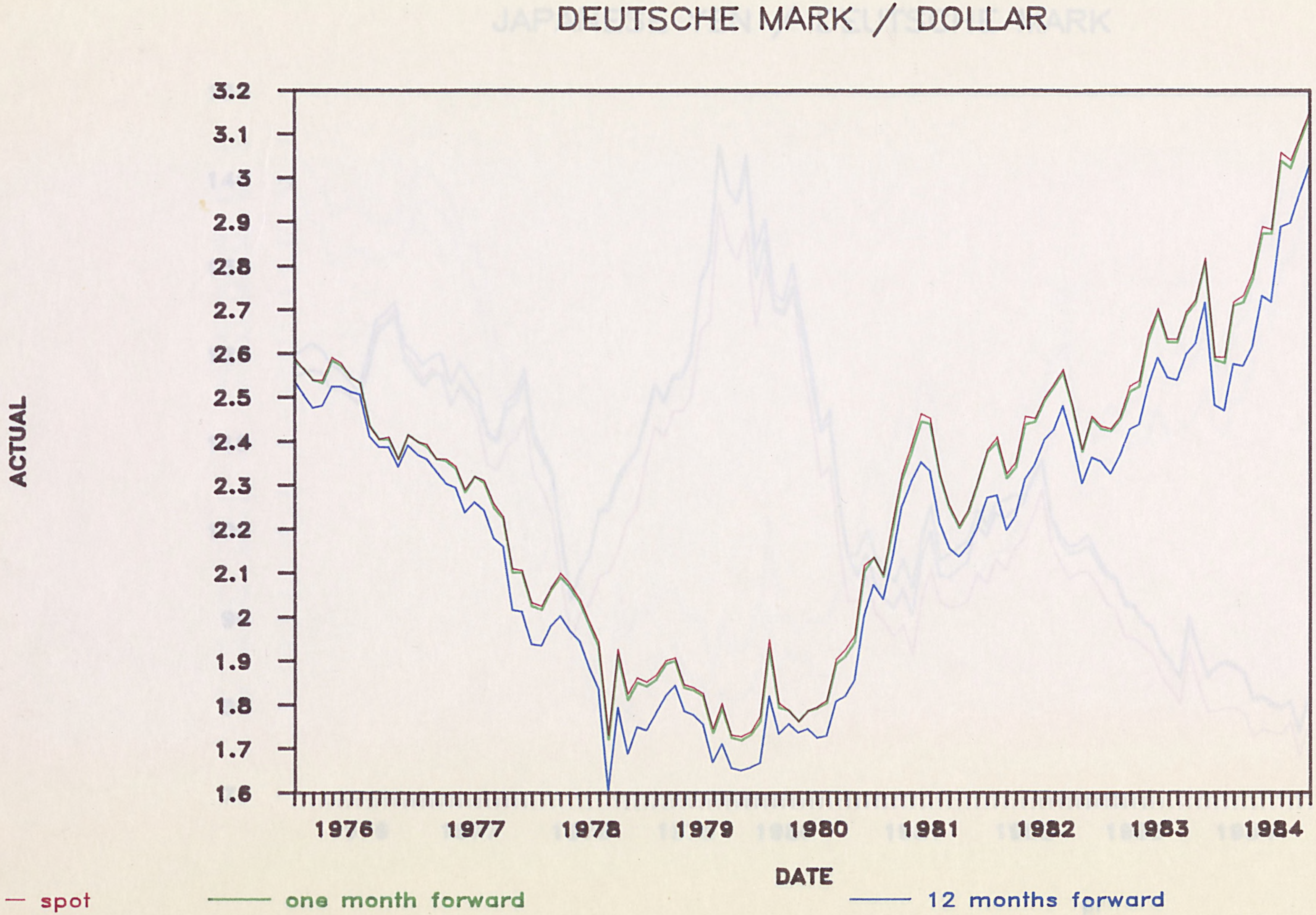


Figure 1.2

(Month end values. Source: Data Resources Incorporated)

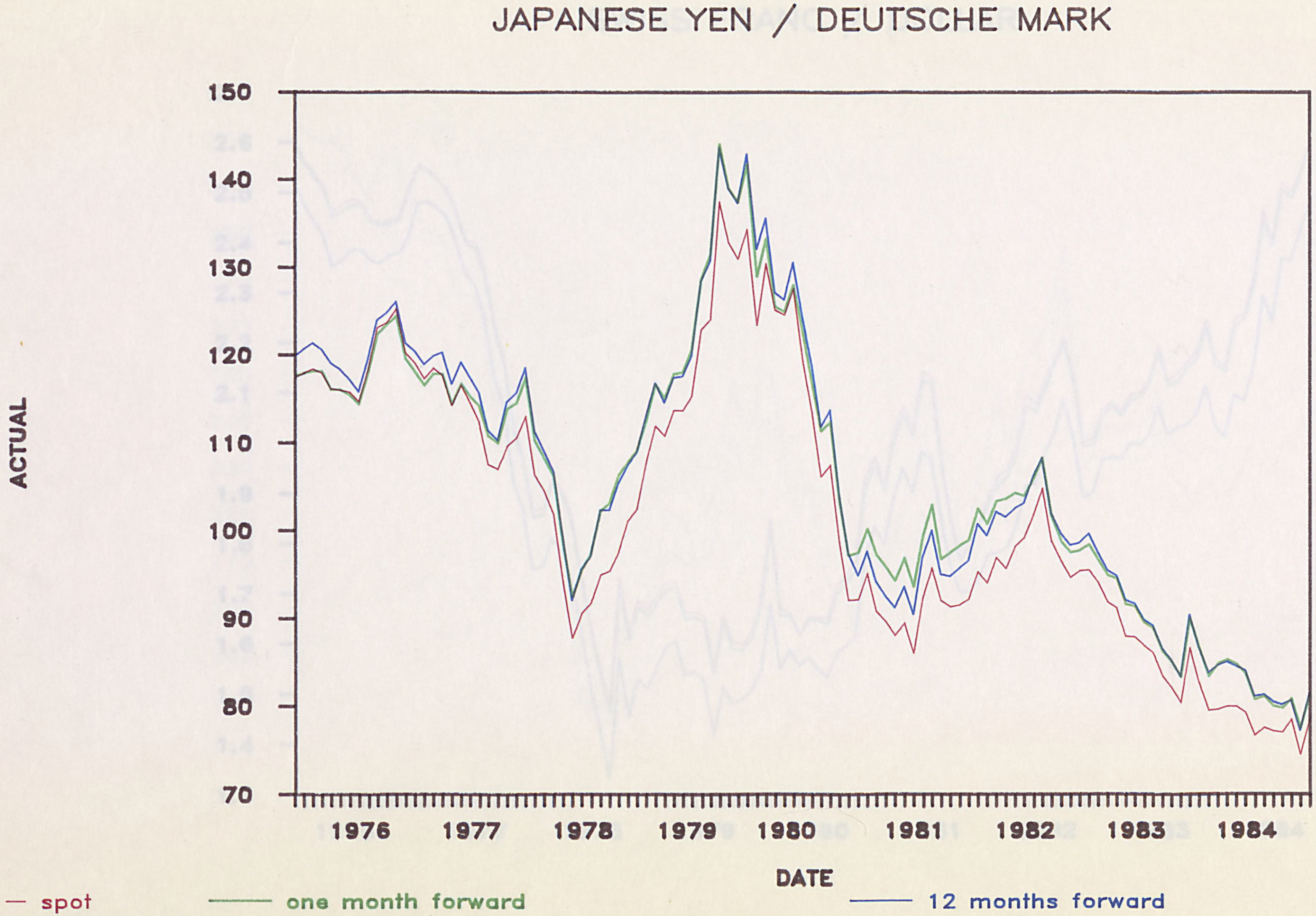


Figure 1.3

(Month end values. Source: Data Resources Incorporated)

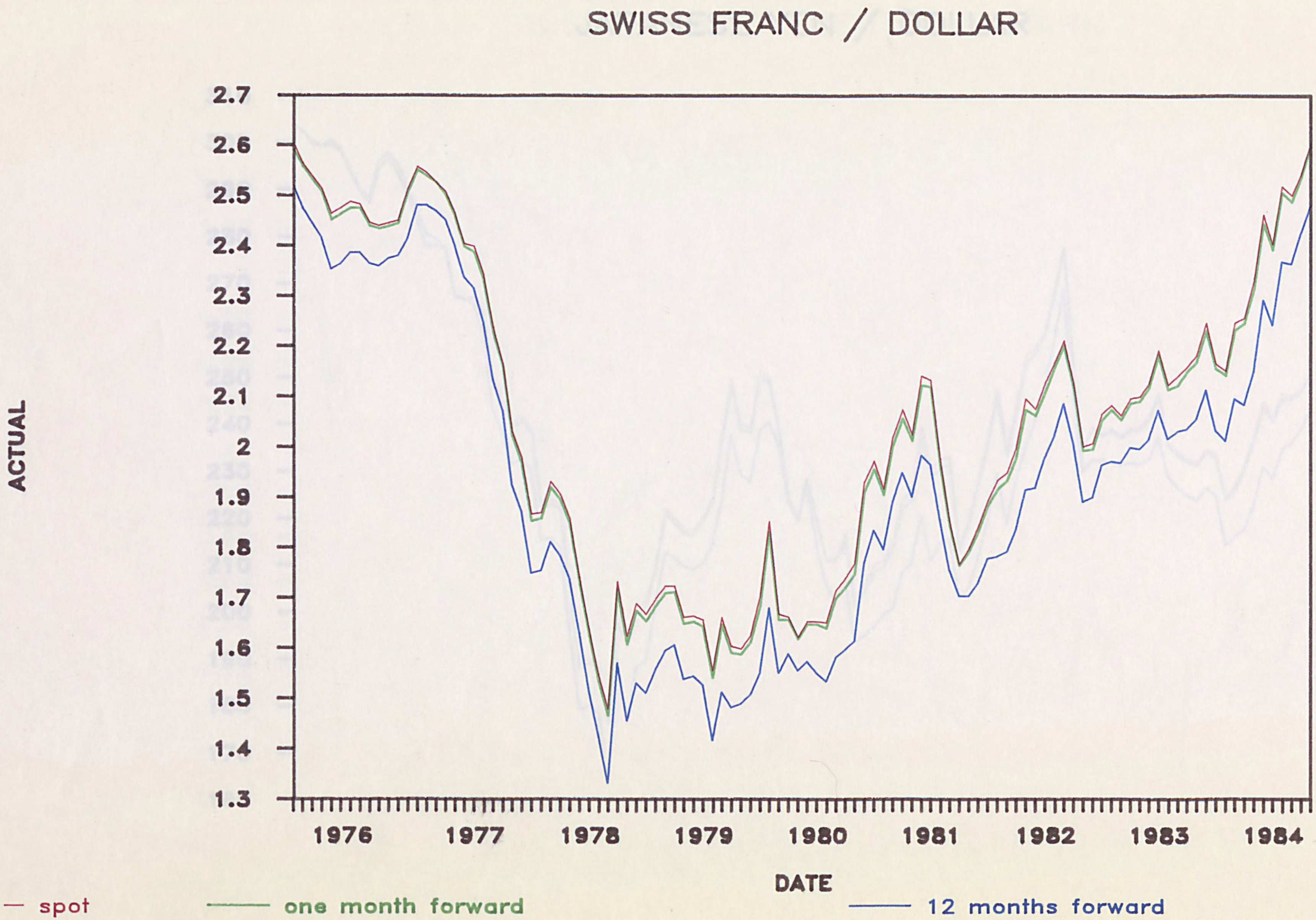


Figure 1.4

(Month end values. Source: Data Resources Incorporated)

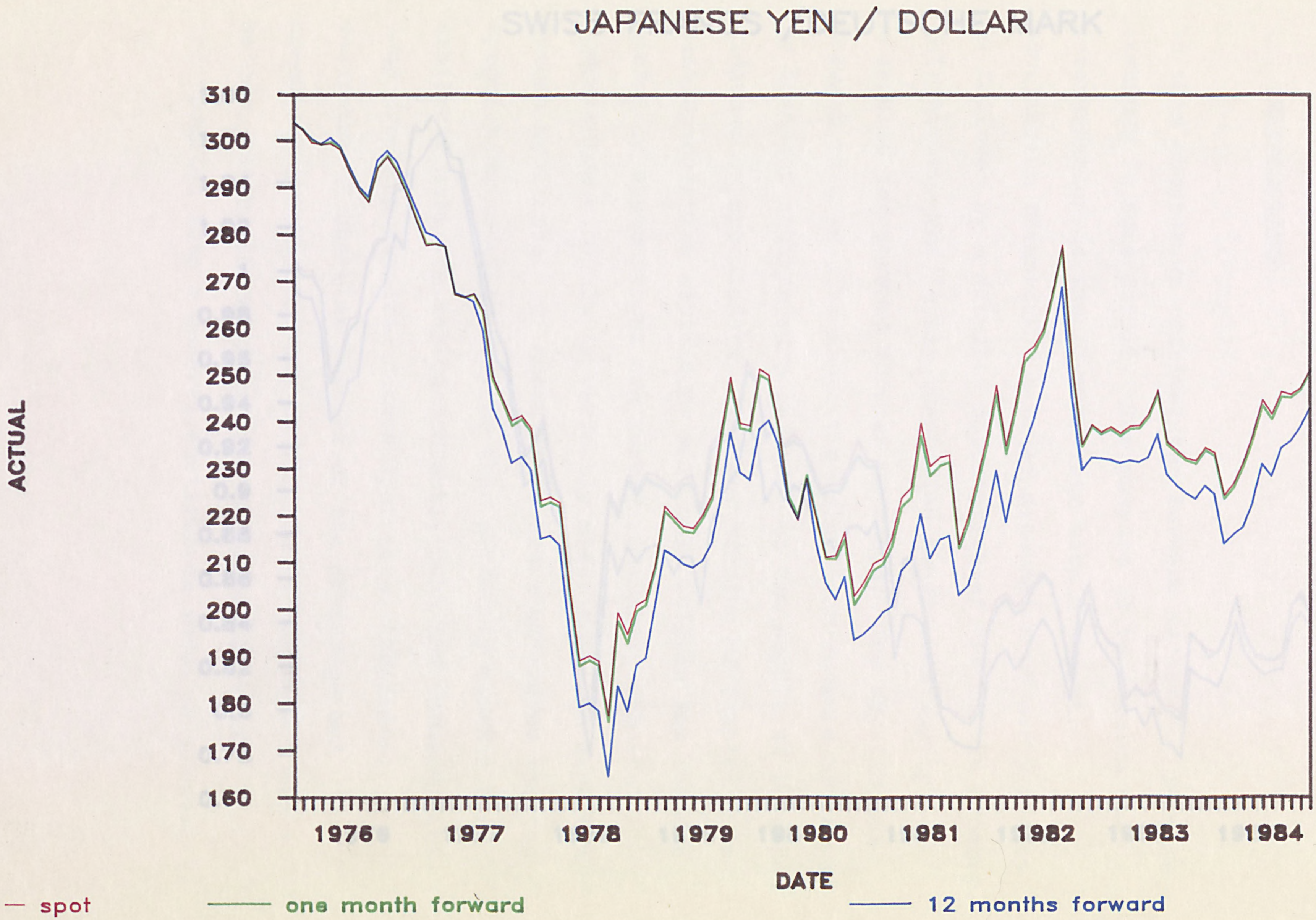


Figure 1.5

(Month end values. Source: Data Resources Incorporated)

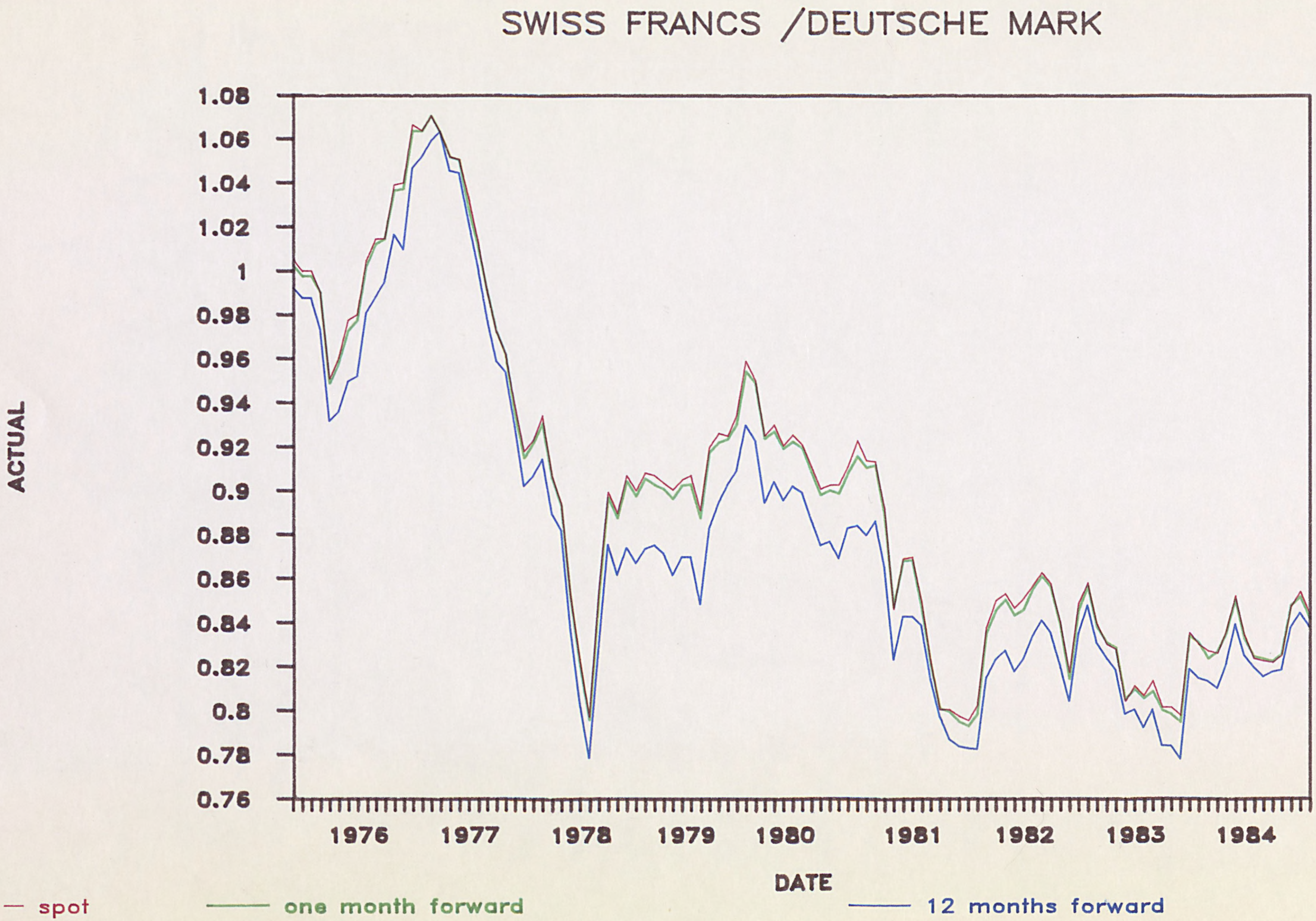


Figure 1.6

(Month end values. Source: Data Resources Incorporated)

Chapter 2

The Forward Market for Foreign Exchange

1. Introduction

In this chapter we consider the forward market for foreign exchange in some detail. The purpose is to examine the determination of the forward rate within a partial equilibrium framework. A brief discussion of early theory is followed by a detailed description of the Modern Theory (MT) model. The latter identifies demand and supply schedules for forward foreign exchange. The equilibrium forward rate results where the demand for forward exchange by interest arbitrageurs is equal to the supply of forward exchange by speculators. The key finding of Chapter 2 is that speculative efficiency will only hold in the forward market if expectations are formed rationally and the speculation schedule is perfectly elastic at the expected future spot rate. If speculators are risk-averse and the speculation schedule is less than perfectly elastic then arbitrage activity may consistently push the forward rate away from the expected future spot rate. Empirical estimates of the elasticities of the arbitrage and speculation schedules are considered in Chapters 3 and 4 below. Later, the MT framework outlined below is incorporated into a general equilibrium model in Chapter 6.

2. Early Theory

Keynes wrote in 1922:

> "The nature of forward dealings in exchange is not generally understood. The rates are seldom quoted in the newspapers. There are few financial topics of equal importance which have received so little discussion or publicity", ((62),p.100)

In fact, forward exchange facilities were available in a highly developed form for some time before. Forward transactions were carried out on the Vienna and Berlin markets in the late 19th century and the London market had attracted a considerable turnover by the outbreak of the First World War. However, forward exchange attracted little attention in academic circles. Early articles by Lotz (77) and Deutsch (23) indicated a relationship between interest rates in two financial centres and the price of forward foreign currency in relation to the spot exchange rate, but the first formal statement of "interest parity theory" is attributed to Keynes (62), (63).

Keynes addressed himself to the factors which determine the sign and amount by which spot rates and forward rates diverge. He argued that, abstracting from considerations of exchange risk, "The difference between the spot and forward rates is .... precisely and exactly the measure of the preference of the money and exchange market for holding funds in one international centre rather than in another ...." ((62), p. 103)

Keynes illustrated this argument with the following example. If spot Dollars are quoted at $4.40 to the Pound and forward Dollars for one month are quoted at $4.4050 to the Pound, then the owner of $4.40 can sell Dollars spot for one Pound and buy them back one month forward at a profit of half a cent on the month or 1.5% per annum. This indicated to Keynes the compensating profit required by the market to forego the use of funds in New York. That is to say, the forward discount on Dollars is a measure of the market's preference for employing spot funds in New York rather than London.

In determining this preference, "the most fundamental cause is to be found in the interest rates obtainable on 'short' money", ((62), p. 103). When interest rates are higher in one centre than in another, "forward quotations for the purchase of the currency of the dearer money market tend to be cheaper than spot quotations by a percentage per month equal to the excess of the interest which can be earned in a month in the dearer market over what can be earned in the cheaper". ((62), p. 103).

Keynes is regularly credited as the founder of "interest parity theory" (IPT) as expressed above (a formal derivation of the interest parity condition is provided below). In normal circumstances he believed that the pressure of arbitrageurs would lead to a rapid adjustment of the discount or premium on forward exchange to a change in the interest differential between two centres. The major part of the adjustment would take place in the forward market with little flow of funds across exchanges, provided that the influence of a change in the forward margin on exchange speculators is limited. However, Keynes did lend extensive analysis to the factors which may cause deviations from interest parities.

First, he argued that in the absence of a developed money market in one centre, the forward exchange market would tend to place that centre's currency at a discount regardless of the ruling interest rate level. Second, considerations of political and economic risk might limit available arbitrage funds to be held in foreign centres. Thirdly, given a limitation on arbitrage supply, excess demand for forward exchange, over and above the net position of arbitrageurs, would cause the forward margin to deviate from the interest parity level by a sufficient amount to induce an increased supply of arbitrage funds. Finally, in the absence of a freely competitive market forward margins may deviate from interest parities.

The other major contributor to early forward exchange theory was Einzig ((31) and (32)). Einzig identified four types of operation in the forward exchange market; commercial covering of foreign exchange exposure by importers and exporters, hedging against the impact of foreign exchange movements on the domestic currency value of foreign assets, speculation and arbitrage. He demonstrated that limited arbitrage funds might prevent a fully compensating adjustment to interest parities for much the same reasons as outlined earlier by Keynes. If so, then "one-sided" pressure arising from operations other than arbitrage might drive the forward margin away from its interest parity level. That is to say, if for example, the future spot rate is expected to exceed the interest parity level of the forward rate, then there will be a preponderance of buyers of forward foreign currency. Excess demand for forward foreign currency will push the forward rate to an intrinsic premium, inducing an increased supply of arbitrage funds.

Thus early forward exchange theory stressed "interest parity" as the key determinant of the relationship between spot and forward exchange rates. In its most rigid form this theory stated that the forward rate was set by arbitrageurs such that the forward margin would tend to equal the interest differential between two currencies. In this model the forward rate need not be equal to the market's expected future spot rate. However, early proponents of interest parity theory recognised that limited availability of arbitrage funds might mean that in practice the forward rate would be set by the joint influence of arbitrageurs and speculators.

3. Modern Theory of Forward Exchange

The Modern Theory of Forward Exchange (MT), developed in the late 1950s by Jasay (57), Tsiang (104) and Reading (91), extended the earlier work of Keynes and Einzig and provides a formal framework for analysing the relationship between spot and forward exchange rates. MT aimed to identify the demand and supply schedules for forward exchange. Later work enabled the theory to incorporate both fixed and flexible exchange rate regimes and the effect of government intervention.

Five sources of demand and supply of forward exchange are identified. These result from operations related to hedging foreign currency exposure against adverse exchange rate movements, commercial covering of future foreign currency requirements to finance trade, speculation, interest arbitrage amd the government's forward exchange intervention policy. Before examining each of these within the framework of the MT model we first introduce some notation. In the analysis below it is initially assumed that the spot exchange rate, domestic and foreign interest rates are given. Let,

S_t = the spot price of one unit of foreign currency expressed in terms of domestic currency at time t

$_{t+i}F_t$ = the forward price, at time t, of one unit of foreign currency expressed in terms of domestic currency for contract maturity in t+i

$_{t+i}E(S)_t$ = the expected spot rate at t+i, based on information available at t

$_iR^d_t$ = the i period domestic interest rate at t

$_iR^f_t$ = the i period foreign interest rate at t

$_{t+i}A_t$ = forward exchange commitments entered into by arbitrageurs at t, maturing at t+i

$_{t+i}C_t$ = forward exchange commitments entered into by speculators at t, maturing at t+i

(a) Interest Arbitrage

Consider an investment of one unit of domestic currency in a domestic security for period i at interest rate R^d_t (for convenience we drop the subscript i). At time t+i the investor will possess $(1 + R^d_t)$. Alternatively, it is possible to sell one unit of domestic currency at the spot exchange rate S_t, invest foreign currency for period i at interest rate R^f_t and simultaneously arrange to convert the proceeds at t+i back into domestic currency at the forward rate F_t. If we assume that domestic and foreign assets are perfect substitutes, except for the unit of denomination, then arbitrageurs wil ensure that the proceeds are equal from both operations. That is

$$(2.1) \qquad (1 + R^d_t) = \frac{F_t}{S_t} (1 + R^f_t)$$

From this we can derive the interest parity forward rate, F^*_t, at which the returns from covered interest arbitrage are zero. Thus

$$(2.2) \qquad F^*_t = S_t \frac{(1 + R^d_t)}{(1 + R^f_t)}$$

Alternatively, we can express the interest rate parity condition in its more easily recognisable form. From (2.1),

$$(2.3) \qquad \frac{F_t - S_t}{S_t} = \frac{R^d_t - R^f_t}{(1 + R^f_t)}$$

If we denote the forward discount expressed as a ratio of the spot rate as FD and allow for the fact that $FD.R^f_t$ is close to zero, then we can derive the common approximation to interest rate parity which states that the forward discount is equal to the interest rate differential between domestic and foreign assets.

$$(2.4) \qquad FD_t = R^d_t - R^f_t$$

If $F_t > F^*_t$ then arbitrageurs will purchase spot foreign currency and enter into a forward contract to sell foreign currency at time t+i. The supply (demand) of forward foreign currency will be positively (negatively) related to $(F_t - F_t^*)$. For purposes of exposition we can express the supply of forward foreign exchange by arbitrageurs as a linear function of $(F_t - F_t^*)$,(see Stoll (101));

$$(2.5) \qquad A_t = a(F_t - F_t^*), \quad a>0$$

Equation (2.5) is represented by the arbitrage schedule AA in Figure 2.1. AA passes through the interest parity forward rate, F_t^*, on the vertical axis. At forward rates below F_t^* arbitrageurs will demand forward foreign exchange and vice-versa.

Deviations from interest rate parity may result from transactions costs and a less than perfectly elastic arbitrage schedule (i.e. $a \neq \infty$). Non-comparability of assets will, of course, result in a similar outcome. The subject of transactions costs is investigated in Frenkel and Levich (40) and Branson (14). Transactions costs are estimated and used to explain deviations from the interest parity condition. (The impact of transactions costs on the interest rate parity condition is outlined below in Chapter 3).

A number of considerations have been advanced to support the possible existence of an upward sloping arbitrage schedule. Prachowny (90) demonstrated the impact of a spread between borrowing and lending rates and the existence of an upward sloping supply curve of funds on the

Figure 2.1 The Arbitrage Schedule

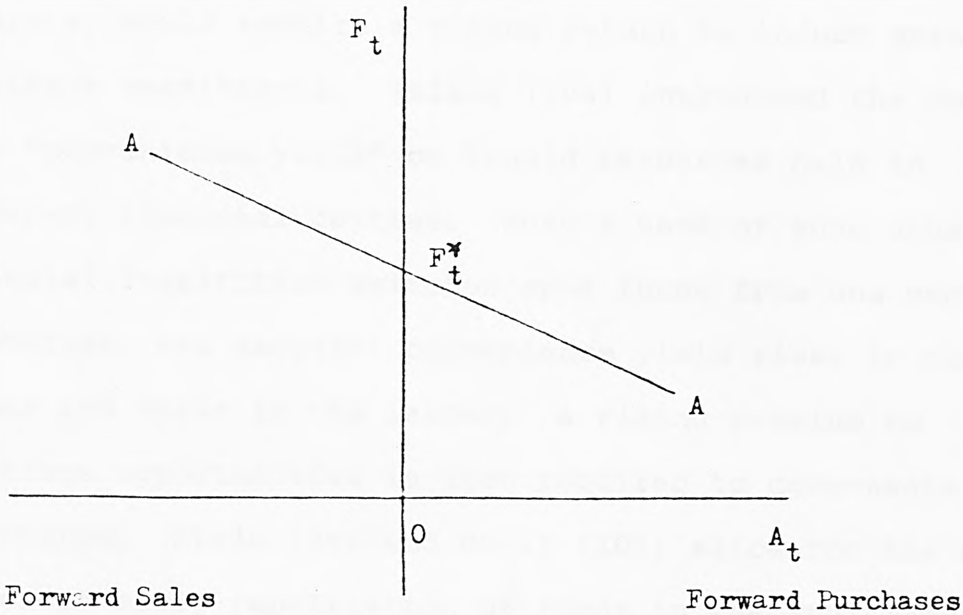
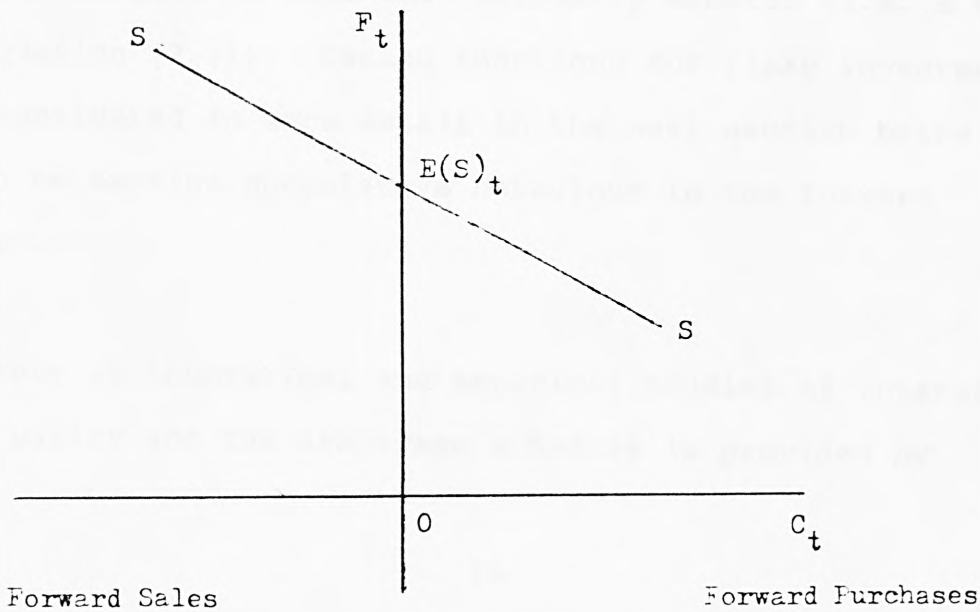


Figure 2.2 The Speculation Schedule



arbitrage condition. Default risk arising from both economic and political considerations was considered by Stoll (101) and Aliber (4). The presence of default risk, arising from perhaps a bank collapse (e.g. Herstatt and Banco Ambrosiano in recent years) or the threat of exchange controls, would require a rising return to induce greater arbitrage commitments. Tsiang (104) introduced the notion of a "convenience yield" on liquid resources held in different financial centres. When a bank or some other financial institution switches spot funds from one centre to another, the marginal convenience yield rises in the former and falls in the latter. A rising premium on arbitrage opportunities is then required to compensate for the change. Stein (99) and Stoll (101) allow for the risk of forced early repatriation of funds in the arbitrage schedule. Finally, Modern Portfolio Theory (see Markowitz (81), Lintner (74), Sharpe (94) and Tobin (103)) would consider all of the above as special cases of the general principle that risky investment and risk aversion will lead to diversification between assets. Demand for any individual asset will be positively related to expected return but will be less than perfectly elastic (i.e. $a \neq \infty$ in equation (2.5)). Demand functions for risky investments are considered in more detail in the next section below in which we examine speculative behaviour in the forward market.

A survey of theoretical and empirical studies of interest rate parity and the arbitrage schedule is provided by

Officer and Willett (86). These issues are discussed in greater depth in Chapter 3 below.

(b) Speculation

Speculators assume exchange risk with the objective of making profit from an expected price movement. It is possible to speculate through either the spot market or the forward market. Spot speculators will purchase foreign currency at the spot exchange rate and invest the proceeds on an uncovered basis. The expected return over period i will depend on the expected future spot rate at time t+i. Using the notation introduced above, the (expected) return to spot speculation, for each unit of domestic currency is

$$(2.6) \qquad E(S)_t \; \frac{(1 + R_t^f)}{S_t}$$

Alternatively, speculators will purchase foreign currency forward if the exchange rate at t+i is expected to be below the current forward rate. (Note that a fall in the exchange rate represents appreciation of domestic currency). Profit or loss results from unwinding or reversing the position in the spot market at t+i. Spot funds accumulate interest at the domestic interest rate R_t^d The total expected return, expressed in units of domestic currency, is

$$(2.7) \qquad \frac{E(S)_t \cdot (1 + R^d_t)}{F_t}$$

If we compare the expected returns from both forms of speculative activity, spot speculation will be more profitable if

$$(2.8) \qquad \frac{E(S)_t \cdot (1 + R^f_t)}{S_t} > \frac{E(S)_t \; (1 + R^d_t)}{F_t}$$

$$\Rightarrow \qquad \frac{F_t}{S_t} \frac{(1 + R^f_t)}{(1 + R^d_t)} > 0$$

In other words, spot speculation will be more profitable if the covered margin is greater than zero (from (2.1) and (2.2) if $F_t \neq F^*_t$). Conceptually, we can treat this operation as being composed of, firstly, covered interest arbitrage, and secondly, an outright purchase of forward foreign currency. In this respect, spot speculation adds nothing new to the analysis and so can be disregarded.

The demand for forward foreign exchange by speculators can be expressed as a linear function of the difference between the expected future spot rate and the current forward rate,

$$(2.9) \qquad C_t = b(E(S)_t - F_t), \qquad b > 0$$

Equation (2.9) is represented by the speculation schedule SS in Figure 2. The SS curve passes through $E(S)_t$ on the vertical axis. At forward prices below $E(S)_t$ speculators demand forward foreign currency and vice-versa. The slope of SS will be determined by (i) the degree of certainty with which expecations are held about the future exchange rate, (ii) the degree of investor risk aversion and (iii) institutional or legal contraint on the supply of speculative funds. Increased certainty (lower risk) will, all other things being equal, be represented in a more elastic SS schedule. For example, one-way speculation in a fixed exchange rate regime may give rise to a more elastic SS schedule. Points (ii) and (iii) are commonly advanced in support of the claim that the SS schedule is highly inelastic as a result of insufficient private speculative capital.

More generally, Modern Portfolio Theory provides a framework for examining the elasticity of demand with respect to expected return for any risky investment. Consider a choice between two assets with expected returns $E(r_1)$ and $E(r_2)$ and with standard deviations of returns σ_1 and σ_2.

The investor is assumed to allocate wealth, W, between the two assets consistent with the maximisation of expected utility, E(U), where,

$$(2.10) \quad E(U) = U(E(r_p), \sigma_p)$$

and
$$\frac{\partial E(U)}{\partial E(r_p)} > 0; \quad \frac{\partial E(U)}{\partial (\sigma_p)} < 0$$

If x_1 and x_2 denote the amounts allocated to each asset, such that $W = x_1 + x_2$, then portfolio returns can be expressed as

$$(2.11) \quad E(r_p) = x_1 E(r_1) + x_2 E(r_2)$$

Similarly, the variance of portfolio returns is found to be

$$(2.12) \quad \sigma_p^2 = \sigma_1^2 x_1^2 + \sigma_2^2 x_2^2 + 2Cov(1,2)\, x_1 x_2$$

Maximising expected utility, subject to the wealth constraint, we find that,

$$(2.13) \quad \frac{\partial E(U)}{\partial x_i} = \frac{\partial E(U)}{\partial E(r_p)} \cdot \frac{\partial E(r_i)}{\partial x_i} + \frac{\partial E(U)}{\partial \sigma_p} \cdot \frac{\partial \sigma_p}{\partial x_i} - \lambda = 0$$

$$i = 1,2$$

where λ is the Lagrangian multiplier.

The demand curves for assets 1 and 2 can then be derived from (2.13). If we assume, for ease of exposition, that the returns on the two assets are independent, that is $Cov(1,2) = 0$, then

$$(2.14) \quad x_1 = \frac{1}{\Delta}(E(r_1) - E(r_2)) + \frac{\sigma_2^2}{(\sigma_1^2 + \sigma_2^2)} . W$$

$$(2.15) \quad x_2 = \frac{1}{\Delta}(E(r_2) - E(r_1)) + \frac{\sigma_1^2}{(\sigma_1^2 + \sigma_2^2)} . W$$

Where $\Delta = (-1/A\sigma_p)(\sigma_1^2 + \sigma_2^2)$ and $A = \dfrac{\partial E(U)}{\partial E(r_p)} \Big/ \dfrac{\partial E(U)}{\partial (\sigma_p)}$

Hence we see that in the general case, with investor risk aversion, the coefficient b in the speculation schedule in equation (2.9) above is likely to be less than infinity.

Empirical examination of the speculation schedule requires some measure of the expected future spot rate in equation (2.9). There have been three broad approaches to the measurement of exchange rate expectations in the literature. First, there have been attempts to model expectations through some ad-hoc relationship to other economic variables (for example, Kesselman (61), and Kohlhagen (66)). A variety of "real world" economic variables such as trade flows, capital flows and official intervention have been incorporated as proxies for $E(S)_t$ in the SS schedule. The criterion for inclusion of different variables is simply whether they add to the overall explanation of the estimated equations. There is no explicit attempt to model the nature of the relationship between expectations and movements in different economic variables. The second approach has been to model extrapolative and regressive expectations functions using distributed lags of observed spot rates (see, for example, Stoll (101), Kesselman (61) and Haas (49)). Finally, there have been attempts to incorporate rational expectations. In the rational expectations framework of Muth (84) and Fama (34) the expected value of an economic variable (the exchange rate) fully and correctly reflects all available information on relationships between economic variables which affect the future outcome. Thus expectations are consistent with the underlying model of exchange rate determination. Beenstock (7), Driskill (28), and McCallum (79) have estimated models of capital flows using rational expectations.

A useful survey of the problems encountered in the empirical literature on the measurement of exchange rate expectations is provided by Kohlhagen (66). The application of rational expectations to the foreign exchange market is fully considered in a review of "efficient market" theory in Chapter 4 below.

(c) Commercial Covering

A further use of the forward market is made by importers and exporters seeking to eliminate exchange risk which arises from foreign currency receipts and payments. Contracts are typically drawn up some time before payment is due in international trade. If the price is set in foreign currency terms then exchange fluctuation increases uncertainty about the size of final payment in terms of domestic currency. For example, a UK importer of goods may require foreign currency in x months time. Alternatively, a UK exporter may receive foreign currency payment in y months time. The forward exchange market eliminates the risk of unexpected exchange rate movements such that contract prices may be fixed in domestic currency terms. In practice it is possible to distinguish four alternative responses to exchange risk in international trade.

(i) Traders may never cover future foreign currency receipts and payments in the forward market. Instead foreign currency is purchased spot either at the time of contract exchange or at the time of due payment. In this case there is no effect on the forward market.

(ii) Traders may always immediately obtain forward cover, irrespective of exchange rate expectations or whether foreign currency stands at a forward intrinsic premium or discount (i.e. above or below the interest parity forward rate). In terms of Figures 2.1 and 2.2 this action may be represented by a parallel shift in either the SS or AA schedule. If there is net demand for forward foreign currency from this source then the new curve will lie to the right of the existing curve and vice-versa in the case of net supply.

(iii) Traders may sometimes cover future commitments on the forward market and at other times purchase future currency needs on the spot market. Consider a future outlay of one unit of foreign currency at t+i. Traders may purchase foreign currency spot with x units of domestic currency and invest the proceeds at the foreign interest rate R_t^f, such that

$$(2.16) \qquad \frac{x.(1 + R_t^f)}{S_t} = 1$$

The outlay today is $x = S_t/(1 + R_t^f)$. Alternatively, it is possible to purchase one unit of foreign currency on the forward market at F_t. The present value of this outlay in terms of domestic currency is $F_t/(1 + R^d_t)$. The present value cost of hedging will be equal in both cases when

$$(2.17) \qquad \frac{S_t}{1 + R^f_t} = \frac{F_t}{1 + R^d_t} \Rightarrow \frac{S_t}{F_t} = \frac{1 + R^f_t}{1 + R^d_t}$$

i.e. the interest parity condition holds. If $F_t < F^*_t$ then the domestic currency is said to stand at an "intrinsic premium" and, in terms of the example above, traders will cover on the forward market. The process is of course reversed if domestic currency stands at an "intrinsic discount". This behaviour in purchasing either spot or forward cover according to the above decision framework is termed "trader arbitrage" by Spraos (97). This may impart greater elasticity to the AA schedule although the precise impact will depend on whether the home country is a net exporter or importer.

(iv) Finally, traders who sometimes cover forward and sometimes do not cover at all will be influenced by the same factors as speculators as set out above. If the forward rate exceeds the expected future spot rate then exporters will sell foreign currency forward and vice-versa in the case of importers. Spraos (97) termed this behaviour "speculator arbitrage" and it may be included in the speculation schedule in Figure 2.2. Again the shape of the schedule when this influence is included in addition to pure speculation will depend on whether the home country is a net importer or exporter.

(d) Hedging

Einzig (32) distinguishes between hedging and commercial covering of exchange risk in the following way. Commercial covering of exchange risk is related to underlying trade flows while hedging operations are not necessarily self-liquidating. The decision framework involved in hedging is the same as that outlined above for commercial covering. Thus hedging can also be included in either the arbitrage or the speculation schedule.

(e) Intervention

Central Bank intervention in the forward market can easily be accomodated within the above framework but a detailed analysis is not given until later (see below). Briefly, Central Bank intervention in the forward market takes place either through an "outright" purchase or sale of forward foreign currency or through the "swap" mechanism. A currency "swap" takes the form of a spot transaction with a simultaneous offsetting position in the forward market. An "outright" forward deal has no counter transaction in the spot market. Forward intervention may provide an alternative means of securing official objectives, as for example in terms of altering capital flows, stabilising the spot exchange rate, securing monetary base control or bolstering foreign currency reserves. The effectiveness of forward market intervention will depend on the relative elasticities of the arbitrage and speculation schedules. This point will be illustrated below.

(f) Triangular Arbitrage

To complete the model it is necessary to consider the possiblity of triangular arbitrage which may result from the use of a third intermediary currency (see Brown (17), Einzig (32), and Spraos (97)). In equilibrium, abstracting from transactions costs, the price of Sterling in terms of Dollars must be equal to the price derived from purchasing a third currency, say Deutsche Marks, from the sale of Dollars and then using Deutsche Marks to buy Sterling. Algebraically,

$$(2.18) \quad (\$.£)_t = (\$.DM)_t \cdot (DM.£)_t$$

In addition to spot transactions triangular operations are also possible in the forward market. The equilibrium condition (2.18) at t will also apply to forward exchange rates for contract maturity in t+i. In addition, if interest parity holds for all pairs of currencies then no possibility exists of a profitable transaction through triangular interest arbitrage.

(g) Equilibrium

In the sections above we have derived an arbitrage and a speculation schedule consistent with theoretical propositions concerning the demand and supply of forward foreign exchange. The behaviour of different operators in the market can be classified either as arbitrage or speculation. In equilibrium the forward rate will be determined where the supply(demand) of arbitrageurs is equal to the demand(supply) of speculators. In terms of Figure 2.3 the forward market is in equilibrium at forward rate F_0 . At F_0 purchases of forward foreign currency by speculators, C_0 , are equal to sales of forward foreign currency by interest arbitrageurs, A_0 . A_0 also represents the spot capital outflow associated with arbitrage operations. At ($F < F_0$) the demand for forward foreign currency by speculators will exceed the supply of forward foreign currency by arbitrageurs. Domestic currency will tend to depreciate in the forward market, enhancing the attraction of covered interest arbitrage and reducing the flow of speculative capital, until equilibrium is reached. The process will be reversed if $F > F_0$.

Figure 2.3 Equilibrium in the Forward Market

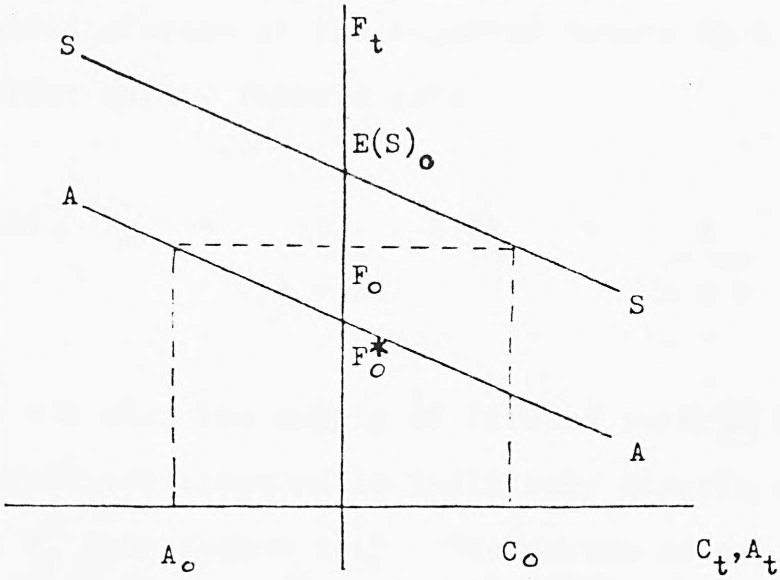


Figure 2.4

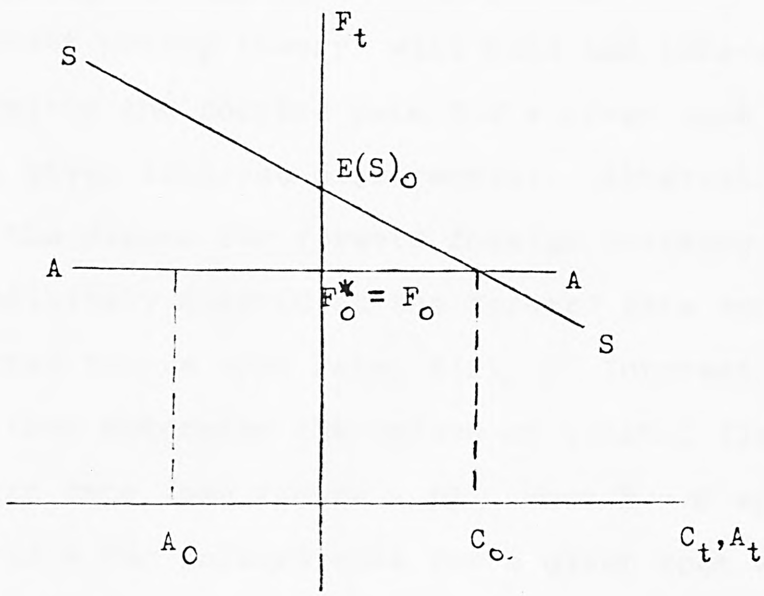
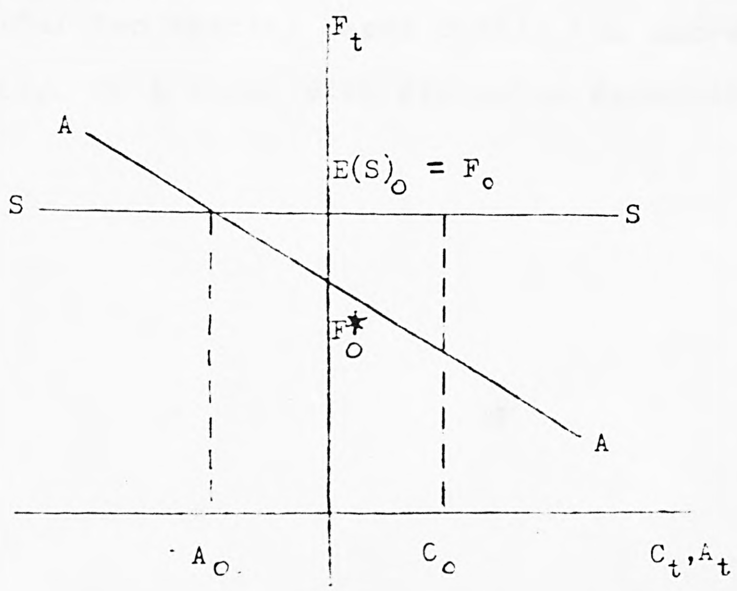


Figure 2.5



Equilibrium in the forward market can be expressed algebraically from equations (2.5) and (2.9) as the weighted average of the expected future spot rate and the interest parity forward rate.

$$(2.19) \quad F_t = \frac{b}{a+b} \cdot E(S)_t + \frac{a}{a+b} \cdot F_t^*$$

If $a = \infty$ then the supply of forward foreign currency by interest arbitrageurs is infinitely elastic at the forward rate F_t^* (see Figure 2.4). The volume of capital flows, A_t is then determined as the arbitrage counterpart to the volume of speculative purchases or sales of forward foreign currency at the forward rate F_t^*. When $a = \infty$ then "interest parity theory" will hold and interest arbitrage determines the forward rate for a given spot exchange rate and a given interest differential. Alternatively, if $b = \infty$ then the demand for forward foreign currency by speculators is infinitely elastic at the forward rate equal to the expected future spot rate, $E(S)_t$. Interest arbitrageurs will then determine the volume of capital flows at this forward rate (see Figure 2.5). When $b = \infty$ speculation will determine the forward rate for a given spot exchange rate and a given interest differential. Finally, we can consider two special cases within the above framework. Firstly, in a model with Fisherian Expectations (see below) $F_t^* = E(S)_t$. If $a = b = \infty$ then the arbitrage and speculation schedules cannot be separately identified. Secondly, consider $a = b = \infty$ but $F_t^* \neq E(S)_t$. This case can be represented similar to Figures 2.3-2.5 with the arbitrage and speculation schedules parallel to each other. Let $E(S)_t > F_t^*$. Speculators determine the level of the forward rate at $F_o = E(S)_o$. Equilibrium is reached as the pressure of interest arbitrage operations leads to depreciation of domestic currency in the spot market and F^* rises to $E(S)$.

The above structure can be used to demonstrate the impact of various changes on both the equilibrium forward rate and the volume of capital flows. The relative elasticities of the arbitrage and speculation schedules will be shown to be crucial to the outcome.

(i) Interest Rates

A widening of the interest differential in favour of domestic assets or a narrowing of the interest differential against domestic assets will, all else being given, lead to an upward shift in the arbitrage schedule $A^o A^o$ (see Figure 2.6). At the original interest parity forward rate F_o^* there will be a covered interest margin in favour of domestic assets. Arbitrageurs will borrow foreign currency, sell the proceeds in the spot market, invest in

Figure 2.6 Shifts of Arbitrage and Speculation Schedules

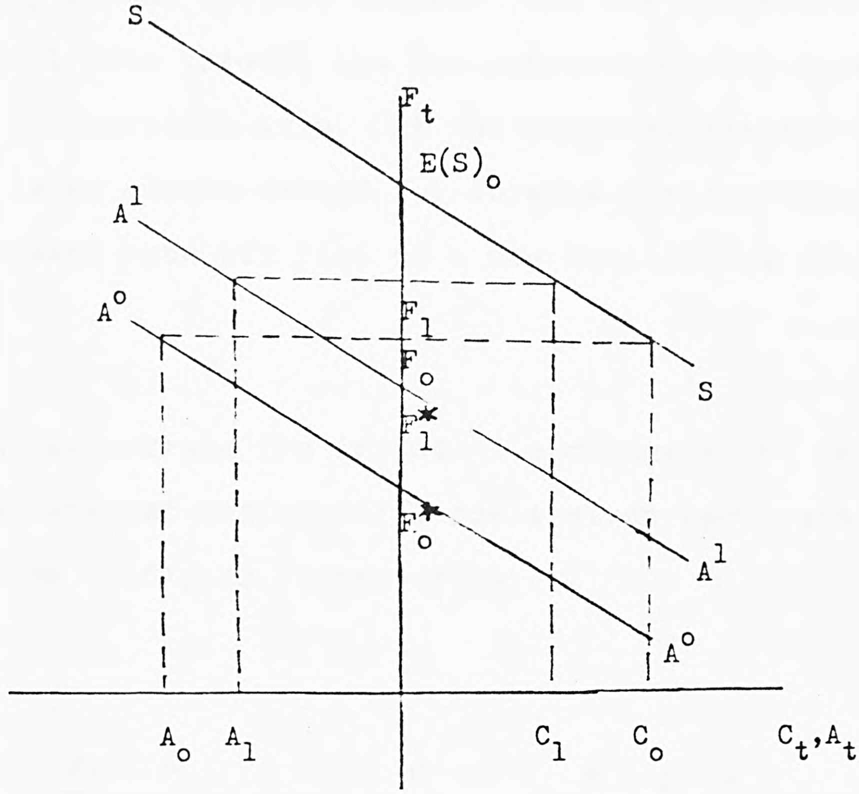
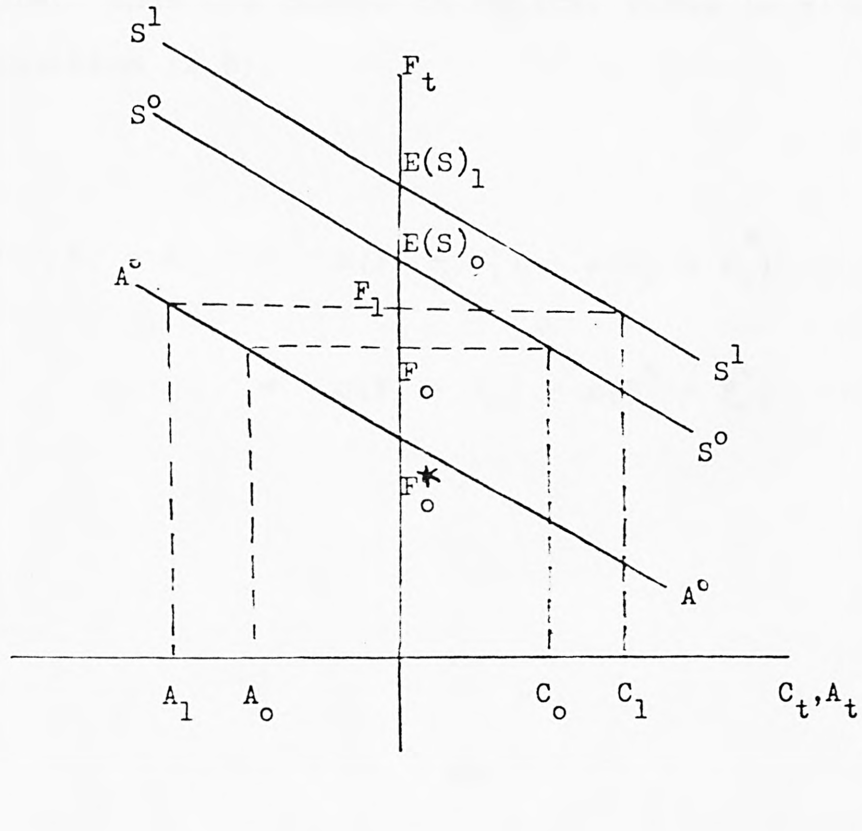


Figure 2.7



domestic assets and simultaneously buy back foreign currency on the forward market. The new arbitrage schedule A^1A^1 will pass through the new interest parity forward rate F_1^* on the vertical axis. At the original forward rate F_0 there is an excess demand for forward foreign currency and the forward rate wil rise to a new equilibrium point at F_1.

We can demonstrate the impact of a change in F^* (a change in the interest differential for a given spot rate) from equations (2.5), (2.9) and (2.19)

$$(2.20) \qquad \frac{dF}{dF^*} = \frac{a}{a+b}, \qquad 0 \leq \frac{a}{a+b} \leq 1$$

Spot capital flows are derived from the arbitrage schedule. Thus the change in capital flows is given by, from equation (2.5),

$$(2.21) \qquad A_1 - A_0 = a(F_1 - F_1^*) - a(F_0 - F_0^*)$$

$$= a(F_1 - F_0) - a(F_1^* - F_0^*)$$

where A_0 represents the original supply/demand of forward foreign currency by arbitrageurs, A_1 represents the new supply/demand of arbitrageurs and time subscripts similarly identify changes in the forward rate, F and the interest parity forward rate F^*.

In general, a rise in F^*, brought about by an increase in the domestic interest rate or a fall in the foreign interest rate, will result in (a) a depreciated forward rate (from (2.20) above, where the SS schedule is less than perfectly elastic), (b) a smaller capital outflow or (c) a greater capital inflow (from (2.21)). For example, in Figure 2.6, $A_1 < A_0$ at the new forward rate F_1.

From equation (2.20) we see that the greater the elasticity of SS (the higher b) then the smaller will be the impact on F and the greater the impact on capital flows for any change in F^*. Similarly, for a given speculation schedule, the more elastic is AA (the higher a) then the greater will be the impact of a change in F^* on the forward rate and the smaller will be the impact on capital flows. Finally, note that when $a = \infty$ the impact of a change in the interest differential on the covered margin is completely offset by a compensating move in the forward rate. When $b = \infty$ the forward rate does not move and a change in the interest differential is reflected in an equal change in the covered margin.

(ii) Exchange Rate Expectations

A change in exchange rate expectations will produce a shift in the SS schedule. A greater than previously expected depreciation of domestic currency will lead to an upward shift from S^0S^0 to S^1S^1 as in Figure 2.7. S^1S^1 passes through the new expected spot rate, $E(S)_1$, on the vertical axis. At the original forward rate, F_0, there is excess demand for forward foreign currency and the rate will return to equilibrium at F_1.

The impact of a change in exchange rate expectations on F is given by, from equation (2.19) above,

$$(2.22) \qquad \frac{dF}{dE(S)} = \frac{b}{a+b}, \quad 0 \leqslant \frac{b}{a+b} \leqslant 1$$

The impact on capital flows, from equation (2.5), is given by

$$(2.23) \qquad \begin{aligned} A_1 - A_0 &= a(F_1 - F_0^*) - a(F_0 - F_0^*) \\ &= a(F_1 - F_0) \end{aligned}$$

In general, a worsening of expectations will produce (a) a depreciated forward rate (for a less than perfectly elastic arbitrage schedule), (b) a greater capital outflow or (c) a reduced capital inflow. For example, in Figure 2.7 $A_1 < A_0$ at the new forward rate F_1. The more elastic is AA then the smaller the impact on the forward rate of a change in exchange rate expectations but the greater will be the impact on the size of capital flows. Similarly, for a given arbitrage schedule, the more elastic is the speculation schedule then the greater will be the impact on the forward rate of a change in exchange rate expectations and the greater will be the impact on the size of capital flows (from equation (2.23)). Finally, note that when $b = \infty$ the change in exchange rate expectations is completely reflected in the forward rate. When $a = \infty$ the change in expectations will be reflected in greater capital flows but will not alter the forward rate.

(iii) Exogeneous Shift in the Spot Rate

An exogeneous shift in the spot rate will, all other things being equal, lead to a change in the covered interest differential and hence a shift in the arbitrage schedule, AA. In Figure 2.8 domestic currency is at a forward premium i.e. $S_0 > F_0$. A rise in the spot rate of exchange from S_0 to S_1 will raise the covered margin on domestic assets and lead to a rightward shift in the AA schedule. The analysis of the impact of a change in the spot exchange rate on the forward rate (and hence the forward discount or premium) and the size of capital flows

Figure 2.8 Shift of the Spot Rate

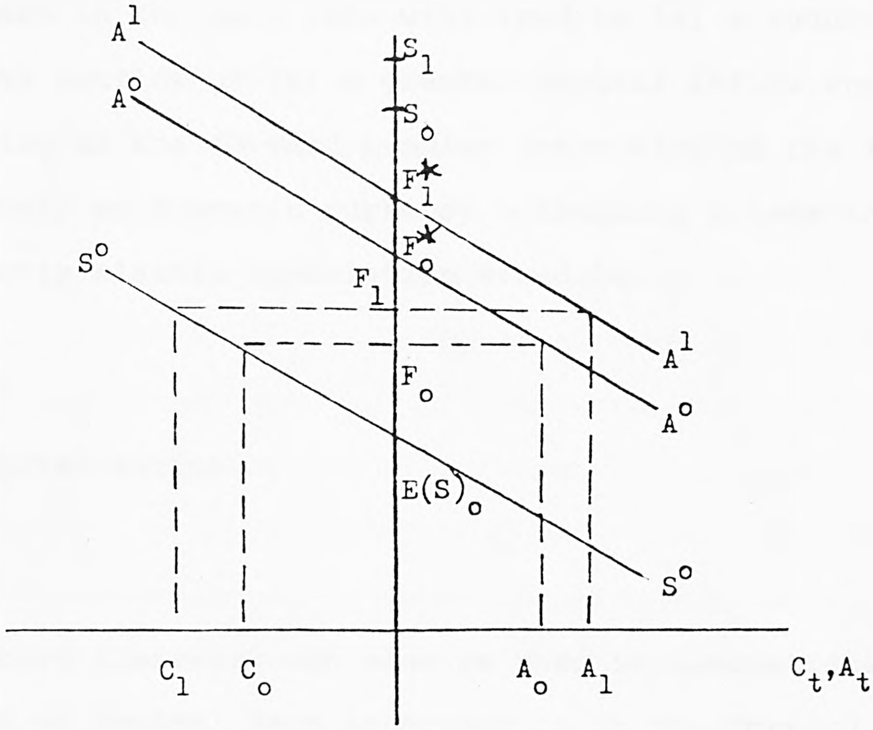
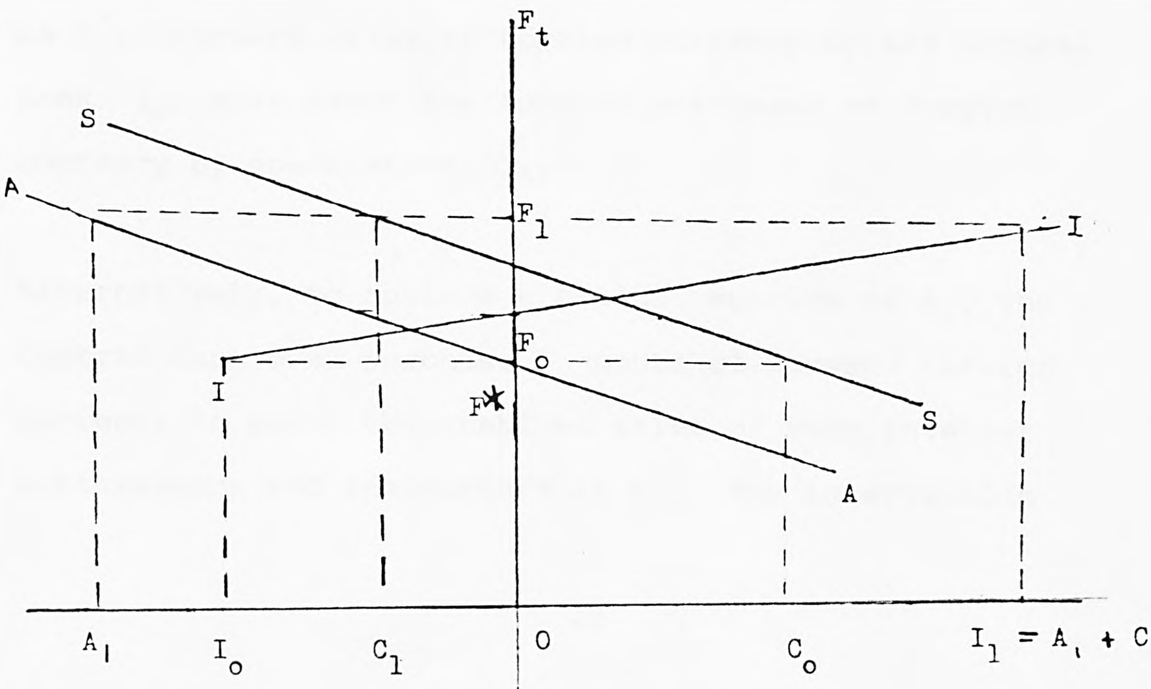


Figure 2.9 Intervention



is thus the same as for the case in which a change in either the domestic or foreign interest rate produces a shift in the AA schedule. In general, an exogeneous increase in the spot rate will lead to (a) a reduced capital outflow or (b) a greater capital inflow and (c) a widening of the forward premium (narrowing of the forward discount) on domestic currency - assuming a less than perfectly elastic speculation schedule.

(iv) Intervention

The above framework can also be used to demonstrate the effect of Central Bank intervention in the forward market. The volume of capital flows at each forward rate is given by the arbitrage schedule AA and intervention must produce the appropiate rate for the capital flow target or vice-versa. In Figure 2.9 the forward market is in equilibrium, in the absence of intervention, at F_0. If the desired capital flow is zero then the target forward rate is F^*. Forward sales of foreign currency by the Central Bank, I_0, must match the forward purchases of foreign currency by speculators, C_0.

Alternatively, to achieve a capital outflow of A_1, the Central Bank must purchase I_1 units of forward foreign currency to match the combined sales of both interest arbitrageurs and speculators at F_1. The intervention schedule for target forward rates (capital flows) is II.

In general, for a given arbitrage schedule, it can readily be seen that the more inelastic is SS then (a) the smaller is the volume of official intervention needed for a given target effect on capital flows and the spot rate and (b) a smaller proportion of official deals are with speculators and a larger proportion are with arbitrageurs. Thus forward intervention may be a powerful means of influencing capital flows and the spot exchange rate when SS is relatively inelastic. When $b = \infty$ forward intervention will be powerless to affect capital flows. Finally, note that the above analysis is based on the heroic assumption that official intervention will not lead to any shift in either the AA or the SS schedule.

(h) Estimation

The relative elasticities of the AA and SS schedules are clearly of great importance in determining the impact of various disturbances on the forward rate and the size of capital flows. In chapters 3 and 4 we consider empirical estimates of the arbitrage and speculation elasticities from structural form equations for the MT model. In this section we briefly describe studies which have sought to estimate relative elasticities from the coefficients in a regression equation of the reduced form

$$(2.24) \qquad F_t = c_1 F_t^* + c_2 E(S)_t + u_t \ , \ u \sim N(0, \sigma_u^2)$$

where a/b can be found from c_1/c_2. Some of the problems encountered in estimating equation (2.24) have already been dealt with, as for example the measurement of exchange rate expectations. An additional problem is the lack of information on the official forward position.

Studies of this form include Argy and Hodjera (5), Beenstock (7), Haas (49), Helliwell (52), Herring and Marston (53), Hutton (55), Kesselman (61, McCallum (79), Spraos (97), Stein (99), and Stoll (101). Estimates of the relative elasticities of the arbitrage and speculation schedules are obtained across different currencies and observation intervals, including periods of fixed and floating exchange rates. A summary of some of these results can be found in Beenstock (7, pp. 84-91).

Briefly, these studies found that a/a+b is high, almost certainly greater than 0.5 but significantly different, in a statistical sense, from unity. The implication is that arbitrage activity dominates the forward market but that the supply of interest arbitrage funds is less than perfectly elastic. This suggests, from the above analysis, that firstly, capital flows are likely to be insensitive to a change in the interest differential as the covered margin is quickly reduced through a movement in the forward rate and secondly, forward intervention will be a powerful means of influencing capital flows through the behaviour of arbitrageurs.

The other major result to appear from these studies is that a/a+b may be higher in a fixed rate regime than in an era of floating exchange rates (see Beenstock (7) and Stoll (101)). This would appear to indicate that the elasticity of the speculation schedule is lower in a period of fixed exchange rates. This contrasts with the usual assumption (for example, see Reading (91)) that the elasticity of speculative demand will be higher in a fixed rate framework because of greater certainty and the presence of a "one-way option". It may be that speculators are attracted by the absence of official intervention which may be viewed as destabilising or unpredictable or by the fact that it is no longer necessary to forecast a step adjustment in the exchange rate when a change in fixed parities is judged to be imminent.

The elasticities of the speculation and arbitrage schedules are relevant to the central issue of this study in as much as they determine whether or not the forward rate is an unbiased predictor of the future spot rate. Empirical estimates of the elasticities are considered in chapters 3 and 4 below. The forward rate will be a biased predictor of the future spot rate in circumstances where the elasticity of the speculation schedule is less than infinitely elastic and in which arbitrage activity pushed the forward rate away from the expected future spot rate. The bias may be either constant or shifting over time and it may exist with expectations being formed rationally. Before proceeding to examine these issues im more detail we first consider two criticisms of the MT approach to forward rate determination in Sections 4 and 5.

4. Banking Practice

A major criticism of the theoretical approach adopted above in the MT framework arises from the conduct of banks in their forward market operations (see Llewellyn (75)). Banking practice, it is argued, will ensure that the forward rate is at all times equal to the interest parity rate i.e. $F_t^* = F$, providing that comparison is made between eurocurrency interest rates. Thus the bank arbitrage schedule is infinitely elastic at F_t^*. Observation of non-zero covered interest rate differentials can only arise from inappropiate comparison between heterogeneous assets (see Chapter 3 below).

Take as an example the case where a non-bank arbitrageur sells the bank forward foreign currency. In effect, the bank is taking an involuntary speculative forward position. It may be possible to eliminate the exchange risk exposure through an equal and opposite transaction with another customer. However, in practice the bank will either cover itself via a foreign currency "swap" or through the eurocurrency mechanism.

The bank is contracted to buy forward foreign currency. It will typically offset this through a swap rather than an outright deal. In other words it will simultaneously contract to sell foreign currency forward and buy foreign currency spot. The bank will then sell foreign currency in a separate spot deal to eliminate the spot position which has been unintentionally created through the swap.

Alternatively, the bank will (i) borrow foreign currency in the euromarket, (ii) sell the currency in the spot market and (iii) invest the proceeds back in the euromarket. This has enabled the bank to match a forward asset in foreign currency with a forward liability. The spot position of the bank will be equal and opposite to the spot position of the non-bank arbitrageur.

The first major implication of banking practice in the forward market is that because banks take equal and offsetting positions to interest rate arbitrageurs then the forward rate must always equal the interest parity rate. A covered margin which would yield profit to interest arbitrageurs would by definition lead to a loss for the bank. Hence an intrinsic premium or discount on forward foreign currency cannot exist. Indeed, foreign exchange dealers quote forward rates based on eurocurrency interest rates and vice-versa. (Note, of course, that although prices are exogeneous to individual dealers in a competitive market, interest rates and forward rates are determined simultaneously for the system as a whole.). The concept of a non-bank arbitrage schedule is then meaningless since intrinsic premia and discounts cannot exist by definition. Only in the case of heterogeneous assets can a non-bank arbitrage schedule exist.

The second implication is that spot capital flows can only result from banks operations to offset non-bank forward speculation or from uncovered interest arbitrage. Banks will always take equal and offsetting positions in the spot market to interest rate arbitrageurs. This contrasts with MT analysis where spot capital flows result from the actions of covered arbitrage. However, in both cases net capital flows reflect speculative positions in the forward market.

In Table 1 below (from Llewellyn (75), p.59) a series of transactions illustrate the eurocurrency mechanism for covering bank forward positions. Assume initially a covered arbitrage flow into German Treasury Bills from U.S. Treasury Bills. The non-bank arbitrageurs transactions can be summarised as 1-2 in the table. The bank effects its forward purchase of Deutsche Marks in 2A by borrowing Euro-Deutsche Marks, selling the proceeds spot for U.S. Dollars and investing in the Euro-Dollar market. Transactions 1 and 4A cancel and there are no net spot capital flows. The second half of the table relates to a series of transactions arising from a sale of forward Dollars for Deutsche Marks by non-bank speculators. The bank's action to offset its own forward position results in a net spot purchase of Deutsche Marks at 7A.

Finally, note that given the major implication of banking practice in the forward market i.e. $F_t = F_t^*$ then the forward rate will only equal the expected future spot rate if $F_t^* = E(S)_t$. Changes in expectations will only alter the forward rate to the extent that they are reflected in interest rates and hence the AA schedule. This is the possibility that we now explore in Section 5.

5. Fisherian Expectations

In the MT framework the forward rate is determined jointly

Table 2.1

The Euro-Currency Mechanism

	Non-Banks	Banks
Arbitrage	1. Sell spot $	2A. Buy forward DM
	1A. Buy spot DM	3. Borrow DM
	2. Sell forward DM	4. Sell spot DM
		4A. Buy spot $
Speculation	5. Sell forward $	5B. Sell forward DM
	5A. Buy forward DM	5C. Buy forward $
		6. Borrow $
		7. Sell spot $
		7A. Buy spot DM

by covered interest arbitrage and speculation. If the elasticity of the speculation schedule is less than infinity then the forward rate will only equal the expected future spot rate, $E(S)_t$, if $E(S)_t$ is equal to the interest parity forward rate, F_t^*. This will be the case where (i) covered returns are the same on both domestic and foreign assets, (ii) real rates of interest are equal across countries and (iii) purchasing power parity holds.

Let the nominal interest rate R_t be expressed as the real rate of interest, I_t, plus expected future inflation. Since trade with capital flows will equate real interest rates, the ratio of domestic to foreign interest rates can be expressed as the ratio of domestic to foreign expected inflation rates. Thus

$$(2.25) \qquad \frac{1 + R_t^d}{1 + R_t^f} = \frac{(1 + I_t^d)(1 + E(\dot{P})_t^d)}{(1 + I_t^f)(1 + E(\dot{P})_t^f)} = \frac{(1 + E(\dot{P})_t^d)}{(1 + E(\dot{P})_t^f)}$$

where $E(\dot{P})_t$ denotes the change in the price level expected at t to take place over period i.

Next we write the purchasing power parity condition which equates the domestic and foreign price levels. At t

$$(2.26) \quad S_t = \frac{P_t^d}{P_t^f}$$

Similarly, at t+i

$$(2.27) \quad E(S)_t = \frac{E(P)_t^d}{E(P)_t^f}$$

Thus

$$(2.28) \quad E(S)_t = \frac{P_t^d \ (1 + E(\dot{P})_t^d)}{P_t^f \ (1 + E(\dot{P})_t^f)}$$

$$= S_t \frac{(1 + E(\dot{P})_t^d)}{(1 + E(\dot{P})_t^f)}$$

Finally, we restate the covered interest parity condition,

$$(2.29) \qquad \frac{F_t}{S_t} = \frac{(1 + R_t^d)}{(1 + R_t^f)}$$

From equations (2.25) - (2.29) above we see that

$$(2.30) \qquad \frac{F_t}{S_t} = \frac{(1 + R_t^d)}{(1 + R_t^f)} = \frac{(1 + E(\dot{P})_t^d)}{(1 + E(\dot{P})_t^f)} = \frac{E(S)_t}{S_t}$$

The implications of the above analysis are (i) the forward rate is equal to the interest parity forward rate and the expected future spot rate, (ii) eurocurrency interest rates and forward premia or discounts are determined simultaneously and (iii) in terms of the MT framework above it is not possible to identify separately the arbitrage and speculation schedules.

6. Conclusion

Forward exchange theory has progressed from a simple expression of the covered interest arbitrage equilibrium condition to the Modern Theory framework in which the demand for and supply of forward foreign currency arises from operations which may be classified either as arbitrage or speculation. The equilibrium forward price results when the demand (supply) for forward foreign currency by interest arbitrageurs matches the supply (demand) of speculators. It is then possible to consider the impact of various changes in the slope and position of the arbitrage and speculation schedules. In this approach, if the arbitrage and speculation schedules are less than perfectly elastic the forward rate is a weighted average of the interest parity forward rate and the expected future spot rate. The forward rate will not equal the expected future spot rate unless, in the absence of official intervention, the speculation schedule is infinitely elastic (with a less than infinitely elastic arbitrage schedule) or the expected future spot rate is equal to the interest parity forward rate.

Two major problems were considered in the MT model. First, from a practical stand point, it is alleged that banking practice ensures that $F = F^{*}$ (when comparison is made between eurocurrency interest rates) and renders the concept of a non-bank arbitrage schedule redundant. Second, in an efficient market without transactions costs and in the absence of risk aversion it can be demonstrated that $F^{*} = E(S)$ in which case we cannot separately identify the arbitrage and speculation schedules. The first of these observations makes little difference to the major analytical results from MT - at least in terms of the relationship between F and E(S). The second requires that we introduce more information or place the foreign exchange market in a more general framework in which interest rates, forward rates and spot rates are simultaneously determined. This is done later in Chapter 5 below.

Chapter 3

International Arbitrage

1. Introduction

In this chapter we analyse in more detail the role of the forward market in international arbitrage operations and conclude that covered interest rate parity holds for classes of assets such as eurocurrency deposits which are almost identical in every respect except for the currency unit of denomination. Given this, arbitrage operations may push the forward rate away from the expected future spot rate if the speculation schedule is less than perfectly elastic.

2. Transactions Costs

Interest rate parity theory states that arbitrage operations will reduce the covered differential on comparable assets in different currency units of denomination to zero. The supply of arbitrage funds is assumed to be infinitely elastic at the interest parity forward rate. The interest parity condition is restated from equation (2.3) in Chapter 2 above (using notation from Chapter 2, p.23)

$$(3.1) \qquad \frac{F_t - S_t}{S_t} = \frac{R_t^d - R_t^f}{1 + R_t^f}$$

The empirical question of whether deviations from covered interest parity are observed in practice is considered below. Clearly such an investigation must take into account the size of transactions costs. Allowance for transactions costs will provide a neutral band of forward rates consistent with a zero covered differential rather than a single value.

Frenkel and Levich (40) derived the interest parity condition under transactions costs in the following way. Assume that arbitrageurs hold domestic securities (bank deposits). Outward arbitrage will consist of four separate transactions each with associated cost; (a) sale of domestic securities with transactions costs of c_1 per cent, (b) purchase of foreign currency spot with transactions costs of c_2 per cent, (c) purchase of foreign securities with transactions costs of c_3 per cent and, finally, (d) sale of foreign currency forward with transactions costs of c_4 per cent. The cost of an outflow of one unit of domestic currency is the interest foregone on holdings of domestic securities

$$(3.2) \qquad C_t = (1 + R_t^d)$$

The revenue from a covered outflow of one unit of domestic currency is given by

$$(3.3) \qquad R_t = \Omega(1 + R_t^f) \cdot \frac{F}{S}$$

where $\Omega = (1-c_1)(1-c_2)(1-c_3)(1-c_4)$. The new interest parity condition where arbitrage drives the profit from this operation to zero is

$$(3.4) \qquad \overline{FD} = \frac{(1 + R_t^d) - \Omega(1 + R_t^f)}{(1 + R_t^f)}$$

where $\overline{FD}$ is the upper limit on the forward discount $FD = (F_t - S_t)/S_t$. Similarly, for a covered inflow, the lower limit on FD is given by

$$(3.5) \qquad \underline{FD} = \frac{\Omega(1 + R_t^d) - (1 + R_t^f)}{(1 + R_t^f)}$$

Thus the presence of transactions costs alters the original specification of the interest parity condition to a neutral band, where

$$(3.6) \qquad \underline{FD} \leqslant FD \leqslant \overline{FD}$$

Frenkel and Levich (40) have suggested that transactions costs in the foreign exchange market can be estimated from observed percentage deviations from the triangular arbitrage condition (see Chapter 2, p.36). They take the per cent deviation which bounds 95% of the discrepancies from triangular arbitrage in the spot and forward markets from weekly data for the U.S. Dollar, Pound Sterling and Deutsche Mark over the period January 1962 to November 1967. The total cost of transacting in securities was assumed to be 2.5 times the bid-ask spread for Treasury Bills. Frenkel and Levich estimate the total costs of interest arbitrage to be 0.15%. This is consistent with Branson's estimate of 0.19% (see (14)) but much lower than estimates cited in the early work of Einzig (31) and Keynes (63). Frenkel and Levich use their estimate of total transactions costs to compute the neutral band for covered arbitrage. They find that this explains roughly 85% of apparent profit opportunities from comparing domestic assets (U.K. and U.S. Treasury Bills) and roughly 99% for external assets (eurocurrency bank deposits). The same authors found that transactions costs had increased by the order of five to ten times with the 1973-1975 floating rate period. Their measure of transactions costs is still able to explain deviations from interest pariy under normal trading conditions in either the fixed or floating rate era. However, it breaks down when trading conditions are turbulent under floating exchange rates (see (41)).

3. Elasticities Approach

In the above it has been assumed that rates of interest are independent of amounts borrowed and lent. Prachowny (90) investigated the impact on the interest parity condition of firstly, assuming that the rate of interest at which an arbitrageur can borrow is not the same rate at which he can invest and, secondly, assuming that the borrowing rate rises with the amount of arbitrage funds supplied to the market.

The cost of borrowing x units of domestic currency is

$$(3.7) \qquad C_t = x(1 + R_t^{d,b})$$

where $R_t^{d,b} = R_t^{d,b}(x)$. The revenue of the hedged investment is

$$(3.8) \qquad R_t = x(1 + R_t^{f}) . \frac{F_t}{S_t}$$

The profit on a covered outflow of funds is given by

$$(3.9) \qquad \pi_t = x(1 + R_t^{f}) . \frac{F_t}{S_t} - x(1 + R_t^{d,b})$$

Profit maximisation requires that, dropping time subscripts,

$$(3.10) \qquad \frac{\partial \pi}{\partial x} = (1 + R^{f}).\frac{F}{S} - \left[1 + x(dR^{d,b}/dx) + R^{d,b}\right] = 0$$

Now let FD = (F-S)/S. We can rewrite equation (3.10) as

$$(3.11) \qquad (1 + R^{f})(1 + FD) = 1 + x(dR^{d,b}/dx) + R^{d,b}$$

Assuming that $FD.R^{f} = 0$, we obtain

$$(3.12) \qquad FD = R^{d,b}(1 + 1/\epsilon_{R^{d,b}}) - R^{f}$$

where $\epsilon_{R^{d,b}} = (dx/dR^{d,b})(R^{d,b}/x)$. This defines the elasticity of the borrowing schedule with respect to the domestic interest rate. The parity condition for a covered outflow in equation (3.11) compares with the simple abbreviation of interest parity derived in Chapter 2, $FD = R^{d} - R^{f}$, again where $FD.R^{f} = 0$.

Similarly, the parity condition for an inward covered flow is given when profits are maximised by

$$(3.13) \qquad d\pi/dx = (1 + R^{d}).\frac{S}{F} - \left[1 + x(dR^{f,b}/dx) + R^{f,b}\right] = 0$$

$$\Rightarrow \quad FD = \frac{R^{d} - R^{f,b}(1 + 1/\epsilon_{R^{f,b}})}{R^{f,b}(1 + 1/\epsilon_{R^{f,b}}) + 1}$$

where $\epsilon_{R^{f,t}} = (dx/dR^{f,t})(R^{f,t}/x)$. This defines the elasticity of the borrowing schedule with respect to the foreign interest rate.

Prachowny derived an equilibrium interest parity range given by

$$(3.14) \quad \frac{R^{d} - R^{f,t}\lambda^{*}}{R^{f,t}\lambda^{*} + 1} \leq FD \leq R^{d,t}\lambda - R^{f,t}$$

where $\lambda^{*} = 1 + 1/\epsilon_{R^{f,t}}$ and $\lambda = 1 + 1/\epsilon_{R^{d,t}}$

Frenkel (38) modified the Prachowny model to test weekly data on U.K. and U.S. Treasury bills and the forward discount on the Dollar/Sterling exchange rate for 1959-1970. He noted that the maximum elasticities implied in order to bound all observations within the revised interest parity condition would be very low. Indeed, they would suggest monopoly/monopsony power on the part of arbitrageurs which is at odds with casual inspection of the foreign exchange market.

Frenkel and Levich (40) extended the Prachowny thesis to the more general case in which rates of interest are not independent of amounts that are borrowed or lent and neither is the price of foreign exchange (spot and forward) independent of quantities bought and sold. The neutral band around the interest parity condition is widened if the elasticities of demand and supply in the securities and foreign exchange markets are less than infinite. They observe that, allowing for transactions costs, residual deviations from interest parity are small. Thus implied elasticities (assuming all are equal) necessary to bound all observed deviations from simple interest parity would be very high. They conclude that this accords with the highly competitive organisation of the securities and foreign exchange markets.

4. Risk

The interest parity condition results from arbitrage operations which compete away covered returns between assets which are the same in every way except for the currency unit of denomination. Only exchange risk remains to differentiate such assets and a forward transaction enables such risk to be eliminated. Comparison between heterogeneous assets may result in non-zero covered returns because of different non-price risk characteristics. Risk aversion will prevent arbitrage operations from exploiting apparently profitable opportunities. In Chapter 2 we noted that these non-price factors include the risk of default and also political risk through, for example, the possible imposition of exchange controls . Default risk can explain the presence of a covered differential between say bank CDs in one currency and Treasury Bills in another currency. Similarly, exchange controls may prevent arbitrage from competing away covered returns on domestic assets. This latter point is illustrated in the next section when we consider arbitrage relationships between eurocurrency and domestic assets. Examples of the association of covered returns with default risk and exchange controls are given when we consider the empirical evidence in Section 6. The more general condition that the demand for risky assets will be less than perfectly elastic but a positive function of expected returns was illustrated in detail in Chapter 2, p. 29 above.

5. Exchange Controls

In Sections 2 and 3 above we have seen that the simple interest parity condition must be modified to take into account transactions costs and less than perfectly competitive markets. In this section we examine the impact of exchange controls on international arbitrage. It is possible to distinguish three channels of international arbitrage operations; firstly, between domestic assets in two countries, secondly, between eurocurrency assets and, thirdly, between domestic assets in one country and eurocurrency assets in a different unit of denomination. The alternatives distinguish between firstly the choice of currency and, secondly, the choice of location. The second of these must take into account the possible presence of exchange controls.

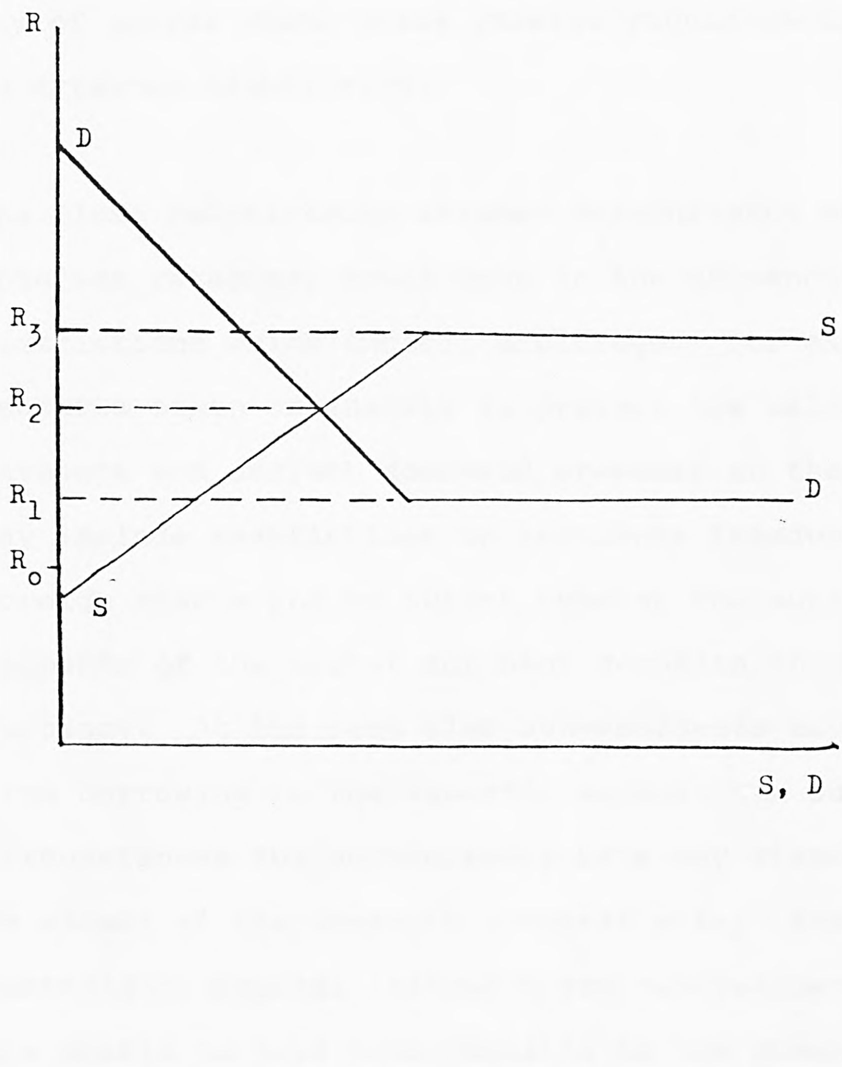
Banks arbitrage operations will in general simultaneously determine domestic interest rates, eurocurrency interest rates and forward exchange rates (see Section 4 in Chapter 2). In the absence of exchange controls the relationship between domestic and eurocurrency interest rates is determined by the level of reserve requirements on domestic and external liabilities. In Figure 3.1 below (see Llewellyn (75), p.83) the supply of funds to the euromarket is a rising function of the differential between the eurocurrency interest rate and the domestic rate, R_0. At R_3 the supply curve is perfectly elastic where the eurocurrency rate is equal to the effective cost of raising funds in the domestic market. The demand for eurocurrency funds is a downward sloping function of the eurocurrency interest rate. Bank demand is infinitely elastic at the rate where the effective cost of borrowing, allowing for reserve requirements on domestic and external liabilities, is the same. Let r_d and r_f be the percentage reserve requirements on domestic and foreign liabilities respectively. Then bank demand will be infinitely elastic where

$$(3.15) \quad 1/(1 - r_d).R^d = 1/(1 - r_f).R^e$$

and where R^d and R^e denote the domestic and eurocurrency interest rates respectively. In Figure 3.1, R_3 is the effective cost of raising domestic funds and, assuming the presence of reserve requirements on external liabilities, R_1 is the equivalent eurocurrency rate where

Figure 3.1

Supply and Demand in the Euro-Currency Market



$1/(1 - r_f).R_1 = R_3$. It follows from the above that banks arbitrage operations will constrain the eurocurrency interest rate to lie between R_1 and R_3. Note that in the above example $R_1 > R_0$ which implies that the reserve requirement on domestic liabilities exceeds the reserve requirement on external liabilities. This corresponds to the commonly observed situation in which eurocurrency interest rates exceed domestic interest rates. The reverse may of course occur where reserve requirements are greater on external liabilities.

The close relationship between eurocurrency and domestic interest rates may break down in the presence of exchange restrictions which inhibit arbitrage. For example, measures taken ostensibly to protect the balance of payments and deflect downward pressure on the exchange rate may include restrictions on residents freedom to purchase foreign assets and to switch between the euro and domestic segments of the market for bank deposits in domestic currency. At the same time non-residents may be forbidden from borrowing in the domestic sector. In such circumstances the eurocurrency rate may stand substantially in excess of the domestic interest rate. Similarly, controls on capital inflows where non-resident investors are unable to hold bank deposits in the domestic sector and banks are forbidden to repatriate funds from the euro sector may be reflected in a eurocurrency interest rate significantly below the corresponding domestic interest rate.

In Chapter 2 we noted that banks arbitrage operations simultaneously determine eurocurrency interest rates and the forward exchange rate. Thus the covered differential on eurocurrency assets will tend to zero. Non-zero covered margins may be observed where comparison is made between dissimilar domestic assets with different risk characteristics as noted in Section 4. In this section we have demonstrated that domestic and eurocurrency interest rates on homogeneous assets (bank deposits) are closely linked via arbitrage. However, exchange controls may lead to a divergence between yields on such assets even where the assets share identical risk characteristics. Thus a covered margin may exist between assets in different national money markets even in the absence of risk.

6. Empirical Research

Interest rate parity theory states that arbitrage will reduce the covered differential on homogeneous assets to zero. In other words, the arbitrage schedule will be perfectly elastic at the interest parity forward rate. The homogeneity assumption extends to the non-price risk characteristics of the assets being compared. Deviations from parity may be observed if there are restrictions on the free movement of capital, market imperfections or transactions costs. (In terms of the formal analysis presented in Chapter 2 above, deviations from interest rate parity may be observed if the arbitrage schedule is upward sloping.) Non-zero covered returns may result from comparison of heterogeneous assets which do not belong to the same risk class. Briefly, the findings of empirical research may be summarised thus;

(i) Interest rate parity appears to hold at all times for eurocurrency assets (see, for example, Roll and Solnik (92), Fratianni and Wakeman (42), Herring and Marston (53)). This results from banks unrestricted arbitrage operations in the eurocurrency and foreign exchange markets.

(ii) In the absence of exchange controls domestic interest rates on bank deposits move very closely with eurocurrency deposit rates as a result of banks arbitrage operations in the money market (see Llewellyn (75), pp. 87-97). Llewellyn applies the term "global parity" to such periods when the covered differential is close to zero for both internal and external assets. Johnston (58) found that from January 1975 to March 1978 the average differential between three month eurodollar deposits and domestic secondary market CDs adjusted for reserve requirements and Federal Deposit Insurance was only 0.07% with variance 0.05%. Similarly, between August 1975 and December 1977 the mean differential between Euro-DM and German domestic interbank rates was only -0.15% with variance 0.03%. The reserve requirement on German banks internal and external liabilities were broadly the same over this interval.

(iii) Eurocurrency deposit rates may vary substantially from domestic interest rates during periods when exchange control restrictions are in force. Johnston found that the gap between the two U.S. Dollar denominated assets mentioned above was greatly increased in the period prior to 1974 when there were restrictions on U.S. bank lending to non-residents. Eurocurrency deposit rates at times rose sustantially above the corresponding domestic interest rate in this period. The reverse applied in Germany in the 1970s on occasions when restrictions were placed on capital inflows. Reserve requirements on external liabilities were far greater than on domestic liabilities between January 1973 and January 1974 and again between January and June of 1978. In addition, under the provisions of the Bardepot Law, the German Government imposed a 100% minimum reserve requirement against foreign loans contracted by German companies between February 1973 and February 1974. During these periods Euro-DM rates at times fell substantially below the corresponding domestic interbank interest rates. The gap between eurocurrency and domestic interest rates which can emerge at times of exchange control implies with point (i) above that non-zero covered differentials may be found from comparison of internal assets.

(iv) During periods of restriction on outward flows of capital large covered differentials at times of heightened curency speculation have tended to be associated with large forward discounts. In other words, monetary authorities have been able effectively to isolate the euro and domestic money markets for some period of time. For example, Euro French Franc interest rates rose substantially above domestic interest rates at a time of severe speculation against the Franc prior to the realignment of parities in the European Monetary System in March 1983. Thus the Franc traded at a substantial discount in the forward market although the interest differential between foreign and French Franc denominated domestic assets remained relatively unaffected.

(v) Allowance for transactions costs greatly reduces apparently profitable ooportunities for covered interest arbitrage (see Frenkel and Levich (40)).

7. Conclusion

In this chapter we have presented a more detailed analysis of the factors which determine the slope of the arbitrage schedule. Interest rate parity theory states that the free movement of capital will ensure that the covered differential between similar assets belonging to the same risk class will be zero. In other words, the supply of arbitrage funds is perfectly elastic at the interest parity forward rate. Necessary conditions for the existence of deviations from interest rate parity are the presence of transactions costs or an upward sloping arbitrage schedule. An upward sloping arbitrage schedule may result from market imperfections or different non-price risk characteristics of assets under comparison.

Interest rate parity appears to hold for comparison of eurocurrency assets. A significant proportion of deviations from parity can be explained through allowance for transactions costs. However, exchange controls may lead to non-zero covered returns between homogeneous internal as opposed to external assets. This conclusion is supported by the evidence cited in Section 6 above.

In chapter 2 we noted that the forward rate would be a biased predictor of the expected future spot rate if the elasticity of the arbitrage schedule is infinite unless the expected future spot rate is equal to the interest parity forward rate. This chapter supports the case that interest rate parity appears to hold for a broad class of assets. Thus the arbitrage schedule is likely to have a very high elasticity if not equal to infinity.

Chapter 4

Speculative Efficiency in the Forward Market

1. Introduction

This chapter considers the speculation schedule in more detail and introduces the notion of rational expectations and the "efficient markets hypothesis". In an efficient market prices fully reflect all available information thus eliminating unusual (after adjusting for transactions costs and risk) profit opportunities. If tests of efficient market theory (EMT) are unsuccessful we cannot be sure whether the assumption of efficiency is invalidated or whether the specified model for generating exchange rate behaviour is itself incorrect. For this reason most research effort has been concentrated on the joint hypothesis that the speculation schedule is infinitely elastic at the expected future spot rate and that expectations are formed rationally. This yields the testable hypothesis that the forward rate is an unbiased predictor of the future spot rate. However, tests of the "speculative efficiency hypothesis" have been inconclusive. Moreover, some tests have been based on weak econometric analysis. The chapter concludes that tests of speculative efficiency may be more fruitfully pursued within the framework of a general equilibrium model. The time paths of spot and forward exchange rates can then be examined under alternative assumptions about risk-averse behaviour in the forward market.

2. Efficient Markets Theory

In Chapter 2 we noted that many ad-hoc measures of exchange rate expectations have been used in past studies of exchange rate behaviour (see Chapter 2, p.31). These have ranged from applying simple regressive or extrapolative expectations schema to employing economic variables, for example the trade balance, as proxies for the expected future exchange rate. By contrast, the Rational Expectations Hypothesis (REH) asserts that individuals fully utilise available information in seeking to base expectations or forecasts on the true underlying economic structure which gives rise to exchange rate movements. Thus the expected future exchange rate is the mathematical expectation derived from the true model generating exchange rate behaviour. In this sense market expectations are optimal.

Let Φ_t be the set of information available at time t. Φ_t describes the "state of the world" at t. It includes past and present values of all relevant variables and knowledge of past, present and perceived future relationships between variables. There exists a joint probability density function for the sequence of spot exchange rates between currencies i and j, j = 1,...,n. This can be expressed as

$f(S_{i,1,t+r} \ldots, S_{i,n,t+r} \mid \Phi_t)$, for all r > 1. It is assumed that exchange rates at t are set on the basis of characteristics of the joint probability density function of the time path of exchange rates assessed by the market at t using the information set Φ_t^m. That is, exchange rates are set based on $f_m(S_{i,1,t+r} \ldots, S_{i,n,t+r} \mid \Phi_t^m)$. Φ_t^m is a subset of Φ_t containing at most the information in Φ_t although it could contain less. Market efficiency states that

$$(4.1) \qquad \Phi_t^m = \Phi_t$$

Since Φ_t includes all that is "knowable" this implies

$$(4.2) \qquad f_m(S_{i,1,t+r} \ldots S_{i,n,t+r} \mid \Phi_t^m) = f(S_{i,1,t+r} \ldots S_{i,n,t+r} \mid \Phi_t)$$

In conclusion, "market efficiency means that the market is aware of all available information and uses it correctly" (Fama (34), p.136).

There are a number of criticisms of REH (for example see Begg (8), pp. 62-69). Firstly, it is claimed that the sophisticated behaviour credited to individuals under REH is not an accurate description of the real world. In other words, individuals neither have the ability nor the inclination to engage in large-scale econometric modelling prior to any investment decision. However, this criticism is not serious if we take into account the vast resources devoted to economic research and the predominance of institutions in the financial markets. A second objection is that information is costly to gather but this criticism is overcome if a more rigorous analysis of the costs and benefits to acquiring information is allowed for. A third set of criticisms are based on the observation that there is disagreement over the correct model generating asset price or exchange rate behaviour. In other words, individuals employ different information sets in forming expectations. However, in answer to this criticism, it might be argued that in an efficient market a convergence of views will result from a "learning effect" over the long run. Finally, the strongest case against REH is that the complex and changing nature of economic relationships make it impossible to discover the true model. This criticism is of course not unique to REH but is applicable to most aspects of economic theory.

The logical simplicity of the REH provides powerful insights into economic behaviour which yield testable hypotheses for empirical research. Similarly, by extension, EMT provides predictions about asset price behaviour which are open to empirical testing. Sufficient conditions for asset market efficiency to hold are firstly, that there are no transactions costs in trading securities, secondly, that all available information is costlessly available to all market participants and, thirdly, that all agree on the implications of current information for the current price and distributions of future prices of each security. These conditions do not hold perfectly in the real world as noted in the criticisms of REH above but with small transactions costs and a large number of participants in the market it is possible for market efficiency to hold "if sufficient numbers of investors have ready access to available information" (Fama (33), p. 388).

The major implication of market efficiency is that exchange rates will continuously, fully and correctly reflect the information set thus eliminating any profit opportunities over and above equilibrium expected returns.

Let $\tilde{x}_{i,j,t+1} = \tilde{S}_{i,j,t+1} - {}_{t+1}E(\tilde{S}_{i,j})_t \mid \Phi_t$ where $\sim$ denotes a random variable. Then the implication of market efficiency is that (in the absence of risk and transactions costs) ${}_{t+1}E(\tilde{x}_j)_t \mid \Phi_t = 0$. This states that the sequence of prediction errors $\{x_{j,t}\}$ is a "fair game". In other words, market participants do not make systematic forecasting errors.

Tests of market efficiency are in fact joint tests, firstly of efficiency and, secondly, of the process of price formation in determining equilibrium prices. Since we cannot observe $f_m(S_{i,j,t+1} \ldots S_{i,n,t+1} | \Phi_t^m)$ we cannot determine whether equation (4.2) holds or whether the real world capital market is efficient.

In the literature tests of EMT distinguish three levels of market efficiency. Specifically, each is concerned with the nature of Φ_t^m as a subset of Φ_t. In "weak form" prices are held to fully discount all information based on the history of prices and returns performance. In "semi-strong" form the information subset Φ_t^m includes all publically available knowledge about the asset. Finally, in "strong" form EMT states that where the information subset Φ_t^m includes all relevant information then no individual or group of individuals should prove consistently "able to beat the market". If it was possible to do so this would imply either that an individual or group of individuals had monopolistic access to information or that they were better able to assess available information in the market. In either case the market would not be efficient.

3. Weak Form Foreign Exchange Efficiency

In the weak form of market efficiency the information set utilised by the market, ϕ_t^m, in assessing the joint probability density function of future exchange rates contains the history of spot and forward prices. Thus if the market does not make systematic forecasting errors, that is $E(\tilde{x}_{j,t}) = 0$, it will not be possible to earn abnormal returns from a trading strategy which is based on a supposed ability to spot recurring patterns of price movement. That is, today's price fully discounts past price behaviour.

In early treatments of weak form exchange market efficiency the claim that today's price fully discounts past price information was taken to imply that exchange rates followed a "random walk". In other words, successive price changes are independently and identically distributed and the price at time t is the best forecast of the price at t+1. This can be expressed as

$$(4.3) \qquad {}_{t+1}E(S)_t = S_t$$

where S_t is the spot exchange rate. The most common form of test of the random walk hypothesis is to estimate the martingale process below and examine the mean-variance structure of the error terms.

$$(4.4) \qquad S_t = S_{t-1} + e_t, \qquad e \sim N(0, \sigma_e^2)$$
$$E(e_t e_{t-s}) = 0, \ \forall \ s \neq 0$$

Evidence of zero correlation between error terms is evidence in support of the random walk model although exchange rate changes may be random about a trend. Poole (89) found evidence of serial correlation between spot exchange rate changes for nine currencies in the post World War 1 floating rate period and for the Canadian Dollar from 1950-1962. Similarly, Burt, Kaen and Booth (19) rejected the random walk model. By contrast, Giddy and Dufey (44), Cornell (21) and Pippenger (88) found evidence to support the random walk hypothesis in studies of several currencies across different time periods.

In fact it can be demonstrated that efficiency implies only that the "fair game" variable x, defined above, will follow a random walk and that such behaviour is perfectly consistent with serial correlation between actual successive price changes. This renders tests of the simple random walk hypothesis inoperative as tests of market efficiency.

Altering the earlier notation slightly let x_{t-s}^{t} be the prediction error at t, based on the information set available at t-s. Then, as earlier,

$$(4.5) \qquad E(x^t_{t-s} \mid \Phi^m_{t-s}) = 0, \qquad \Phi^m_{t-s} \subseteq \Phi_{t-s}$$

For r < s if we assume that $\Phi^m_{t-s} \subseteq \Phi^m_{t-r}$ then it follows that

$$(4.6) \qquad E(x^t_{t-r} - x^t_{t-s} \mid \Phi^m_{t-s}) = 0$$

The information set Φ_{t-s} will contain the observation x^t_{t-u} for $u \geqslant s$ such that

$$(4.7) \qquad E(x^t_{t-r} - x^t_{t-s} \mid x^t_{t-s}, x^t_{t-s-1}, \ldots) = 0$$

Set r = s-1, then

$$(4.8) \qquad E(x^t_{t-s+1} \mid x^t_{t-s}, x^t_{t-s-1}, x^t_{t-s-2} \ldots) = x^t_{t-s}$$

The sequence x^t_{t-s} is therefore a martingale in s. If one makes the further assumption that $\mathrm{var}(x^t_{t-s+1} - x^t_{t-s})$ is independent of s then the sequence is a random walk. However, to illustrate the point made above it can easily be shown that successive changes in the spot price may exhibit non-zero correlation while successive changes in the prediction error will satisfy the random walk criteria. Stein (98) has constructed a dynamic model of the foreign exchange market which might be expected to exhibit precisely such behaviour.

Most tests of the random walk hypothesis have failed to take account of the above through neglecting either to confirm that the exchange rate is a stationary series or to specify the implicit model generating exchange rate behaviour. Subsequent weak form tests of exchange market efficiency have sought to find a proxy for ${}_{t+1}E(S)_t \big| \Phi_t^m$ to see whether prediction errors follow a random walk. Cornell and Dietrich (22) employed the premium on forward exchange contracts for six currencies over the period March 1973-September 1975 as a measure of the expected return on currency holdings. They found no evidence of statistically significant autocorrelation for successive daily observations on "excess" rates of return defined by the "fair game" variable.

Similarly, Geweke and Feige (43) estimated the following set of regression equations

$$(4.9) \qquad q_{i,t} = \alpha_i \, q_{i,t-1} + e_{i,t}\,, \qquad E(e_{i,t}\, q_{i,t-1}) = 0$$
$$i = 1, \ldots, n$$

and tested the null hypothesis that $\alpha_i = 0$ for seven currencies in the periods 1962-1967 and 1972-1977. The realized rate of exchange gain for currency i, q_i, was defined as

$$(4.10) \quad q_{i,t} = (S_{i,t} - {}_{t}F_{i,t-1}) \; / \; S_{i,t-1}$$

Geweke and Feige also examined the concept of multi-market efficiency in the regression equations

$$(4.11) \quad q_{i,t} = \sum_{j=1}^{N} \beta_{i,j} q_{j,t-1} + \eta_{i,t} \qquad E(\eta_{i}, q_{j,t-1}) = 0$$

$$j = 1,\ldots,N$$

$$i = 1,\ldots,n$$

The multi-market efficiency hypothesis requires that $\beta_{i,j} = 0$ for all i and j. Single market efficiency is rejected in the first (fixed exchange rate) period at the 5% level for the British Pound and the Belgian Franc. Multi-market efficiency is rejected in the case of Canada and the United Kingdom and also in a more powerful joint test across markets at the 0.1% level of significance. The results are similar for the second period of managed floating with the joint test of multi-market efficiency again rejecting EMT. Geweke and Feige then provide evidence that the results of their test are more favourable to market efficiency when allowance is made for both transactions costs and differential risk across markets.

Finally, a third set of researchers have tested the "weak efficiency" hypothesis by considering whether significant profits can be earned from following simple trading strategies based solely on price information. Under EMT prices always fully reflect all available information.

However, "technical analysis" assumes that financial markets adjust slowly to news thus causing prices to move in trends. Moreover, it is claimed that changes in trend are indicated by repeated patterns of price movement. Chartists try to identify such patterns. Trading rules suggested by technical analysis are designed to identify trends and changes in trends of price movement. Examples of this include the filter rule - buy a currency if it appreciates x per cent from a previous low and sell when x per cent below the last high - and the use of moving averages. Rules based on the latter are designed to spot changes in trend by comparing today's price or the recent history of prices with a longer run of data. Technical analysis has a long history of accepted use in stock and commodity markets but has only more recently become widely applied within the foreign exchange market.

Tests of EMT based on the returns earned from following simple trading strategies formulated solely on price movements must take several factors into account. Firstly, the results must allow for the costs of executing transactions. Secondly, if the trading rules give rise to spot speculation then account must be given to the cost of financing the position or the "cost of carry". Thirdly, speculative returns may not be unusual after allowing for risk and risk-aversion. Fourthly, a true test of EMT should be based on examination of ex-ante prediction errors and not on the search for an optimal ex-post trading rule. Such a procedure is possible through analysis of the available track records of currency advisory services which use technical trading models (see for example Goodman (45)).

Levich (71) has suggested a simple procedure for evaluating the performance of trading strategies. A measure of profit is given by

$$(4.12) \quad \sum_{i=1}^{M} d_i (S_{t+n,i} - F_{t,i}) / M.F_{t,i}$$

where $d_i = +1$ if ${}_{t+n}E(S)_t > {}_{t+n}F_t$

$d_i = -1$ if ${}_{t+n}E(S)_t < {}_{t+n}F_t$

and M is the number of periods over which the rules are followed. Buy and sell signals can be interpreted as implying that ${}_{t+n}E(S)_t \gtrless {}_{t+n}F_t$ although technical trading rules do not generally provide point forecasts of the exchange rate. Levich assesses the significance of trading rule profits judged in terms of the profit available from "perfect information". The latter is given by

$$(4.13) \quad \sum_{i=1}^{M} \left| S_{t+n,i} - F_{t,i} \right| / (M.F_{t,i})$$

Levich demonstrates that the ratio

$$(4.14) \quad H = \sum_{i=1}^{M} d_i (S_{t+n,i} - F_{t,i}) / \sum_{i=1}^{M} \left| S_{t+n} - F_{t,i} \right|$$

has expected value $(2p-1)$ and variance $4p(1-p)/m$, where p is the probability of choosing d_i correctly in every period and m is the independent number of sample observations. A rule which is correct half of the time has $p = 0.5$ and $E(H) = 0$. Unusual profits correspond to the case where H is greater than zero or p is greater than one half. The major drawback of the Levich approach is that it fails to take into account that trading systems do not generate buy and sell signals over regular intervals and thus it is possible to close out a speculative position early with an offsetting forward deal.

Weak form tests of EMT have not always taken the above considerations into account. Poole (89) found that abnormal profits could be earned from filter rules for the Canadian Dollar in 1950-1962 and for nine other flexible exchange rates in the post World War One period. However, he did not allow for either relative interest rates or transactions costs. Similarly, Logue, Sweeney and Willett (76) reported filter rule profits for seven currencies based on daily data from April 1973 to January 1977 but again did not allow for interest expense or income or transactions costs. Cornell and Dietrich (22) found that both filter rules and moving average trading rules consistently produced profits using daily data for the

German Mark, Dutch Guilder and Swiss Franc from March 1973 to September 1975. However, the returns were reduced after allowing for transactions costs and the authors did not take relative interest rates into consideration. Finally, Dooley and Schafer (24) rejected spot market efficiency using filter rules corrected for both interest rates and transactions costs for nine countries (Belgium, Canada, France, Germany, Italy, Japan, Netherlands, Switzerland and the United Kingdom) over the period March 1973 to September 1975.

To sum up, tests of weak form EMT have not been conclusive. Firstly, the implication of weak form efficiency for the path of exchange rates has not been fully understood. Secondly, insufficient allowance has been made for the nature of speculative position taking in the foreign exchange market. Thus the cost of financing an outright speculative deal and the cost of transacting have often both been ignored. Finally, and most importantly, tests have not been set within a coherent framework of equilibrium exchange rate determination. Thus it has not been possible to measure whether or not returns to speculation have been excessive when judged in terms of compensation for the bearing of risk. This point is re-emphasised later when it is suggested that tests of efficient market theory should be conducted against the predictions of a general equilibrium model. This is the approach adopted in Chapters 5-7 below.

4. The Speculative Efficiency Hypothesis

By far the largest amount of research into the EMT hypothesis in the foreign exchange markets has been concentrated on what Bilson terms "speculative efficiency". Bilson explains the concept of speculative efficiency in these terms: "if a market is subject to efficient speculation, the supply of speculative funds is infinitely elastic at the forward price that is equal to the expected future spot price", ((12), p. 436). That is, in the framework of Chapter 2, the speculation schedule is perfectly elastic at the expected future spot exchange rate.

Let Φ_t^m be the information set which the market uses to assess the joint distribution of spot exchange rates at time t+1 between curencies i and j, j = 1,......,n. The joint distribution is $f_m(S_{i,1,t+1},\ldots,S_{i,n,t+1} \mid \Phi_t^m)$. This implies a distribution $f_m(S_{i,j,t+1} \mid \Phi_t^m)$ for the spot exchange rate between currencies i and j at t+1 and this distribution has mean or expected value $E(\tilde{S}_{i,j,t}) \mid \Phi_t^m)$. Having assessed the expected spot exchange rate for t+1, based on information avaiable at t, the market sets the price of forward exchange corresponding to maturity at t+1 such that the expected return to forward speculation is zero. That is

$$(4.15) \quad {}_{t+1}F_t = {}_{t+1}E(\tilde{S}_{i,j})_t \Big| \Phi_t^m$$

such that

$$(4.16) \quad E(\tilde{R}_{i,j})_t \Big| \Phi_t^m = {}_{t+1}E(\tilde{S}_{i,j})_t \Big| \Phi_t^m - S_{i,j,t} = 0$$

where $\breve{R}_{i,j}$ is the expected return to forward speculation.

If the market is efficient ($\Phi_t^m = \Phi_t$) and if equilibrium forward exchange rates are determined in this fashion then there should not be a consistent bias in the prediction error of the forward rate. Thus many tests of the speculative efficiency hypothesis compare the forecasting performance (not ability) of the forward rate as compared to alternative forecasting procedures (see Levich (70) and (71)).

A test of the speculative efficiency hypothesis is provided by computing the mean error, the mean absolute error or the mean-squared error of the implicit forecast contained in the forward rate (see for example Giddy and Dufey (44) and Kohlhagen (66)). In general, these tests show that mean errors are typically close to zero and uncorrelated over time. An alternative test is to compare the mean-squared error (M.S.E.) of the forward rate with another forecasting rule such as the lagged value of the spot rate. Agmon and Amihud (3) compared the M.S.E of the forward rate with a no change martingale model using Theil's measure of inequality (see Theil (102)) defined as

$$(4.17) \qquad U = \left[\sum_{t=1}^{n} (D_t - A_t)^2 \Big/ \sum_{t=1}^{n} A_t^2 \right]^{1/2}$$

where $D_t = \ln(F_t / S_t)$

$A_t = \ln(S_{t+i} / S_t)$

They concluded that "the ability of the forward rate to predict the future spot rate is about as good as the naive no change extrapolation" ((3),p.429) for the British Pound, German Mark and Swiss Franc between mid-1973 and mid-1977. Agmon and Amihud also found that the major explanation of the M.S.E. of the forward rate is not to be found in bias but due to the inability of the forward rate to track the future spot rate i.e. the variance of the actual spot rate changes exceeds the variance of the forward rate. This point will be developed further at some length below.

A further test of speculative efficiency is provided by the following regression equation

$$(4.18) \quad S_{t+1} = a + bF_t + u_t, \qquad u_t \sim N(0, \sigma_u^2)$$

The null hypothesis is a joint hypothesis that the market is efficient and that the forward exchange rate is an unbiased predictor of the future spot rate. If the market is efficient and if the model determining forward and spot exchange rates is correctly specified then the forward rate should contain all relevant information concerning the market's expectation of the future spot rate. In terms of equation (4.18) coefficient a should not be significantly different from zero, coefficient b should be insignificant from unity and there should be no serial correlation between the error terms.

Interpretation of equation (4.18) is not simple. Evidence of some bias in the regression equation indicated by $a \neq 0$ may remain consistent with market efficiency if international assets are priced to reflect risk and risk aversion. As outlined earlier tests of market efficiency are in fact joint tests of efficiency and of the process of equilibrium price formation. The joint hypothesis of unbiasedness and efficiency outlined above implies that international asset markets are dominated by risk-neutral investors. Thus only the expected value of the probability distribution of future exchange rates is assumed to determine asset preference. In Modern Portfolio Theory assets are priced to reflect both expected returns and risk. The relevant measure of risk for an individual security is "systematic risk" or the extent to which the returns on the security are determined by movements in the market as a whole. Adler and Dumas (1), Fama and Farber (35), Fratianni and Wakeman (42), Grauer, Litzenberger and Stehle (47) and Roll and Solnik (92) have investigated the implications of the Sharpe-Lintner Capital Asset Pricing Model for the foreign exchange market. The forward rate will in general not be an unbiased predictor of the future spot rate if assets are priced internationally in real terms and investors are averse to purchasing power risk.

Assume that capital markets are perfect and fully integrated and that there exists an indexed bond with constant return in terms of international commodity purchasing power (i.e. a riskless real rate of interest constant across countries). Let the continuosly compounded risk-free rate of return be I_t. Consider an investment in a foreign bond with nominal interest rate R_t^f. Investors must be compensated not only for the expected loss of purchasing power but also for the uncertainty of loss of purchasing power (i.e. the entire distribution of purchasing power changes is relevant). The expected real return on the foreign bond can be written as (see Fratianni and Wakeman (42))

$$(4.19) \qquad E(R_t^f - \pi_t^f) = I_t + \lambda \mathrm{Cov}(R_t^f - \pi_t^f, R_t^m - \pi_t^m)$$

where π_t^f is the foreign inflation rate over the period t to t+1, λ is the price of risk, R_t^m is the nominal yield on the market portfolio of all risky assets and π_t^m is the world inflation rate. By rearranging terms

$$(4.20) \qquad R_t^f = I_t + E(\pi_t^f) + \lambda \mathrm{Cov}(R_t^f - \pi_t^f, R_t^m - \pi_t^m)$$

Thus the Fisher equation for nominal interest rates is revised to reflect uncertainty of purchasing power loss. Next, using equations for both domestic and foreign nominal interest rates and incorporating interest rate parity and expected purchasing power parity (see Chapter 2, p.53) we can derive

$$(4.21) \qquad \ln F_t = E(\ln S_t) + \lambda\Big[\mathrm{Cov}(R_t^f - \pi_t^f, R_t^m - \pi_t^m) - \mathrm{Cov}(R_t^d - \pi_t^d, R_t^m - \pi_t^m)\Big]$$

Since R^f and R^d are known quantities at t we can simplify to

$$(4.22) \qquad \ln F_t = E(\ln S_t) + \lambda\Big[\mathrm{Cov}(R_t^f, \pi_t^m) - \mathrm{Cov}(\pi_t^m, R_t^d) - \mathrm{Cov}(\pi_t^f, R_t^m) - \mathrm{Cov}(\pi_t^d, R_t^m)\Big]$$

Empirical support for the CAPM approach to the pricing of foreign exchange risk is limited. Fratianni and Wakeman (42) estimated the regression equation

$$(4.23) \quad \ln S_t - \ln F_t = \alpha + \lambda^d \operatorname{Cov}(\pi^d_t, \pi^m_t) - \lambda^f \operatorname{Cov}(\pi^f_t, \pi^m_t) + e_t$$

where $\alpha = 0$ and $\lambda^d_t = \lambda^f_t$. They found some support for the hypothesis for Belgium, France and the United Kingdom over the period 1967-1978.

A second difficulty in assessing the joint hypothesis of market efficiency and unbiasedness from regression equation (4.18) has been highlighted by Meltzer and Cuckierman (82). Evidence of serial correlation between the error terms from (4.18) has in the past led to rejection of the speculative efficiency hypothesis on grounds that it would be possible to outperform the forward rate by correcting for the autocorrelation. However, Meltzer and Cuckierman have demonstrated that serial correlation between error terms may be consistent with market efficiency. Assume that the exchange rate S_t is composed of both permanent (S^p_t) and transitory (S^q_t) components,

$$(4.24) \quad S_t = S^p_t + S^q_t, \qquad S^p_t - S^p_{t-1} \sim N(0, \sigma^2_p)$$
$$S^q_t \sim N(0, \sigma^2_q)$$

and that $(S_t^p - S_{t-1}^p)$ and S_t^q are statistically independent.

Individuals can never observe the permanent and transitory components of S_t separately. If permanent changes are small over time relative to transitory changes then a permanent shock, for example a shift in the terms of trade, may not be recognised for several periods although individuals may make the best use of available information. Forecast errors will be serially correlated leading to rejection of the speculative efficiency hypothesis even though it is true. Meltzer and Cuckierman also demonstrate that failure to recognise permanent changes in structure may lead to an attempt to correct for such serial correlation which may bias the estimates of coefficients in the equation.

In the above we have noted two problems which arise with interpretation of equation (4.18). Firstly, rejection of speculative efficiency is often mistakenly taken to imply rejection of EMT because of a failure to recognise the joint hypothesis. Secondly, it is possible through use of equation (4.18) to reject the notion of speculative efficiency even though it is true. In addition to the problems of interpreting the regression results there are several statistical obstacles to estimation.

Firstly, it can be demonstrated that where the sampling interval on spot and forward rates is smaller than the forecast interval implied in the forward exchange rate then the error terms in equation (4.18) will follow a moving average process. Take, for example, the case of weekly observations on the one month forward rate at t and the subsequent spot rate at t+4. It is clear, in an intuitive sense, that information available between t and t+3 which determines the spot rate S_{t+4} will overlap with the information available between t+1 and t+4 which determines the spot rate S_{t+5}. Frankel (36) provides the following formal proof. Let the spot rate be a linear combination of all the information available at t

$$(4.25) \quad S_t = I'\beta$$

where I is the information set containing variables X_i. In addition, assume that information follows a first order autocorrelation

$$(4.26) \quad I_{t+1} = I'\rho + \eta'$$

where ρ is the matrix of autocorrelation coefficients and

η' is new information available between t and t+1. If the observation and forecasting interval is one period then we have

$$(4.27) \quad S_{t+1} = I'_{t+1}\beta = \left[I'\rho + \eta'\right]\beta$$

The speculative efficiency hypothesis can be stated as

$$(4.28) \quad F_t = E(S_{t+1} \mid I)$$
$$= E(I'\rho\beta + \eta'\beta) = I'\rho\beta$$

Under the null hypothesis we have

$$(4.29) \quad S_{t+1} = a + b(I'\rho\beta) + u_t$$

If a = 0, b = 1 this will imply $u = \eta'\beta$ and the error terms will be uncorrelated. Now assume that the observation interval is one period but the forecast implied in the forward rate is for two periods,

$$(4.30) \quad S_{t+2} = I'_{t+2}\beta$$
$$= (I'_{t+1}\rho + \eta'_{t+1})\beta$$
$$= (I'\rho^2 + \eta'\rho + \eta'_{t+1})\beta$$

The speculative efficiency hypothesis implies

$$(4.31) \quad F_t = E(S_{t+2} \mid I) = (I'\rho^2)\beta$$

but if the test of the regression equation passes the null hypothesis a = 0, b = 1 this would imply that $u_{t+2} = \eta'\rho + \eta'_{t+1}$ and the error terms would follow a moving average process. (Note: an alternative proof is provided by Stockman (100)).

The major implication of the moving average error process is that the OLS formula for the sampling variance of b is likely to provide an underestimate of the true variance. This will make rejection of the null hypothesis spuriously easy. Some researchers therefore use non-overlapping data (see for example Frenkel (39) and Levich (70)) but at the expense of losing observations, while others have transformed the data via GLS to retain as many observations as possible. However, Hansen and Hodrick (51) note that the assumption of strict exogeneity of the explanatory variables necessary for GLS does not hold in this case and hence GLS estimators will be inconsistent. They use a modified OLS which corrects for asymptotic bias in the OLS estimates of the covariance matrix of regression coefficients.

Secondly, tests which seek to examine the speculative efficiency hypothesis through estimation of equation (4.18) across markets must take into account the likely joint distribution of error terms. In most studies exchange rates are expressed relative to the U.S. Dollar but shocks emanating from the United States economy might then be expected to affect all of these rates together. OLS will then be an inefficient estimation technique given contemporaneous correlation between the error terms in each equation. MacDonald (78) applied the Zellner technique of "seemingly unrelated regressions" to estimate the regression coefficients of equation (4.18) in "stacked form" for six currencies over the period 1972/Q1 - 1979/Q4.

Thirdly, regressing the level of the spot rate on the level of the forward rate lagged x periods will produce spuriously high R^2 if the exchange rate is dominated by trends (see Granger and Newbold (46) and Theil (102)). We know that spot and forward rates are correlated closely over time but this does not tell us anything about the predictive power of the forward rate. Thus a popular variant of the above test of speculative efficiency is to regress actual spot rate changes on the forward premium (see Frenkel (39), Kaserman (59), Papadia (87) and Frankel (36)). However, the variance of observed changes in the spot rate greatly exceeds the observed variance of the forward premium (see Agmon and Amihud (3)). In these cicumstances the sample variance on estimated coefficients may be very large rendering coefficients insignificant in a statistical sense.

Bearing these problems in mind we turn next to a brief summary of results obtained from studies of the speculative efficiency hypothesis carried out along the lines set out above. The studies refer to a wide spectrum of currencies across different observation periods. Frenkel (39), Kaserman (59), Levich (70) and Cornell (21) find that the evidence supports the joint hypothesis that the market is efficient and that the forward exchange rate is an unbiased estimator of the expected future spot rate. Thus Frenkel concludes that "the behaviour of the foreign exchange market during the 1970s has been broadly consistent with the general implications of the efficient market hypothesis and that the forward exchange rate summarizes the relevant available information concerning the evolution of the rate"

((39), p.10). On the other hand, Fratianni and Wakeman (42), Papadia (87), Frankel (36) and Bilson (12) find evidence of bias in the forward rate and autocorrelated error terms. In addition the use of more sophisticated estimation techniques has also enabled Geweke and Feige (43), Hansen and Hodrick (51) and MacDonald (78) to reject the notion of speculative efficiency. A useful survey and summary of these results can be found in Levich (72).

5. Variance Tests of Speculative Efficiency

In the literature most tests of the speculative efficiency hypothesis have proceeded along the lines of either examining the forecast errors of the forward rate or regressing the spot rate on the past forward rate as in equation (4.18). The latter approach implies a further set of tests based on the relative variance of spot and forward rates. The tests seek to establish whether the forward rate is statistically too volatile relative to the spot rate to be consistent with the null hypothesis of speculative efficiency. Similar tests have been conducted by Shiller (95), Le Roy and Porter (69) and Singleton (96) to produce evidence that long term interest rates and stock prices are too volatile to be consistent with efficient market theory.

From equation (4.18) above, if a = 0, b = 1 and there is no serial correlation between the error terms, then

$$(4.32) \quad \text{Var } S_{t+1} > \text{Var } F_t \text{ , since Var } u_t > 0$$

This provides a necessary but not sufficient condition for speculative efficiency to hold. Thus the variance of the spot rate would exceed the variance of the forward rate if $\text{Cov}(F_t u_t) > 0$ but this would not be consistent with speculative efficiency. An alternative test based on relative variance terms is provided in equation (4.33) below. The coefficients in equation (4.18) and the variance terms in equation (4.32) are sample estimates. Statistical inference requires that the time series of spot and forward exchange rates are stationary. Meese and Singleton (80) and Huang (56) have noted that the time series of spot and forward rates are non-stationary and have indicated that tests of speculative efficiency are more robust if conducted in terms of changes in the spot rate and forward premia or discounts. Thus Huang considered the following variance inequality,

$$(4.33) \quad \text{Var}(S_t - S_{t-1}) > \text{Var}(F_{t-1} - S_{t-1})$$

Using monthly data from March 1973 to January 1979 for nine exchange rate series he concluded that the evidence supported the null hypothesis of speculative efficiency. However, it can easily be demonstrated that a similar result will be obtained if the forward rate stands at a constant premium or discount to the spot rate. Such behaviour would clearly be inconsistent with speculative efficiency.

Let $F_{t-1} = S_{t-1} + k$, where k denotes a constant. Then $Var(F_{t-1} - S_{t-1}) = 0$ and the variance inequality in equation (4.33) is satisfied. Clearly this result would be repeated if the assumption of a constant forward premium or discount is relaxed to allow for small variation of k. This would correspond to the observed behaviour of spot and forward rates noted in Chapter 1 and represented graphically in Figures 1.1-1.6 in that chapter. Hence the cost of adjusting for the non-stationarity of spot and forward rate series as Huang does renders meaningless relative variance tests of the speculative efficiency hypothesis.

Finally, Meese and Singleton (80) have established a further set of variance bounds tests based on equation (4.18). They sought to determine whether departures from speculative efficiency can be explained by the existence of a time-varying risk premium. Equation (4.18) can be re-written as,

$$(4.34) \quad H(t+n) = H^{n}(t) + \varepsilon^{n}(t+n)$$

where $\quad H(t+n) = \dfrac{S_{t+n} - S_t}{S_t}$

and $\quad H^{n}(t) = \dfrac{F_t^{n} - S_t}{S_t}$

and $\varepsilon^{n}(t+n)$ is the forecasting error. The regression tests of the null hypothesis that the ex-ante risk premium is zero are based on the orthogonality of $H^{n}(t)$ and $\varepsilon^{n}(t+n)$. The same assumption can be tested, as above, from the variance inequality

$$(4.35) \quad \text{Var } H(t+n) > \text{Var } H^{n}(t)$$

which is implied from the assumption $\text{Cov}(H^{n}(t), \varepsilon^{n}(t+n)) = 0$ and where $\text{Var } \varepsilon^{n}(t+n)$ is non-negative. Note as before that condition (4.35) might still hold if $\text{Cov}(H^{n}(t), \varepsilon^{n}(t+n))$ was positive so the variance inequality is a necessary but not sufficient condition of the null hypothesis of speculative efficiency.

If the ex-ante risk premium is not identically zero this implies the testable prediction that the ex-ante risk premium has non-zero variance. Let $E\left[\varepsilon^{n}(t+n) \mid \Phi_t\right]$ denote the ex-ante risk premium and define Q(t) as the set of past ex-post risk premia or forecast errors. Consider the linear least squares projection of $\varepsilon^{n}(t+n)$ based on Q(t), $\hat{\varepsilon}(t+n)$. We can write

$$(4.36) \quad \varepsilon^{n}(t+n) = \hat{\varepsilon}^{n}(t) + \Theta^{n}(t+n)$$

where $\Theta^{n}(t+n)$ is uncorrelated with $\hat{\varepsilon}^{n}(t)$. Given that $Cov(\Theta^{n}(t+n), \hat{\varepsilon}^{n}(t)) = 0$ and $Var(\Theta^{n}(t+n)) > 0$, this implies

$$(4.37) \quad Var\,\varepsilon(t+n) > Var\,\hat{\varepsilon}^{n}(t)$$

Moreover, since Q(t) is contained in $\Phi(t)$ we can write

$$(4.38) \quad Var\,(E(\varepsilon^{n}(t+n) \mid \Phi(t))) > Var\,\hat{\varepsilon}^{n}(t) > 0$$

Since the inclusion of more variables in Q(t) cannot decrease the variance of $\hat{\varepsilon}^{n}(t)$, this provides a lower bound for the variance of the ex-ante risk premium. Thus a test of $Var\,\hat{\varepsilon}^{n}(t) > 0$ provides a test of whether the ex-ante risk premium is identically equal to zero. Meese and Singleton (80) reject the null hypothesis that Var $\hat{\varepsilon}^n(t) = 0$ for the German Mark, Canadian Dollar, and Swiss Franc in terms of the U.S. Dollar over 1976-1979.

5. Conclusion

Any study of the joint determination of spot and forward prices of foreign exchange must address two issues. Firstly, what is the process by which exchange rate expectations are formed? Secondly, under what sets of conditions will the forward rate be equal or not equal to the expected future spot rate? In the Modern Theory of forward exchange the equilibrium forward rate results where the demand for forward foreign currency by speculators is equal to the supply of forward foreign currency by interest arbitrageurs. If the elasticities of the speculation and arbitrage schedules are finite then the forward rate will be a weighted average of the interest parity forward rate and the expected future spot rate. The equilibrium forward rate will only represent the market's expectation of the future spot rate if the speculation schedule is infinitely elastic or if the interest parity forward rate is equal to the expected future spot rate.

In Chapter 4 we have introduced the Rational Expectations Hypothesis which asserts that individuals fully utilise available information in seeking to base expectations or forecasts on the true underlying economic structure which gives rise to exchange rate movements. Thus the expected future spot rate is the mathematical expectation derived from the true model generating exchange rate behaviour.

Efficient Market Theory extends the REH to asset markets. Sufficient conditions for market efficiency to hold are firstly that there are no transactions costs, secondly, that all available information is costlessly available to all market participants and, thirdly, that all agree on the implications of current information for the current price and distribution of future prices of each asset. In an efficient market prices should continuously, fully and correctly reflect the information set thus eliminating any profit opportunities over and above equlibrium expected returns.

Weak form tests of EMT have sought to investigate the time series properties of exchange rates to see whether unusual returns may be earned from spotting recurring patterns of price movement. However, early researchers failed to recognise that EMT implies only that prediction errors follow a random walk and not the spot exchange rate. In addition, insufficient attention was paid to the nature and costs of position-taking in the foreign exchange market. Thus no standard was specified for equilibrium expected returns and insufficient allowance was made for the possible existence of risk and risk aversion.

The largest amount of research into EMT in the foreign exchange market has focused on the hypothesis of speculative efficiency. This joint hypothesis states first that expectations are formed rationally and second that the forward rate is equal to the expected future spot rate. Speculators are assumed to be risk neutral. Thus in terms of the MT framework speculative efficiency implies that the speculation schedule is infinitely elastic. Under these conditions the forward rate would be an unbiased predictor of the future spot rate. The principal test of the speculative efficiency hypothesis has taken the form of regressing the spot rate on the implicit forecast contained in the past corresponding forward rate. The results are then examined for evidence of bias or serial correlation in the error terms. However, not only are there many econometric problems associated with this approach which have often been ignored but there are also problems of interpretation which may lead to rejection of the hypothesis when in fact it is true and vice-versa.

Empirical evidence has been inconclusive although more recent work utilising more efficient estimation techniques has tended to reject the joint hypothesis. Of course this need not be inconsistent with EMT since rejection of the joint hypothesis may be due to mis-specification of the model determining exchange rates rather than the assumption of market efficiency. Forward bias may be due to risk aversion and some researchers have suggested the possible existence of a time-varying risk premium.

The above provides prima facie grounds for rejecting the hypothesis of speculative efficiency but also suggests that an alternative approach to testing the hypothesis may prove fruitful. In Chapter 5 the MT model of the forward market is integrated into a general equilibrium model which permits investigation of the dynamic behaviour of spot and forward prices. This will enable us to examine the time path of forward and spot exchange rates under alternative assumptions about risk-averse behaviour in the forward market.

Chapter 5

Dynamic Adjustment of Spot and Forward Exchange Rates

1. Introduction

In Part One (Chapters 2-4) above, we examined the relationship between spot and forward exchange rates within a partial equilibrium setting. In Part Two (Chapters 5 and 6) we consider the dynamic adjustment paths of spot and forward rates within a general equilibrium framework. The starting point in this chapter is a brief discussion of the simple monetary model developed by Dornbusch (25) to demonstrate that spot exchange rates will initially "overshoot" equilibrium following a monetary disturbance. Overshooting implies that, given both covered and uncovered interest rate parity, the variance of the spot rate around the path of the long-run equilibrium exchange rate will exceed the variance of the forward rate. Subsequently, retaining the assumption that domestic interest-bearing assets are perfect substitutes for foreign interest-bearing assets, we consider how changing some of the parameters of the model may alter this result. It is found that a rich variety of adjustment paths for the spot exchange rate can be obtained but that none will alter the basic result that the variance of the spot rate will exceed the variance of the forward rate. Finally, we briefly consider a more general "portfolio balance" framework in which domestic and foreign currency denominated interest-bearing assets are not perfect substitutes. This allows for explicit consideration of risk-averse behaviour in the forward market through relaxation of the uncovered interest parity condition. The Eaton and Turnovsky (see (30)) model, which forms the core of Chapters 6 and 7 below is briefly introduced.

2. The Dornbusch Model

In a seminal paper written in 1976 Dornbusch set out to "develop a theory that is suggestive of the observed large fluctuations in exchange rates while at the same time establishing that such exchange rate movements are consistent with rational expectations formation." ((25), p.1161). Dornbusch demonstrated that if real goods markets adjust slowly relative to asset markets then the exchange rate will initially overshoot its long run equilibrium following a monetary disturbance. The degree of overshooting in the Dornbusch framework is dependent on firstly, the nature of the model and, secondly, the size of coefficients on the structural parameters.

Assume a small country facing a given world interest rate, i^*, and a given foreign currency price of imports, p^*. Residents may hold domestic money and foreign currency denominated interest-bearing securities. Residents are assumed not to hold foreign money and, similarly, domestic money is assumed not to be held by non-residents. Domestic securities are assumed to be perfect substitutes for foreign securities. That is, securities are free of both default and political risk (see Aliber (4)). Capital is assumed to be perfectly mobile and asset markets are in continuous equilibrium. Thus both covered and uncovered interest parity will hold continuously. The uncovered interest parity condition can be written as,

$$(5.1) \qquad i = i^{*} + z$$

where i is the domestic interest rate and z is the expected rate of depreciation of domestic currency or the the expected rate of increase in the domestic price of foreign currency. The existence of both covered and uncovered interest parity implies that z also equals the forward premium or discount. The expected rate of depreciation of the spot rate is assumed to be proportional to the difference between the current and long-run equilibrium exchange rates, s and $\bar{s}$ respectively ($\bar{x}$ denotes the long-run value of variable x and lower case characters denote natural logarithms).

$$(5.2) \qquad z = -\theta(s - \bar{s})$$

The demand by residents for real money balances is assumed to be linear in the log of real income and interest rates. The nominal money stock is fixed exogeneously by the Central Bank. Equilibrium in the money market is given by

$$(5.3) \qquad m - p = -\lambda i + \phi \bar{y}$$

where $\bar{y}$ is the log of (fixed) full employment output and p is the log of the domestic price level.

Domestic output is assumed to be an imperfect substitute for imports and thus aggregate demand will determine both the absolute and the relative price of domestic goods. Demand for domestic output is given by

(5.4) $$d = u + \delta(s + p^* - p) + \gamma\bar{y} - \sigma i$$

where d is the log of real aggregate demand for domestic output and u is a shift parameter capturing the effects of government action and other structural features. In what follows the foreign price level is set at unity such that $p^* = 0$. Finally, the rate of increase in domestic prices is assumed to be proportional to an excess demand measure,

(5.5) $$\dot{p} = \pi(d - \bar{y}) = \pi\left[u + \delta(s - p) + (\gamma - 1)\bar{y} - \sigma i\right]$$

In full long-run equlibrium the price level and the exchange rate are $\bar{p}$ and $\bar{s}$ respectively and $\dot{s} = \dot{p} = 0$ (where for any variable x, $\dot{x} = dx/dt$) and $i = i^*$. From (5.3) we see that

(5.6) $$\bar{p} = m + \lambda i^* - \phi\bar{y}$$

From (5.5), with $\dot{p} = 0$, we have,

(5.7) $$u + \delta(\bar{s} - \bar{p}) + (\gamma - 1)\bar{y} - \sigma i^* = 0$$

Substituting (5.6) into (5.7) yields

(5.8) $$\bar{s} = m + \left[\frac{1-\gamma}{\delta} - \phi\right]\bar{y} + \left(\lambda + \frac{\sigma}{\delta}\right) - \frac{u}{\delta}$$

Equations (5.6) and (5.8) reveal the long-run neutrality of money, such that, $d\bar{p} = d\bar{s} = d\bar{m}$.

Since

(5.9) $$i = \frac{p - m}{\lambda} + \frac{\phi}{\lambda}\bar{y}$$

and

(5.10) $$i^* = \frac{\bar{p} - m}{\lambda} + \frac{\phi \bar{y}}{\lambda}$$

then, from $i = i^* + z = i^* - \theta(s - \bar{s})$, we have

(5.11) $$(s - \bar{s}) = \frac{-(i - i^*)}{\theta} = \frac{-(p - \bar{p})}{\lambda\theta}$$

Subtracting (5.7) and (5.5) and substituting $(i - i^*) = \theta(s - \bar{s})$ gives

(5.12) $$\dot{p} = \pi\delta(s - \bar{s}) - \pi(\delta + \frac{\sigma}{\lambda})(p - \bar{p})$$

Then, by substituting (5.11),

(5.13) $$\dot{p} = -v(p - \bar{p}), \quad \text{where } v = \pi\left\{\left[(\delta + \sigma\theta)/\theta\lambda\right] + \delta\right\}$$

This has solution

(5.14) $$p_t = \bar{p} + (p_o - \bar{p}) \exp^{-vt}$$

whence we can sustitute back into (5.11) to give the path of the exchange rate,

(5.15) $$s_t = \bar{s} - (1/\lambda\theta)(p_o - \bar{p}) \exp^{-vt}$$
$$= \bar{s} + (s_o - \bar{s}) \exp^{-vt}$$

Bhandari (10) demonstrates that the expectations structure chosen by Dornbusch is consistent with the perfect foresight solution along the stable arm of the saddle-point path implied in the model. The speed of adjustment in the exchange rate is given by v. Perfect foresight implies, from (5.2)

(5.16) $$v = \theta = \pi \left[\delta + \sigma\theta/\theta\lambda + \delta\right]$$

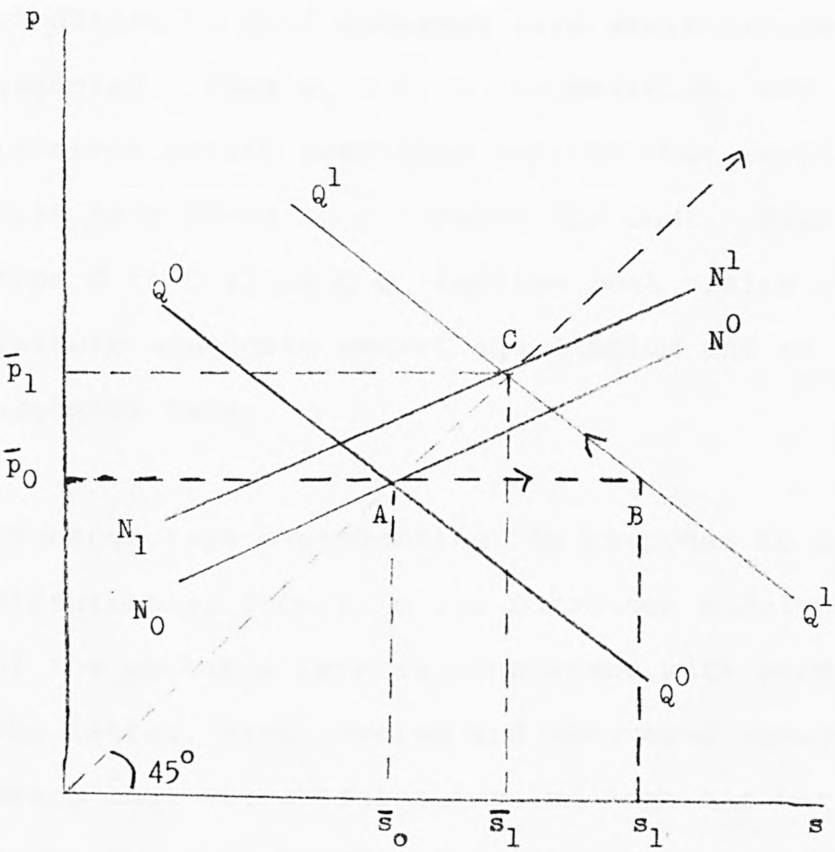
The positive and therefore stable root of the solution to $\theta = v$ is a function of the structural parameters of the model,

(5.17) $$\theta(\lambda,\delta,\sigma,\pi) = \pi(\sigma/\lambda + \delta)/2 + \left[\pi^2(\sigma/\lambda + \delta)^2/4 + \pi\delta/\lambda\right]^{1/2}$$

The Dornbusch model can be presented in diagrammatic form to facilitate analysis. In Figure 5.1 the QQ schedule represents asset market equilibrium given by (5.11). That is, if $s > \bar{s}$, $p < \bar{p}$. Continuous asset market equilibrium implies a combination of exchange rate and price level which always lies on the QQ schedule. The NN schedule represents combinations of s and p which give $\dot{p} = 0$ consistent with commodity market equilibrium. The curve has upward slope since a higher s (exchange rate depreciation) will create excess demand for commodities by lowering their relative price. Domestic prices must rise to restore equilibrium, though proportionately less than the increase in s since aggregate demand will also be reduced via the impact on interest rates. Prices are rising to the right of the $\dot{p} = 0$ schedule and vice-versa.

The economy is in equilibrium at A with $\bar{s}_o = \bar{p}_o = \bar{m}_o$. Consider an increase in the money stock from $\bar{m}_o$ to $\bar{m}_1$. Given the homogeneity condition $d\bar{s} = d\bar{p} = d\bar{m}$ and there is a parallel shift of the QQ schedule from Q^oQ^o to Q^1Q^1. The exchange rate adjusts instantaneously to clear the asset market at the original price level and moves to B on Q^1Q^1.

Figure 5.1 Exchange Rate Adjustment



The exchange rate overshoots the final long-run equilibrium. The increase in the money stock requires a fall in domestic interest rates to restore equilibrium in the money market. For the uncovered interest parity condition to hold exchange rate appreciation must be expected. Thus $s_{i} > \bar{s}_{i}$. In addition, the covered interest parity condition implies that foreign currency must have moved to a forward discount. Final adjustment from B to C along $Q'Q'$ implies both rising prices to restore commodity market equilibrium and an appreciating exchange rate.

Exchange rate overshooting, in response to a monetary disturbance, occurs in the Dornbusch model even if the path of the exchange rate is consistent with perfect foresight. The latter, with covered and uncovered interest parity, means that overshooting implies that the variance of the spot rate will exceed the variance of the forward rate. The degree of overshooting and hence the size of the relative variance term is greater the lower the interest elasticity of the demand for money. Adjustment to steady-state long-run equilibrium will be quicker the lower is the interest elasticity of money demand and the greater the response of commodity demand to a change in the relative price of domestic output. The overshooting result will also hold in the Dornbusch framework as a result of anticipated disturbances (see Wilson (105) and Gray and Turnovsky (48)).

3. Refinements

Exchange rate overshooting in the Dornbusch model appears to follow from the assumption that real goods markets adjust slowly relative to asset markets. Subsequent research has focussed on the restrictive nature of the model to investigate the extent to which relaxing this and other assumptions may alter that result. Recall that the central assumptions made in the Dornbusch model are firstly, that output is fixed at the full employment level, secondly, that price adjustment in the commodity market is sluggish, thirdly, that asset market adjustment is instantaneous, fourthly, that capital is perfectly mobile and, fifthly, that domestic securities are regarded as perfect substitutes for foreign securities. Bhandari (10) has compiled a comprehensive survey of the exchange rate dynamics literature which has evolved through investigation of the impact of relaxing these assumptions.

(a) Output Adjustment

In Section 2 it was assumed that output is fixed at the full employment level $\bar{y}$. Dornbusch considered the impact of relaxing this assumption and allowing output to be demand determined in the short run. Equation (5.4) is replaced by,

$$y = d = u + \delta(s - p) + \gamma y - \sigma i \tag{5.18}$$

and price adjustment is proportional to the difference between actual and potential or full employment output

$$\dot{p} = \pi(y - \bar{y}) \tag{5.19}$$

The impact effect of monetary expansion on the exchange rate might now be dampened if a short run output response raises the demand for money and mitigates the fall in interest rates. Dornbusch notes the possibility that the output effect may be strong enough to produce a rise in interest rates. Since the uncovered parity condition would then predict expected future depreciation of the exchange rate this would imply initial undershooting of long run equilibrium. However, this would require a very powerful impact of a change in the exchange rate on the demand for domestic output. Hence the exchange rate would be seen as a key variable in the monetary transmission mechanism.

(b) Asset Market Adjustment

One of the key assumptions of the Dornbusch model is that asset markets are in continuous equilibrium whereas commodity markets are assumed to adjust only slowly over time. Niehans (85) investigated the impact of relaxing the assumption of continuous asset stock equilibrium. This introduced interaction between stock equilibrium and flow variables such as the trade balance. Niehans demonstrated that initial undershooting of long run equilibrium would follow a monetary disturbance if asset holdings are assumed to adjust only slowly to desired holdings.

An increase in the money stock in this framework is followed by instantaneous depreciation of the exchange rate which leads to a trade surplus and accumulation of foreign balances. However, individuals are assumed to only build foreign asset holdings if the exchange rate is expected to depreciate. Thus, given the long-run neutrality of money, the initial change in the exchange rate must undershoot full long run equilibrium. Moreover, since in full equilibrium holdings of foreign assets (money) are invariant to changes in the domestic money stock, it follows that periods of asset accumulation must be followed by periods of running down foreign balances. This implies a whole range of adjustment paths for the real exchange rate consistent with periods of trade surplus and deficit. However, the implied condition that the variance of the spot rate exceeds the variance of the forward rate (since perfect foresight is assumed and covered and uncovered interest parity hold at all times) remains unchanged from the simple Dornbusch framework.

(c) Flexible Commodity Prices

In (a) and (b) above, the assumption of "sticky-price" adjustment in the commodity market has remained central to the analysis. Bhandari (9) investigated the impact on exchange rate adjustment of assuming continuous commodity market equilibrium while introducing the empirical observation that the short run response of trade flows to a change in the real exchange rate is less than the long run impact. This produced the result that the dynamics of exchange rate adjustment in the Bhandari model reflect the adjustment of the trade balance and aggregate demand.

Bhandari retained the assumptions of a small open economy facing a given world interest rate and a fixed price of importables in foreign currency terms. Domestic output is seen as an imperfect substitute for imports. Residents may hold both domestic and foreign interest bearing securities in addition to domestic money. Thus the model is essentially that of Dornbusch in equations (5.1) to (5.4) above. However, the assumption of continuous domestic price flexibility dispenses with equation (5.5) and ensures that output is fixed at the full employment level. Finally, aggregate demand for domestic output is composed of private absorption, government expenditure and the real trade balance. The latter is assumed to adjust only sluggishly to a change in the terms of trade.

In the Bhandari model the exchange rate and the price level jump instantaneously to maintain continuous equilibrium in the commodity and money markets following a monetary disturbance. This follows intuitively from the assumption that both prices and exchange rates are fully flexible. In full long run equilibrium the model remains homogeneous of degree one to monetary shocks. However, in the short term there is no overshooting, as in the Dornbusch model, following a monetary disturbance, since the sticky price assumption, and hence the source of money illusion in the model, has been removed. Interestingly, Bhandari demonstrates that overshooting will follow a real expenditure disturbance within this framework.

Consider an increase in government spending, for example, which is financed by the sale of bonds to the non-bank private sector (i.e. which is not accomodated by monetary expansion). The long-run stationary state result gives us, with fixed full employment output, a decline in the trade balance which must be associated with an appreciation of the real exchange rate. Fiscal expansion tends to raise the price level which, in turn, lowers real money balances. An increase in nominal interest rates restores money market equilibrium and, via the uncovered interest parity condition, is consistent with expected future depreciation of the currency. In the long run, the stance of fiscal policy does not have an impact on the price level and both the nominal and hence the real exchange rate must have appreciated. The key result is that the Bhandari model, which implicitly assumes both covered and uncovered interest rate parity, will predict that, in the face of a fiscal disturbance, the variance of the spot rate will exceed the variance of the forward rate.

(d) Wealth

Driskill (27) introduced wealth effects into the Dornbusch framework while retaining the assumptions of continuous portfolio equilibrium and sticky price adjustment in the goods market. The latter results from the adjustment of actual wealth to its long run desired level, with the speed of adjustment being a key variable in the the dynamic behaviour of both the exchange rate and the price level. Residents are assumed to hold domestic money and foreign currency denominated interest-bearing bonds. The domestic interest rate is equal to the foreign interest rate plus the expected rate of depreciation of the exchange rate. Thus Driskill also retains the assumption of perfect capital mobility. The exchange rate is simultaneously determined by stock equilibrium for portfolio balance and flow equilibrium relating the trade balance and change in the stock of foreign assets to the real terms of trade. The inclusion of wealth in the money demand equation leads to the result that exchange rate undershooting may follow a monetary disturbance. Intuitively, an increase in the domestic money stock which leads to exchange rate depreciation via portfolio adjustment will raise the domestic currency value of foreign asset holdings and hence real wealth. This will automatically raise the demand for money and help to restore equilibrium to the money market. Depending on the degree of homogeneity on wealth in the money demand function it is possible that interest rates will rise following an increase in the money stock. Recalling the perfect capital mobility condition this would imply expected future depreciation of the currency. Hence the exchange rate would initially undershoot its full long run equilibrium value.

4. Portfolio Balance and the Forward Market

In the above we have seen that, in contrast to the overshooting observed in the Dornbusch framework, a rich variety of adjustment paths for the spot exchange rate around long run equilibrium can be observed by relaxing assumptions about sticky output and prices and about the speed of adjustment in asset markets. In this section we briefly consider the impact of relaxing the assumptions that domestic and foreign currency denominated interest-bearing assets are perfect substitutes. A portfolio balance approach to exchange rate determination allows for explicit consideration of forward market behaviour. Perfect capital mobility is assumed to ensure that covered interest parity will hold at all times. However, exchange risk (rather than default or political risk) and risk-aversion imply that the interest differential need not equal the expected rate of depreciation. Thus the forward rate need not equal the expected future spot rate. This may remain consistent with rational expectations but is not consistent with speculative efficiency in the forward market. In addition, overshooting or undershooting of the spot rate need no longer necessarily imply that the variance of the spot rate exceeds the variance of the forward rate once we allow for risk aversion.

Eaton and Turnovsky (30) introduced the forward market in a portfolio balance framework. The full details of the model are not reproduced here since a version will be set out in Chapters 6 and 7 below. Covered interest parity was assumed to hold at all times such that domestic bonds are perfect substitutes in asset portfolios for foreign bonds held on a covered basis. However, exchange risk prevents the uncovered parity condition from holding. Eaton and Turnovsky demonstrate that exchange rate undershooting may result from a monetary shock (to retain the long run money neutrality evident in Dornbusch and others Eaton and Turnovsky assume that an increase in the money supply is accompanied by a proportionate increase in the domestic bond supply).

Undershooting in the Eaton and Turnovsky model may be explained in these terms. An increase in the supplies of money and domestic bonds will lead to an instantaneous fall in the domestic interest rate (assuming the wealth effect in the demand for money function is less than unity). This requires a widening of the forward premium (depreciation of the forward rate relative to the spot rate) to maintain covered interest parity. If uncovered interest parity holds then the forward rate equals the expected future spot rate and full equilibrium requires continuous appreciation of the currency. Thus there may be initial overshooting of long run equilibrium. However, if an increase in the forward rate raises the domestic value of covered bonds this increases the supply of forward foreign exchange by arbitrageurs. The increase in the forward rate required for forward market equilibrium may then be greater than the increase in the forward rate required for money market equilibrium via the covered interest parity condition. It is possible that full equilibrium will result consistent with continuous expected depreciation of the currency i.e. initial undershooting.

The implications for relative variance of spot and forward rates is unclear however. Since uncovered interest parity is no longer assumed to hold the interest rate differential will only reflect the risk-adjusted view of expected depreciation. Moreover, the risk premium need not be constant over time. It follows that in the Eaton and Turnovsky model the variance of the spot exchange rate need not necessarily exceed the variance of the forward rate, when both are measured relative to the long run equilibrium exchange rate. The relative variance term will depend firstly, on the parameters of the model and, secondly, on the behaviour of the forward market. In Chapters 6 and 7 below we examine the relative variance term under alternative assumptions about the relative role of speculation and arbitrage activity in the forward market and examine the impact on these results of changes in other key structural parameters of the model.

5. Conclusion

In this chapter we have considered exchange rate adjustment within a general equilibrium framework. It has been demonstrated that, following a monetary disturbance, a rich variety of adjustment paths to long-run equilibrium can be obtained depending on the assumptions underlying the model. If covered and uncovered interest parity are assumed to hold at all times then the implication of the dynamic adjustment path of the spot rate is that the variance of the spot rate will exceed the variance of the forward rate. The ratio of the variance terms will increase with the degree of either overshooting or undershooting. A portfolio balance approach allows explicit consideration of forward market behaviour since exchange rate risk and risk-aversion assumes that domestic and foreign currency denominated interest-bearing assets will not be perfect substitutes. This means that, although perfect capital mobility and the absence of default risk will ensure covered interest parity, the assumption that uncovered interest parity must hold at all times is relaxed. The variance of the spot rate, measured relative to long run equilibrium, then need no longer exceed the variance of the forward rate. Eaton and Turnovsky introduced the forward market within a portfolio balance framework. This permits investigation of the impact of forward market behaviour and other structural parameters of the model on the relative variance term.

Chapter 6.

Exchange Rate Dynamics and Market Efficiency:

The Model

1. Introduction

The original contribution of this study is to provide a framework for investigating the speculative efficiency hypothesis within a general equilibrium model. Building on the above, in this chapter we examine the dynamic adjustment paths of spot and forward exchange rates employing a simple portfolio balance model in the tradition of, for example, Branson (15), Branson, Haltunnen and Masson (16), Driskill (28), Eaton and Turnovsky (30), Kenen and Allen (60) and Kouri (64). The forward market is introduced, using the MT framework of Chapter 2. The short and long run properties of the model are examined following an increase in the supplies of money and domestic bonds. General expressions are derived for the variances of spot and forward exchange rates. Later, in the next chapter, plausible estimates of coefficients will be introduced to investigate the impact of alternative assumptions about the role of speculation within the forward market on the time paths of spot and forward exchange rates.

2. The Model

Consider a small open economy facing a given world interest rate and price level. Residents are assumed to hold nominal wealth in the form of one-period domestic or foreign government bonds, free from default risk, and domestic non-interest bearing money. Residents and non-residents do not hold monies denominated in other than own currency. Assets stocks are predetermined at any moment. The supplies of domestic bonds and money are altered via the budget deficit and government funding policy, while holdings of foreign assets reflect changes in the current account of the balance of payments. Domestic and foreign bonds are assumed to be imperfect substitutes. The supply of domestic goods and services is fixed at the full employment (the natural rate of unemployment) level. Prices are assumed to respond sluggishly to excess demand. A forward market for foreign exchange is introduced in the general form proposed by Stein (99). Finally, where an expectations formation process must be defined we assume perfect foresight.

Some of the assumptions made above, particularly the last, are recognised to be highly restrictive but this facilitates comparison with other work in the area and the model can easily be generalised later. Although emphasis is placed on adjustment to a monetary disturbance, the same lines of analysis can be pursued to examine the dynamics of adjustment following a change in the stance of fiscal policy.

The real demands for money and bonds are homogeneous of first degree in real wealth. This allows us to express the nominal demands for each asset as a proportion of nominal wealth. Nominal wealth is approximated around equilibrium by a Cobb-Douglas function (see Driskill (28)). Thus

$$(6.1) \qquad w = \mu_1 m + \mu_2 b + (1 - \mu_1 - \mu_2)(s + b^*)$$

where w is the log of nominal wealth, m is the log of the domestic money stock, b is the log of the stock of domestic bonds, b^* is the log of the stock of foreign currency denominated bonds and s is the log of the spot exchange rate (the domestic currency price of one unit of foreign exchange). μ_1 is the share of money in domestic wealth and μ_2 is the share of domestic bonds. (Hence $(1 - \mu_1 - \mu_2)$ is the share of foreign bonds.

Money holdings as a proportion of nominal wealth can be expressed as

$$(6.2) \qquad m - w = \alpha_1 y - \alpha_2 r - \alpha_3 r^* - \alpha_4 E(\dot{s}) - \alpha_5 f$$

where y is the log of real (fixed) output, r is the domestic interest rate, r^* is the given foreign currency interest rate and f is the instantaneous forward premium, such that f = ln(1 + (F - S)/S). E is the expectations operator and the time derivative of any variable x, dx/dt, is expressed as $\dot{x}$.

The demand for foreign bonds as a proportion of nominal wealth is given by

$$(6.3) \qquad s + b^* - w = \beta_1 (r^* - r + E(\dot{s})) + \beta_2 (r^* - r + f) - \beta_3 y$$

Foreign bonds held on a covered basis are related positively to deviations from covered interest parity, while uncovered holdings are a positive function of the difference between expected exchange rate depreciation and the interest margin between domestic and foreign assets.

A fourth equation, implied by equations (6.1)-(6.3) relates holdings of domestic bonds to nominal wealth but is clearly redundant for any given level of wealth and is not shown here. Supplies of domestic assets are determined by the government's budget constraint and funding policy. The supply of domestic bonds and the domestic money stock are thus taken as exogeneous.

The log of real aggregate demand for domestic output, d, is given by

$$(6.4) \qquad d = \gamma_1 y - \gamma_2 (r - E(\dot{p})) + \delta (s - p + p^*)$$

where p is the log of the domestic price level, $E(\dot{p})$ is the expected rate of inflation, p^* is the log of the foreign price level and $(s-p+p^*)$ is the real exchange rate. It is assumed that units are set for convenience such that the given foreign price level is equal to unity and $p^* = 0$.

The adjustment of domestic prices is given by an excess demand measure

$$(6.5) \qquad \dot{p} = \pi (d - y)$$

Prices are assumed to respond only sluggishly to excess demand and instantaneous jumps in the domestic price level are not admitted.

Forward market equilibrium is achieved when the supply of forward foreign currency by interest arbitrageurs is equal to the demand for forward foreign currency by speculators. This is the forward market of the MT framework set out in equations (2.11)-(2.13) in Chapter 2 above. Equilibrium can be expressed as

$$(6.6) \qquad \beta_2 (r^* - r + f) = \sigma (E(\dot{s}) - f)$$

where the arbitrage supply of forward foreign currency is given by holdings of foreign bonds on a covered basis in equation (6.3).

Finally, following Eaton and Turnovsky (30), since the supplies of money and domestic bonds are given at all times except for one instant, asset accumulation or saving must take the form of increased holdings of foreign bonds. The real change in foreign bond holdings, expressed in domestic currency units, is the difference between total real saving and changes in holdings of money and domestic bonds, m and b, where $\dot{m}, \dot{b} = 0$. Real saving is a function of real income and the difference between actual and desired long run real wealth. The latter is taken to depend on real income only and the impact of changes in the real rate of interest is ignored. Thus

$$(6.7) \qquad s + \dot{b}^{*} - p = -\phi_1 (w - p) + \phi_2 y$$

The structure of the model rests on several limiting assumptions and omissions. Firstly, there is no supply function for real output. Secondly, sticky price adjustment in the real goods market is imposed by assumption and is not endogeneous to the model. Thirdly, the treatment of real savings behaviour is highly simplistic. Finally, explicit treatment of expectations formation is necessary. In what follows we assume perfect foresight, such that $E(\dot{s}) = \dot{s}$ and $E(\dot{p}) = \dot{p}$. The limitations of the model are well recognised but as a first step it extends earlier work in the same field and can easily be made more general later.

3. Solution

Equations (6.1)-(6.7) can be solved via substitution to yield simultaneous differential equations in p, s and b^*. Solving these, it is then possible to examine the dynamic adjustment paths of spot and forward exchange rates following any disturbance to the model. First, for convenience, let each variable be expressed in terms of deviation from initial steady state i.e. $x = \ln x - \ln x_o$. Thus x is the percentage deviation from its initial steady state value. Note that in what follows this implies that $r^* = y = 0$. Full workings for this section are contained in the Appendix to this chapter.

The differential equations can be shown to take the form

$$(6.8) \qquad \begin{bmatrix} \dot{s} \\ \dot{p} \\ \dot{b}^* \end{bmatrix} = \begin{bmatrix} a_1 & 0 & a_3 \\ c_1 & c_2 & c_3 \\ g_1 & g_2 & g_3 \end{bmatrix} \begin{bmatrix} s \\ p \\ b^* \end{bmatrix} + \begin{bmatrix} a_0 \\ c_0 \\ g_0 \end{bmatrix}$$

It is useful to consider the signs of these coefficients since this will have an important bearing on the later findings reported below. The following relationships can be readily ascertained from 6.12A, 6.15A and 6.16A in the appendix to this chapter on p.145 below -

(6.9) $a_1 = a_3$; $a_1, a_3 > 0$ (from 6.12A)

$c_3 - c_1 = c_2$; $c_2 < 0$ if $\pi\gamma_2 < 1$, (from 6.15A)

$g_3 - g_1 = 1$; $g_1, g_3 < 0$; $g_2 > 0$ (from 6.16A)

Finally, note from 6.15A that the denominator of c_3 is almost certainly positive. The numerator can be simplified to $\pi\gamma_2(\alpha_2 + \alpha_5)[\alpha_4(1-\mu_3) - \mu_3\beta_1]$. Referring back to the original model, c_3 is almost certainly positive. Since the numerator of c_1 is equal to the numerator of c_3 plus $GK\pi\delta$, c_1 is also likely to be positive.

Solutions to the model can be found by recalling that the model is written in terms of deviation from initial steady state. It will be demonstrated below that if the supplies of domestic bonds and money are raised by $\bar{m}$% then, in the new steady state, as $t \to \infty$, $\bar{s} = \bar{p} = \bar{m}$. Thus the solution to (6.8) is given by

(6.10)
$$s(t) = \bar{m} + A_1 e^{\lambda_1 t} + A_2 e^{\lambda_2 t} + A_3 e^{\lambda_3 t}$$
$$p(t) = \bar{m} + B_1 e^{\lambda_1 t} + B_2 e^{\lambda_2 t} + B_3 e^{\lambda_3 t}$$
$$b^*(t) = C_1 e^{\lambda_1 t} + C_2 e^{\lambda_2 t} + C_3 e^{\lambda_3 t}$$

Where λ_i are solutions to the characteristic equation of (6.8) and A_i, B_i, C_i are arbitrary constants.

However, these are not unrelated. Specifically given A_1, A_2, A_3, then B_i, C_i are determined by the relationships

$$(6.11)\qquad \begin{bmatrix} B_i \\ C_i \end{bmatrix} = \begin{bmatrix} 0 & a_3 \\ g_2 & (g_3 - \lambda_i) \end{bmatrix}^{-1} \begin{bmatrix} \lambda_i - a_1 \\ -g_1 \end{bmatrix} A_i \qquad i = 1,2,3$$

The characteristic equation of (6.8) is

$$(6.12)\qquad \begin{vmatrix} (a_1 - \lambda) & 0 & a_3 \\ c_1 & (c_2 - \lambda) & c_3 \\ g_1 & g_2 & (g_3 - \lambda) \end{vmatrix} = 0$$

$$\Rightarrow (a_1 - \lambda)\left[c_2 g_3 - c_2\lambda - \lambda g_3 + \lambda^2 - c_3 g_2\right] + a_3\left[c_1 g_2 - g_1 c_2 + g_1\lambda\right] = 0$$

$$\Rightarrow \lambda^3 - (a_1 + c_2 + g_3)\lambda^2 - (a_3 g_1 + c_3 g_2 - c_2 g_3 - a_1 g_3 - a_1 c_2)\lambda$$
$$- (a_1 c_2 g_3 - a_1 c_3 g_2 + a_3 c_1 g_2 - a_3 g_1 c_2) = 0$$

Note that expanding the roots of the characteristic equation we obtain

$$(6.13)\qquad (\lambda - \lambda_1)(\lambda - \lambda_2)(\lambda - \lambda_3) = 0$$

$$\Rightarrow \lambda^3 - (\lambda_2 + \lambda_3 + \lambda_1)\lambda^2 + (\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_1\lambda_2)\lambda - \lambda_1\lambda_2\lambda_3 = 0$$

It can be shown, using (6.9) above, from the signs of a_3, c_2, g_2 that the constant term in the characteristic equation is negative. Thus the product of the roots must be greater than zero, implying either that all three roots are positive or that two of the roots are negative. The coefficient on λ in (6.12) can be simplified to

$$(6.14)\qquad -((-a_3 + c_3 g_2 - c_2(a_3 + g_3))$$

Since $|c_3| > |c_2|$ and $|g_2| > |g_3|$, if $|c_2| > 1$ then this term is definitely negative, implying that the sum of cross products of the roots is negative. This in turn would indicate the presence of at least one negative root. Given that the product of the roots is greater than zero this implies the presence of only one unstable root (see Chiang (20), pp. 510-528).

The solution to the model, set out in (6.10), will be used below to examine the dynamic adjustment paths of spot rates and forward rates following an increase in the supply of nominal domestic assets. In the next section we investigate the long-run properties of the model.

4. Long Run Comparative Statics

In full equilibrium all stocks are at their desired levels and $\dot{s} = \dot{p} = \dot{b}^* = 0$. It can be demonstrated that the nominal exchange rate and the domestic price level will vary equi-proportionately with changes in domestic nominal asset supplies. That is, if the supply of money and domestic bonds is increased by $\bar{m}$% then the exchange rate and the domestic price level will also rise by $\bar{m}$% in the long run (recall that the exchange rate is the domestic currency price of one unit of foreign exchange and thus an increase in the exchange rate represents depreciation of the home currency). Using the above notation, with variables expressed in deviations from initial steady state, s and p converge to $\bar{m}$. Holdings of foreign bonds are therefore left unchanged.

From equation (6.12A), setting $\mathring{s} = 0$, subtracting $[K(1-\mu_3) + A\mu_3]/G.s$ from both sides and dividing by the coefficient on s gives

$$(6.15) \qquad s = -b^* + \frac{A(1-\mu_1)+K\mu_1}{K(1-\mu_3)+A\mu_3} . m + \frac{(K-A)\mu_2}{K(1-\mu_3)+A\mu_3} . b$$

From this it can be verified that ds/dm + ds/db = 1.

Next, from equation (6.15A), setting $\mathring{p} = 0$, adding $\pi\delta/(1-\pi\gamma_2).p$ to both sides and dividing by the coefficient on p,

$$(6.16) \qquad p = \left\{\frac{\pi\gamma_2 H[K(1-\mu_3)+A\mu_3] + [K\pi\delta - \pi\gamma_2(1+\tau)\mu_3]G}{GK\pi\delta}\right\}. s$$

$$+ \left\{\frac{\pi\gamma_2 H(K(1-\mu_3)+A\mu_3) - [\pi\gamma_2(1+\tau)\mu_3].G}{GK\pi\delta}\right\}. b^*$$

$$+ \left\{\frac{\pi\gamma_2 G(1+\tau)(1-\mu_1) - \pi\gamma_2 H[A(1-\mu_1)+K\mu_1]}{GK\pi\delta}\right\}. m$$

$$- \left\{\frac{\pi\gamma_2 H(K-A)\mu_2 + \pi\gamma_2(1+\tau)\mu_2 G}{GK\pi\delta}\right\}. b$$

The total differential is

(6.17) $$dp = \frac{\partial p}{\partial s} ds + \frac{\partial p}{\partial m} . dm + \frac{\partial p}{\partial b} . db + \frac{\partial p}{\partial b^*} . db^*$$

and thus, $$\frac{dp}{dm + db} = \frac{\partial p}{\partial s} + \frac{\partial p}{\partial m} + \frac{\partial p}{\partial b} = 1$$

Finally, from equation (6.16A), setting $\dot{b}^* = 0$

(6.18) $$b^* = -\frac{(1+\phi_1\mu_3)s}{\phi_1\mu_3} + \frac{(1+\phi_1)p}{\phi_1\mu_3} - \frac{\phi_1\mu_1 m}{\phi_1\mu_3} - \frac{\phi_1\mu_2 b}{\phi_1\mu_3}$$

Hence $$db^* = \frac{\partial b^*}{\partial s} ds + \frac{\partial b^*}{\partial p} dp + \frac{\partial b^*}{\partial m} dm + \frac{\partial b^*}{\partial b} db$$

Thus $$\frac{db^*}{dm + db} = \frac{\partial b^*}{\partial s} + \frac{\partial b^*}{\partial b} + \frac{\partial b^*}{\partial p} + \frac{\partial b^*}{\partial m}$$

$$= \frac{-1 - \phi_1\mu_3 + 1 + \phi_1 - \phi_1\mu_1 - \phi_1\mu_2}{\phi_1\mu_3}$$

$$= 0$$

The long run neutrality of changes in nominal domestic asset supplies which we have demonstrated is a standard feature of such portfolio balance models.

5. Dynamic Adjustment

In this section we examine the dynamic adjustment paths of spot and forward exchange rates following an increase in domestic nominal asset supplies which generates proportional changes in the steady state domestic price level and the exchange rate, leaving the steady state domestic interest rate and holdings of foreign bonds unchanged. Expressions are derived for the variances of both spot and forward rates around their long run equilibrium levels.

From (6.10), convergence to long run equilibrium requires that the coefficient of the unstable root equal zero. Thus $A_3 = 0$ and, via equation (6.11), $B_3 = C_3 = 0$. Recall that discontinuous jumps in the price level are not permitted. This implies the initial condition, from (6.10), $p(0) = 0$ such that $B_1 + B_2 = -m$. Finally, foreign bond holdings can only be adjusted continuously over time, implying an additional constraint, $b^*(0) = 0$ or $C_1 + C_2 = 0$. These initial conditions, with equations (6.11), allow us to solve for the six coefficients of the stable roots of the system.

Following the increase in nominal asset supplies the exchange rate immediately jumps to

$$(6.19) \qquad s_0^+ = A_1 + A_2 + \bar{m}$$

That is, overshooting or undershooting of long run equilibrium depends on whether $A_1 + A_2 \lessgtr 0$.

It can be shown that (see Appendix to this chapter for full details)

(6.20) $$A_1 + A_2 = \frac{a_3 g_2 (\lambda_2 - \lambda_1)}{(\lambda_2-\lambda_1)(\lambda_2-a_1)(\lambda_1-a_1) + (\lambda_2-\lambda_1)a_3 g_1} \cdot \bar{m}$$

$$= \frac{a_3 g_2}{(\lambda_2-a_1)(\lambda_1-a_1) + a_3 g_1} \bar{m}$$

The numerator of the coefficient on $\bar{m}$ is positive. A necessary and sufficient condition for overshooting is therefore given by

(6.21) $$(\lambda_2 - a_1)(\lambda_1 - a_1) > -a_3 g_1$$
$$\Rightarrow \lambda_1\lambda_2 - a_1(\lambda_1 + \lambda_2) + a_1^2 > -a_3 g_1$$
$$\Rightarrow \lambda_1\lambda_2 - a_1(\lambda_1 + \lambda_2) > -a_3 g_1 - a_1^2$$

Thus a sufficient condition for overshooting is

(6.22) $$a_1^2 > -a_3 g_1$$

Since $a_1 = a_3$, this reduces to $a_1 > -g_1$

Recall that

(6.23) $$g_1 = -(i + \Phi_1 \mu_3)$$

and

(6.24) $$a_1 = \frac{K(1-\mu_3) + A\mu_3}{G}$$

The sufficient condition for overshooting can then be expressed fully as

$$(6.25) \qquad \frac{K(1-\mu_3) + A\mu_3}{G} > (1 + \Phi_1 \mu_3)$$

In Chapter 5 above, a number of conditions were examined under which overshooting will occur. It was found that the overshooting hypothesis contained in the simple model put forward by Dornbusch (25) rested on the restrictive assumptions implicit in the framework of the model. Briefly, these assumptions were firstly, that output is fixed at the full employment level, secondly, that price adjustment in the commodity market is sluggish, thirdly, that asset market adjustment is instantaneous, fourthly, that capital is perfectly mobile and, fifthly, that domestic securities are regarded as perfect substitutes for foreign securities. Relaxing these assumptions produced a variety of adjustment paths for the spot exchange rate. In Chapter 7 below we will examine the impact of changing some of these assumptions within the framework set out above in simulations based on plausible coefficient estimates.

The introduction of a forward market enables us to examine the paths of both spot and forward rates. Recall that a necessary but not sufficient condition for speculative efficiency to hold is that the variance of the spot rate exceeds the variance of the forward rate. From the above we can proceed to derive an expression for the variance of the spot rate relative to the variance of the forward rate.

Recall from equation (6.10)

$$(6.26) \qquad s_t = \bar{m} + A_1 e^{\lambda_1 t} + A_2 e^{\lambda_2 t}$$

The long run expected value of s, as $t \to \infty$, is therefore

$$(6.27) \qquad \underset{t \to \infty}{E(\bar{s})_t} = \bar{m}$$

The variance of the spot exchange rate around its long run value can only be found for a given interval or time period. However, the sum of squared deviations of s around $\bar{m}$ is given by

$$(6.28) \qquad \int_{t=0}^{\infty} (s_t - \bar{m})^2 dt = \int_{t=0}^{\infty} (A_1 e^{\lambda_1 t} + A_2 e^{\lambda_2 t})^2 dt$$

$$= \int_{t=0}^{\infty} \left[A_1^2 e^{2\lambda_1 t} + A_2^2 e^{2\lambda_2 t} + 2A_1 A_2 e^{(\lambda_1 + \lambda_2)t}\right] dt$$

$$= \left[\frac{A_1^2 e^{2\lambda_1 t}}{2\lambda_1} + \frac{A_2^2 e^{2\lambda_2 t}}{2\lambda_2} + \frac{2A_1 A_2 e^{(\lambda_1 + \lambda_2)t}}{\lambda_1 + \lambda_2}\right]_0^{\infty}$$

$$= \frac{-A_1^2}{2\lambda_1} - \frac{A_2^2}{2\lambda_2} - \frac{2A_1 A_2}{\lambda_2 + \lambda_1}$$

To find a similar expression for the forward rate, recall that the path of the forward premium is given by equation (6.7A) in the Appendix.

$$(6.29) \qquad f_t = \frac{(\alpha_2 \tau - \alpha_4)\dot{s}}{K} - \frac{m}{K} + \frac{\mu_1 m + \mu_2 b + \mu_3 (s + b^*)}{K}$$

Therefore, the forward rate, in terms of deviation from initial steady state, is

$$(6.30)\quad (s+f) = \frac{\alpha_2\tau - \alpha_4}{K}\frac{ds}{dt} + \frac{\mu_1+\mu_2-1}{K}\bar{m} + \frac{\mu_3(s+b^*)}{k} + s$$

$$= \frac{\alpha_2\tau-\alpha_4}{K}\frac{ds}{dt} - \frac{\mu_3\bar{m}}{k} + (\frac{\mu_3}{K}+1)s + \frac{\mu_3}{K}b^*$$

In the long run ds/dt = 0 and m, b and $s \rightarrow \bar{m}$. Also $b^* = 0$. Thus $f \rightarrow 0$. Therefore, in the long run, $(s+f) \rightarrow \bar{m}$.

Note that since variables are expressed in terms of deviations from initial steady state this does not deny the existence of a possible non-zero forward premium which remains unaltered in the long run.

To find the sum of squared deviations of the forward rate around its long run value, first substitute solutions for s, b^*. Thus

$$(6.31)\quad (s+f) = \frac{\alpha_2\tau-\alpha_4}{K}\frac{ds}{dt}$$
$$+\left(\frac{K+\mu_3}{K}\right)\bar{m} + \left(\frac{K+\mu_3}{K}\right)A_1e^{\lambda_1 t} + \left(\frac{K+\mu_3}{K}\right)A_2e^{\lambda_2 t}$$
$$+ \frac{\mu_3}{K}C_1e^{\lambda_1 t} + \frac{\mu_3}{K}C_2e^{\lambda_2 t}$$
$$- \frac{\mu_3}{K}\bar{m}$$

Therefore, the sum of squared deviations around $\bar{m}$ is given by

$$(6.32)\quad \int_{t=0}^{\infty}\left[\left(\frac{\alpha_2\tau-\alpha_4}{K}\right)\frac{ds}{dt} + \frac{K+\mu_3}{k}\left(A_1e^{\lambda_1 t}+A_2e^{\lambda_2 t}\right) + \frac{\mu_3}{K}\left(C_1e^{\lambda_1 t}+C_2e^{\lambda_2 t}\right)\right]^2 dt$$

$$ds/dt = \lambda_1 A_1 e^{\lambda_1 t} + \lambda_2 A_2 e^{\lambda_2 t}$$

Let

$$(6.33) \qquad \frac{\alpha_2 T - \alpha_4}{K} = x_1 , \qquad \frac{K + \mu_3}{K} = x_2$$

$$\mu_3/K = x_3$$

Rewriting (6.32)

$$(6.34) \qquad \int_{t=0}^{\infty} \left\{ \left[(x_1\lambda_1 + x_2)A_1 + x_3 C_1 \right] e^{\lambda_1 t} + \left[(x_1\lambda_2 + x_2)A_2 + x_3 C_2 \right] e^{\lambda_2 t} \right\}^2 dt$$

$$= \int_{t=0}^{\infty} \Big\{ \left[(x_1\lambda_1 + x_2)A_1 + x_3 C_1 \right]^2 e^{2\lambda_1 t} + \left[(x_1\lambda_2 + x_2)A_2 + x_3 C_2 \right]^2 e^{2\lambda_2 t}$$

$$+ 2\left[(x_1\lambda_1 + x_2)A_1 + x_3 C_1 \right]\left[x_1\lambda_2 + x_2 A_2 + x_3 C_2 \right] e^{(\lambda_1 + \lambda_2)t} \Big\} dt$$

$$= -\frac{\left[(x_1\lambda_1 + x_2)A_1 + x_3 C_1 \right]^2}{2\lambda_1} - \frac{\left[(x_1\lambda_2 + x_2)A_2 + x_3 C_2 \right]^2}{2\lambda_2}$$

$$- \frac{2\left[(x_1\lambda_1 + x_2)A_1 + x_3 C_1 \right]\left[(x_1\lambda_2 + x_2)A_2 + x_3 C_2 \right]}{\lambda_1 + \lambda_2}$$

Equations (6.28) and (6.34) enable us to derive the relative variance or ratio of sum of squared deviations of spot and forward exchange rates around their respective long run equilibrium values. In Chapter 7 below these algebraic solutions will be used to investigate, within the given structure of the model, the observed high variance of forward rates relative to spot rates and whether such behaviour would appear to be consistent or not with the speculative efficiency hypothesis.

6. Conclusion

In this chapter the forward market for foreign exchange has been integrated into a simple portfolio balance model. Solutions have been derived for the dynamic adjustment paths of spot and forward exchange rates following an increase in domestic nominal asset supplies. It is hoped that this will provide a framework for pursuing a more fruitful approach to re-examing the speculative efficiency hypothesis. A necessary but not sufficient condition of speculative efficiency is that the variance of the spot rate exceeds the variance of the forward rate. In this chapter we have obtained an expression for the variance of the spot rate relative to the variance of the forward rate. This will enable us to investigate the sensitivity of the expression to parameter estimates and, specifically, to behaviour in the forward market. In Chapter 7 we will investigate whether the observed high variance of the forward rate relative to the variance of the spot rate, as outlined from casual inspection in Chapter 1, is consistent with a high degree of speculative behaviour relative to arbitrage behaviour in the forward market.

Appendix

a. Model Solution

This section sets out full details of the derivation of equation (6.8) on page 133.

From (6.6)

(6.1A) $r = -\tau\dot{s} + (1+\tau)f \, , \quad \tau = \sigma/\beta_2$

Next, substituting into (6.2)

(6.2A) $m - \omega = \alpha_2\tau\dot{s} - \alpha_2(1+\tau)f - \alpha_4\dot{s} - \alpha_5 f$

Collecting terms and rearranging gives

(6.3A) $$f = \left[\frac{\alpha_2\tau - \alpha_4}{\alpha_2(1+\tau)+\alpha_5}\right]\dot{s} - \frac{m}{\alpha_2(1+\tau)+\alpha_5} + \frac{\omega}{\alpha_2(1+\tau)+\alpha_5}$$

Substituting into (6.1A) to solve for r,

(6.4A) $$r = -\tau\dot{s} + \frac{(1+\tau)(\alpha_2\tau - \alpha_4)\dot{s}}{\alpha_2(1+\tau)+\alpha_5} - \frac{m(1+\tau)}{\alpha_2(1+\tau)+\alpha_5} + \frac{(1+\tau)\omega}{\alpha_2(1+\tau)+\alpha_5}$$

Collecting terms

(6.5A) $$r = \left[\frac{(1+\tau)(\alpha_2\tau - \alpha_4) - \tau\alpha_2(1+\tau) - \tau\alpha_5}{\alpha_2(1+\tau)+\alpha_5}\right]\dot{s} - \frac{(1+\tau)m}{\alpha_2(1+\tau)+\alpha_5} + \frac{(1+\tau)\omega}{\alpha_2(1+\tau)+\alpha_5}$$

Next, let $K = \alpha_2(1+\tau)+\alpha_5$ and simplify

$$(6.6A)\quad r = -\frac{[\alpha_4(1+\tau)+\tau\alpha_5]\dot{s}}{K} - \frac{(1+\tau)m}{K} + \frac{(1+\tau)\omega}{K}$$

Rewriting (6.3A)

$$(6.7A)\quad f = \left(\frac{\alpha_2\tau-\alpha_4}{K}\right)\dot{s} - \frac{m}{K} + \frac{\omega}{K}$$

Substituting for r and f from (6.6A) and (6.7A) into (6.3)

$$(6.8A)\quad s+b^*-\omega = \frac{(\beta_1+\beta_2)[\alpha_4(1+\tau)+\tau\alpha_5]\dot{s}}{K} + \frac{(\beta_1+\beta_2)(1+\tau)m}{K}$$
$$-\frac{(\beta_1+\beta_2)(1+\tau)\omega}{K} + \beta_1\dot{s} + \frac{\beta_2(\alpha_2\tau-\alpha_4)\dot{s}}{K} - \frac{\beta_2 m}{K} + \frac{\beta_2\omega}{K}$$

Collecting terms

$$(6.9A)\quad (s+b^*) = \Big\{\left[(\beta_1+\beta_2)(\alpha_4(1+\tau)+\tau\alpha_5)+\beta_2(\alpha_2\tau-\alpha_4)+K\beta_1\right]\dot{s}$$
$$+\left[(\beta_1+\beta_2)(1+\tau)-\beta_2\right]m$$
$$+\left[(\beta_2+K)-(\beta_1+\beta_2)(1+\tau)\right]\omega\Big\}\ 1/K$$

Simplifying

$$(6.10A)\quad (s+b^*) = \Big\{\left[\beta_1(\alpha_4(1+\tau)+\tau\alpha_5)+\beta_2\tau(\alpha_4+\alpha_5+\alpha_2)+K\beta_1\right]\dot{s}$$
$$+\left[\beta_1(1+\tau)+\beta_2\tau\right]m$$
$$+\left[K-\beta_1(1+\tau)-\beta_2\tau\right]\omega\Big\}\ 1/K$$

Next substitute for w, noting that $\mu_3 = 1-\mu_1-\mu_2$ and rearranging gives

(6.11A) $$\left[K(1-\mu_3)+\beta_1(1+\tau)\mu_3+\beta_2\tau\mu_3\right]s + \left[K(1-\mu_3)+\beta_1(1+\tau)\mu_3+\beta_2\tau\mu_3\right]b^*$$
$$= \left[\beta_1\left(\alpha_4(1+\tau)+\tau\alpha_5\right)+\beta_2\tau\left(\alpha_4+\alpha_5+\alpha_2\right)+K\beta_1\right]\dot{s}$$
$$+ \left[\beta_1(1+\tau)(1-\mu_1)+\beta_2\tau(1-\mu_1)+K\mu_1\right]m$$
$$+ \left[K-\beta_1(1+\tau)-\beta_2\tau\right]\mu_2 b$$

Let
$$G = \beta_1\left(\alpha_4(1+\tau)+\tau\alpha_5\right)+\beta_2\tau\left(\alpha_4+\alpha_5+\alpha_2\right)+K\beta_1$$
$$A = \beta_1(1+\tau)+\beta_2\tau$$

Thus $$G = A\left(\alpha_4+\alpha_5+\alpha_2\right)$$

Then

(6.12A) $$\dot{s} = \frac{K(1-\mu_3)+A\mu_3}{G}s + \frac{K(1-\mu_3)+A\mu_3}{G}b^*$$
$$- \frac{\left[A(1-\mu_1)+K\mu_1\right]m}{G} - \frac{(K-A)\mu_2 b}{G}$$

Next, substitute for r into (6.5)

(6.13A) $$\dot{p} = \frac{\pi\gamma_2\left[\alpha_4(1+\tau)+\tau\alpha_5\right]\dot{s}}{K} + \frac{\pi\gamma_2(1+\tau)m}{K} - \frac{\pi\gamma_2(1+\tau)w}{K}$$
$$+ \pi\gamma_2\dot{p} + \pi\delta s - \pi\delta p$$

$$\Rightarrow \dot{p}K(1-\pi\gamma_2) = \pi\gamma_2\left[\alpha_4(1+\tau)+\tau\alpha_5\right]\dot{s} + \pi\gamma_2(1+\tau)m - \pi\gamma_2(1+\tau)w$$
$$+ K\pi\delta_s - K\pi\delta p$$

Substitute for w

(6.14A) $$\dot{p}K(1-\pi\gamma_2) = \pi\gamma_2\left[\alpha_4(1+\tau)+\tau\alpha_5\right]\dot{s} + \pi\gamma_2(1+\tau)(1-\mu_1)m$$
$$-\pi\gamma_2(1+\tau)\mu_2 b + \left[K\pi\delta-\pi\gamma_2(1+\tau)\mu_3\right]s - \pi\gamma_2(1+\tau)\mu_3 b^*$$
$$- K\pi\delta p$$

Let H = $$\alpha_4(1+\tau)+\tau\alpha_5$$

Sustitute for $\dot{s}$ from (6.12A) and collect terms

$$(6.15\text{A})\quad \dot{p} = \frac{-\pi\delta}{(1-\pi\gamma_2)}p$$
$$+\left\{\frac{\pi\gamma_2 H[K(1-\mu_3)+A\mu_3]+[K\pi\delta-\pi\gamma_2(1+\tau)\mu_3]G}{GK(1-\pi\gamma_2)}\right\}s$$
$$+\left\{\frac{\pi\gamma_2 H[K(1-\mu_3)+A\mu_3]-[\pi\gamma_2(1+\tau)\mu_3]G}{GK(1-\pi\gamma_2)}\right\}b^*$$
$$+\left\{\frac{\pi\gamma_2 G(1+\tau)(1-\mu_1)-\pi\gamma_2 H[A(1-\mu_1)+K\mu_1]}{GK(1-\pi\gamma_2)}\right\}m$$
$$-\left\{\frac{\pi\gamma_2 H(K-A)\mu_2+\pi\gamma_2(1+\tau)G\mu_2}{GK(1-\pi\gamma_2)}\right\}b$$

Finally, from (6.7), substituting for w

$$(6.16\text{A})\quad s+\dot{b}^*-p = -\phi_1(w-p)$$
$$\Rightarrow\quad s+\dot{b}^* = -\phi_1\mu_1 m-\phi_1\mu_2 b-\phi_1\mu_3(s+b^*)+(1+\phi_1)p$$
$$\Rightarrow\quad \dot{b}^* = -(1+\phi_1\mu_3)s+(1+\phi_1)p-\phi_1\mu_3 b^*-\phi_1\mu_1 m-\phi_1\mu_2 b$$

Equations (6.12A), (6.15A), and (6.16A) can then be expressed in matrix form as (6.8) on page 133.

b. Overshooting

In this section we derive the condition for overshooting in equation (6.20) on page 140. From (6.11)

$$(6.17\text{A})\quad \begin{bmatrix} 0 & a_3 \\ g_2 & (g_3-\lambda_i) \end{bmatrix}^{-1} = \frac{1}{-a_3 g_2}\begin{bmatrix} (g_3-\lambda_i) & -a_3 \\ -g_2 & 0 \end{bmatrix}$$

Thus

$$(6.18\mathrm{A}) \qquad B_1 = \left[\frac{(g_3-\lambda_1)(\lambda_1-a_1)+a_3g_i}{-a_3g_2}\right]A_1$$

$$C_1 = \left[\frac{-g_2(\lambda_1-a_1)}{-a_3g_2}\right]A_1$$

$$B_2 = \left[\frac{(g_3-\lambda_2)(\lambda_2-a_1)+a_3g_i}{-a_3g_2}\right]A_2$$

$$C_2 = \left[\frac{g_2(\lambda_2-a_1)}{a_3g_2}\right]A_2$$

Since $C_1 + C_2 = 0$, $C_1 = -C_2$

$$(6.19\mathrm{A}) \qquad \frac{g_2(\lambda_1-a_1)}{a_3g_2}A_1 = \frac{-g_2(\lambda_2-a_1)}{a_3g_2}A_2$$

$$\Rightarrow \qquad A_1 = \frac{-(\lambda_2-a_1)}{(\lambda_1-a_1)}A_2$$

From $B_1 + B_2 = -\overline{m}$

$$(6.20\mathrm{A}) \qquad \left[\frac{(g_3-\lambda_1)(\lambda_1-a_1)+a_3g_1}{-a_3g_2}\right]A_1 + \left[\frac{(g_3-\lambda_2)(\lambda_2-a_1)+a_3g_1}{-a_3g_2}\right]A_2 = -\overline{m}$$

Substituting for A_1 and rearranging

$$(6.21\mathrm{A}) \qquad A_2 = \frac{-a_3g_2(\lambda_1-a_1)}{(\lambda_2-\lambda_1)(\lambda_2-a_1)(\lambda_1-a_1)+(\lambda_2-\lambda_1)a_3g_i}\cdot\overline{m}$$

Using (6.19A)

$$(6.22\mathrm{A}) \qquad A_1 = \frac{a_3g_2(\lambda_2-a_1)}{(\lambda_2-\lambda_1)(\lambda_2-a_1)(\lambda_1-a_1)+(\lambda_2-\lambda_1)a_3g_i}\,\overline{m}$$

$$\Rightarrow \qquad A_1 + A_2 = \frac{a_3g_2}{(\lambda_2-a_1)(\lambda_1-a_1)+a_3g_i}\,\overline{m}$$

Chapter 7

Exchange Rate Dynamics and Market Efficiency: Model Simulation

1. Introduction

In earlier chapters we have noted that tests of the speculative efficiency hypothesis have been inconclusive. More recently, some researchers have examined the relative variance of spot and forward exchange rates in an attempt to produce fresh evidence on the properties of the forward market. A necessary, although not sufficient, condition of speculative efficiency is that the variance of the spot rate exceeds the variance of the forward rate. In Chapter 6 above the forward market was integrated into a simple portfolio balance model. Solutions were derived for the time paths of both spot and forward rates following an exogeneous increase in the supplies of nominal domestic assets. Expressions were then derived for the sum of squared deviations of spot and forward rates around their respective long run equilibrium values. In this chapter, plausible coefficient estimates are employed in the model to provide simulations under alternative assumptions about forward market behaviour. It is demonstrated that the variance of the spot rate relative to the forward rate increases in line with greater speculative activity in the forward market relative to arbitrage activity. Moreover, and of greater significance, it is shown that, given a highly elastic arbitrage schedule (consistent with the evidence considered in Chapter 3 above), the implied relative variance is far higher than would appear to be indicated from casual observation of exchange rate series. A low relative variance term would be consistent with risk-aversion and low speculative activity. This would appear to support the prima facie evidence against speculative efficiency presented in Chapter 1 above and provides the groundwork for empirical research to be reported in Chapter 8 below.

2.. The Model: Parameter Values

The original model as set out on pages 129-132 of Chapter 6 above is repeated here for convenience. (The reader is referred to the pages noted above for a full explanation of the model and definition of variables.)

$$(7.1) \qquad w = \mu_1 m + \mu_2 b + (1 - \mu_1 - \mu_2)(s + b^*)$$

$$(7.2) \qquad m - w = \alpha_1 y - \alpha_2 r - \alpha_3 r^* - \alpha_4 E(\dot{s}) - \alpha_5 f$$

$$(7.3) \qquad s + b^* - w = \beta_1 (r^* - r + E(\dot{s})) + \beta_2 (r^* - r + f) - \beta_3 y$$

$$(7.4) \qquad d = \gamma_1 y - \gamma_2 (r - E(\dot{p})) + \delta (s - p + p^*)$$

$$(7.5) \qquad \dot{p} = \pi (d - y)$$

$$(7.6) \qquad \beta_2 (r^* - r + f) = \sigma (E(\dot{s}) - f)$$

$$(7.7) \qquad s + b^* - p = -\phi_1 (w - p) + \phi_2 y$$

Recall that solutions are derived in terms of deviations from initial steady state. Thus with domestic output and the foreign interest rate fixed, γ_1, α_1 and α_3 are redundant. In addition, expectations are assumed to be consistent with perfect foresight such that, for any variable x, $E(\dot{x}) = \dot{x}$.

The following coefficient estimates are initially assumed

$$(7.8)\qquad \begin{array}{llll} \alpha_2 = 0.5 & \mu_1 = 0.4 & \beta_1 = 0.3 & \\ \alpha_4 = 0.2 & \mu_2 = 0.4 & \beta_2 = 4.0 & \gamma_2 = 0.3 \\ \alpha_5 = 0.5 & \mu_3 = 0.2 & & \\ \delta = 0.2 & \pi = 2.5 & \phi_1 = 0.8 & \tau = 0.2 \end{array}$$

The relative shares of money, domestic and foreign bonds in total wealth (μ_1, μ_2 and μ_3 respectively) are somewhat arbitrary given the well recognised problems in defining b and b^* (see for example Frankel (37)). If the latter are assumed to be own currency government issued liabilities held by the private sector then the ratios are consistent with the typical experience of small open economies. The elasticities in the demand for money function α_2, α_4 and α_5 are in line with those in studies reported by, for example, Laidler (68). The low values of γ_2, the interest elasticity of the investment function, and δ, the price elasticity of foreign demand for exports are consistent with the findings of Wynn and Holden (106) and Blackhurst (13). Similarly, the value of ϕ_1 in the wealth adjustment equation, which is a log linear approximation to a current account equation, reflects the low value of price elasticities in implicit import and export functions. Finally, the value of τ, the ratio of speculative to arbitrage activity in the forward market, appears reasonable given the findings reported and summarised from elsewhere in Beenstock (7).

3. Solution and Dynamic Adjustment

Using the imposed coefficients set out in Section 2 we can derive the values of K, A, H and G (see pages 146-148, Chapter 6)

(7.9) $\quad K = 1.1 \qquad A = 1.16$

$\qquad H = 0.34 \qquad G = 1.392$

Next, from equations (6.12A), (6.15A) and (6.16A) and using the above we can derive the matrix elements of (6.8)

(7.10) $\quad a_1 = 0.799, \qquad a_3 = 0.799$

$\qquad c_1 = 2.086, \quad c_2 = -2.0, \quad c_3 = 0.086$

$\qquad g_1 = -1.16, \quad g_2 = 1.8, \quad g_3 = -0.16$

The characteristic equation of page 135, Chapter 6 can then be written as

(7.11) $\quad \lambda^3 + 1.361\lambda^2 - 0.634\lambda - 1.278 = 0$

Note that the negative constant implies either the existence of two roots with negative real parts or three roots with positive real parts (see page 135, Chapter 6). The solution of the cubic equation is found to be (using the procedure for solving cubic equations in Lewis (73)).

(7.12) $\quad \lambda_1 = -1.133 + 0.362i, \quad \lambda_2 = -1.133 - 0.362i$

$\qquad \lambda_3 = 0.904$

The example given here produces one positive real root and two complex conjugate roots with negative real parts. Thus the model is stable.

Having now solved for the roots of the system we can proceed to examine the question of overshooting. Recall from Section 5 above that the instantaneous exchange rate following an increase in the supplies of nominal domestic assets of m is $A_1 + A_2 + \overline{m}$. Exchange rate overshooting or undershooting therefore hinges on whether $A_1 + A_2 > 0$.

Since

$$(7.13) \qquad A_1 + A_2 = \frac{a_3 g_2}{(\lambda_2 - a_1)(\lambda_1 - a_1) + a_3 g_1} \bar{m}$$

$$= \frac{1.438}{(-1.931 - 0.362i)(-1.931 + 0.362i) - 0.927} \bar{m}$$

$$= 0.489 \bar{m}$$

$$\Rightarrow A_1 + A_2 + \bar{m} = 1.489 \bar{m}$$

Thus using the coefficient estimates given in the model above will produce initial overshooting of the long run equilibrium value of the spot exchange rate.

The full dynamic adjustment path of the spot exchange rate can be examined before proceeding to examine the variance of the exchange rate around its long run value. In general, a solution of the form

$$(7.14) \qquad s(t) = \bar{m} + A_1 e^{\lambda_1 t} + A_2 e^{\lambda_2 t}$$

can be expressed as

$$\begin{aligned}(7.15) \qquad s(t) &= \bar{m} + A_1 e^{(-\alpha + i\omega)t} + A_2 e^{(-\alpha - i\omega)t} \\ &= \bar{m} + e^{-\alpha t}\left(A_1 e^{i\omega t} + A_2 e^{-i\omega t}\right) \\ &= \bar{m} + e^{-\alpha t}\left[A_1(\cos\omega t + i\sin\omega t) + A_2(\cos\omega t - i\sin\omega t)\right] \\ &= \bar{m} + e^{-\alpha t}\left[(A_1 + A_2)\cos\omega t + i(A_1 - A_2)\sin\omega t\right] \\ &= \bar{m} + e^{-\alpha t}\left[B_1 \cos\omega t + B_2 \sin\omega t\right]\end{aligned}$$

where $B_1 = A_1 + A_2$ and $B_2 = i(A_1 - A_2)$. The solution has a more recognisable form if we write $B_1 = \cos\epsilon$ and $B_2 = B\sin\epsilon$. The solution for the spot exchange rate can then be written

$$(7.16) \quad s(t) = \bar{m} + Be^{-\alpha t}\cos(\omega t - \epsilon) = \bar{m} + Be^{-1.333t}\cos(0.362t - \epsilon)$$

Thus in this particular example the path of the exchange rate consists of the product of an exponential term and a trigonometric term. The exponential term serves to damp oscillations around a path approaching long run equilibrium.

To find the sum of squared deviations of the spot exchange rate around its long run equilibrium value recall equation (6.28) above.

$$(7.17) \quad \int_{t=0}^{\infty} (s_t - \bar{m})^2 dt = \frac{-A_1^2}{2\lambda_1} - \frac{A_2^2}{2\lambda_2} - \frac{2A_1A_2}{\lambda_2 + \lambda_1}$$

where

$$(7.18) \quad A_1 = \frac{a_3 g_2(\lambda_2 - a_1)}{(\lambda_2-\lambda_1)(\lambda_2-a_1)(\lambda_1-a_1) + (\lambda_2-\lambda_1)a_3 g_1}\bar{m}$$

and

$$(7.19) \quad A_2 = \frac{-a_3 g_2(\lambda_1 - a_1)}{(\lambda_2-\lambda_1)(\lambda_2-a_1)(\lambda_1-a_1) + (\lambda_2-\lambda_1)a_3 g_1}\bar{m}$$

Using the above we can calculate the values of A_1 and A_2 to be

$$(7.20) \quad A_1 = (0.245 - 1.307i)\bar{m}, \quad A_2 = (0.245 + 1.307i)\bar{m}$$

Thus

$$(7.21) \quad A_1^2 = (-1.649 - 0.64i)\bar{m}^2, \quad A_2^2 = (-1.649 + 0.64i)\bar{m}^2$$

The expression for the sum of squared deviations of the spot rate can then be solved as

$$(7.22) \qquad \frac{-A_1^2}{2\lambda_1} - \frac{A_2^2}{2\lambda_2} - \frac{2A_1A_2}{\lambda_2+\lambda_1} = 0.405\bar{m}^2$$

Next, recall from equation (6.34) the expression for the sum of squared deviations of the forward rate around its long run equilibrium value

$$(7.23) \qquad \int_{t=0}^{\infty} [(s+f)-\bar{m}]^2 dt = -\frac{[(x_1\lambda_1+x_2)A_1+x_3C_1]^2}{2\lambda_1} - \frac{[(x_1\lambda_2+x_2)A_2+x_3C_2]^2}{2\lambda_2} - \frac{2[(x_1\lambda_1+x_2)A_1+x_3C_1][(x_1\lambda_2+x_2)A_2+x_3C_2]}{\lambda_1+\lambda_2}$$

where

$$(7.24) \qquad x_1 = (\alpha_2\gamma-\alpha_4)/K = -0.091, \quad x_2 = (K+\mu_3)/K = 1.182$$

$$x_3 = \mu_3/K = 0.182$$

Using equation (6.18A) (see p.150, Chap. 6) we have

$$(7.25) \qquad C_1 = \left[\frac{-g_2(\lambda_1-a_1)}{-a_3g_2}\right]A_1, \quad C_2 = \left[\frac{g_2(\lambda_2-a_1)}{a_3g_2}\right]A_2$$

Thus

$$(7.26) \qquad C_1 = (-2.368.10^{-10} + 3.271i)\bar{m}$$

$$C_2 = (-2.368.10^{-10} - 3.271i)\bar{m}$$

The sum of squared deviations of the forward rate is then found to be

$$(7.27) \qquad \int_{t=0}^{\infty} \left[(s+f)-\bar{m}\right]^2 dt = 0.374\bar{m}^2$$

Finally, note that the ratio of the sum of squared deviations of spot and forward rates around their respective long run equilibrium values is the variance of the spot rate relative to the variance of the forward rate and can be written as

$$(7.28) \qquad V(s) \big/ V(s+f) = 0.405\bar{m}^2 \big/ 0.374\bar{m}^2 = 1.082$$

4. <u>Sensitivity</u>

In this section we examine the impact of altering assumptions about forward market behaviour on the simulations reported in Section 3. In particular, we investigate the effect of altering the elasticities of arbitrage and speculation on both overshooting and, more importantly, the relative variance of spot and forward rates. Later, we attempt to assess the degree to which these results may hinge on the assumed coefficients of other variables in the model. The initial coefficient values are those shown on page 154 (with $\phi_1 = 0.8$). Table 7.1 and Table 7.2 show the impact on relative variance and overshooting ($A_1 + A_2$) respectively of different values of β_2 and τ, where β_2 is the elasticity of the supply of arbitrage funds in the forward market and τ is the ratio of the elasticities of the speculation and arbitrage schedules.

Table 7.1 Relative Variance

τ \ β_2	1.0	4.0	7.0	10.0
0.0	0.9587	0.9587	0.9587	0.9587
0.02	0.9640	0.9663	0.9698	0.9742
0.04	0.9694	0.9763	0.9866	0.9991
0.1	0.9858	1.0137	1.0498	1.0888
0.2	1.0133	1.0823	1.1578	1.2308
0.3	1.0399	1.1474	1.2533	1.3488
0.4	1.0651	1.2064	1.3352	1.4459
0.5	1.0885	1.2591	1.4055	1.5262
0.6	1.1101	1.3062	1.4662	1.5934
0.7	1.1300	1.3484	1.5190	1.6504
0.8	1.1484	1.3863	1.5652	1.6992
0.9	1.1654	1.4205	1.6059	1.7414
1.0	1.1811	1.4516	1.6420	1.7782

β_2 = elasticity of arbitrage demand for forward foreign currency.

τ = relative elasticities of speculation and arbitrage functions.

The table shows the ratio of the variance of spot and forward rates when both are measured relative to the fixed long run equilibrium exchange rate.

Table 7.2 Overshooting

τ \ β_2	1.0	4.0	7.0	10.0
0.0	0.4434	0.4434	0.4434	0.4434
0.02	0.4535	0.4779	0.4937	0.5032
0.04	0.4620	0.4967	0.5089	0.5088
0.1	0.4804	0.5096	0.4916	0.4644
0.2	0.4970	0.4899	0.4405	0.3990
0.3	0.5048	0.4655	0.4035	0.3602
0.4	0.5083	0.4448	0.3779	0.3355
0.5	0.5097	0.4281	0.3593	0.3186
0.6	0.5099	0.4145	0.3454	0.3063
0.7	0.5095	0.4033	0.3346	0.2970
0.8	0.5087	0.3941	0.3259	0.2897
0.9	0.5078	0.3862	0.3189	0.2839
1.0	0.5067	0.3796	0.3130	0.2790

β_2 = elasticity of arbitrage demand for forward foreign currency.

τ = relative elasticities of speculation and arbitrage functions.

The table shows values of the term ($A_1 + A_2$) which measures the degree of initial overshooting following an increase in the supplies of money and domestic bonds.

Several comments can be made in respect of Tables 7.1 and 7.2 Firstly, note that for any given level of arbitrage elasticity, an increase in the elasticity of speculation in the forward market is reflected in an increase in the variance of the spot rate relative to the variance of the forward rate. Intuitively, the forward rate tends to the expected long run value of the exchange rate, hence dampening its dynamic path, leaving the spot rate to bear the brunt of adjustment to any disturbance. Secondly, at a low elasticity of arbitrage demand, there is a positive correlation between the degree of overshooting and the relative variance term. Thirdly, however, at greater elasticities of arbitrage demand, increased speculative activity tends to dampen overshooting. Finally, note that the ratio of the variance of spot and forward rates greatly exceeds unity as the role of speculative activity is increased. For a value of τ equal to 0.3, consistent with the survey of studies reported by Beenstock (7), and assuming a high elasticity of arbitrage demand in line with the findings of Chapter 3 above, the ratio is of a considerable magnitude. This clearly has implications for assessing the role played by speculative activity in the forward market and hence the validity of the speculative efficiency hypothesis.

It is clearly of importance to investigate further the extent to which the results obtained above are dependent on the parameters of the model. In Chapter 5 it was noted that the degree of overshooting, in particular, is sensitive to the interest elasticity of money demand and the speed of adjustment in asset and real goods markets.

Simulations were compared with the results reported in Tables 7.1 and 7.2 for different values of α_2, the interest elasticity of the demand for money, and ϕ_1, the speed of adjustment in asset markets. The simulations were carried out for different combinations of β_2 and τ .

(a.) Interest Elasticity of the Demand for Money

Simulations were performed with the interest elasticity of the demand for money varying from 0.1 to 0.8 for given values of β_2 and τ . Three classes of results were obtained. Firstly, for the combination of β_2 and τ used in pages 153-158 above, an increase in interest elasticity dampens overshooting but increases the relative variance term (see Table 7.3). Secondly, in Table 7.4 an example is given where a higher interest elasticity will increase overshooting but reduce the variance of the spot rate relative to the variance of the forward rate. Thirdly, at low values of β_2 , as in Table 7.5, increased interest elasticity leads to greater overshooting and a higher relative variance term. Fourthly, only at high levels of both β_2 and τ (and hence σ) is the result obtained where an increase in the interest elasticity of the demand for money function is reflected in both reduced overshooting and a lower relative variance term. Despite the apparent perversity of these results, the key point is that a change in the interest elasticity of money demand, for given values of β_2 and τ , has only a small impact on the relative variance term when compared to the size of impact obtained by changing τ.

Sensitivity to Interest Elasticity of Demand for Money

Table 7.3

α_2	Rel. Var.	Over-Shoot
0.1	1.0717	0.4906
0.5	1.0823	0.4899
0.8	1.0865	0.4896

$\beta_2 = 4.0, \tau = 0.2$

Table 7.5

α_2	Rel. Var.	Over-Shoot
0.1	1.0013	0.5029
0.5	1.0399	0.5048
0.8	1.0540	0.5055

$\beta_2 = 1.0, \tau = 0.3$

Table 7.4

α_2	Rel. Var	Over-Shoot
0.1	1.1804	0.4391
0.5	1.1578	0.4405
0.8	1.1487	0.4411

$\beta_2 = 7.0, \tau = 0.2$

Table 7.6

α_2	Rel. Var.	Over-Shoot
0.1	1.8267	0.2936
0.5	1.6992	0.2897
0.8	1.6310	0.2879

$\beta_2 = 10, \tau = 0.8$

(b.) Asset Adjustment

A further set of simulations was carried out to assess the sensitivity of the results obtained above to assumptions about the speed of adjustment in asset markets. Recall that the asset adjustment equation was derived from a simple savings function (see Chapter 6, p.132) and may be presented as an approximation to a log linear equation for the current account of the balance of payments or net change in foreign assets (see Eaton and Turnovsky (30)). An increase in the speed of adjustment of asset holdings relative to the speed of adjustment in the real goods market might be expected to cause greater initial overshooting of the exchange rate following a monetary disturbance. To the extent that behaviour in the forward market ensures that the forward rate tends to the expected future spot rate then this would also be expected to increase the variance of the spot rate relative to the variance of the forward rate.

In Tables 7.7-7.10 below, an increase in Φ_1, for given values of β_2 and τ, is always reflected in increased variance of the spot rate relative to the variance of the forward rate. In Table 7.9, the degree of overshooting is also increased. However, at very high elasticities of both arbitrage and speculation functions, the degree of overshooting is dampened as the speed of adjustment in asset markets is increased. Note finally, that the results shown in Tables 7.1 and 7.2 above would appear sensitive to assumptions about Φ_1. However, the simulations reported

Sensitivity to Speed of Adjustment of Asset Holdings

Table 7.7

ϕ_1	Rel. Var.	Over-Shoot
0.1	1.0179	0.5677
0.5	1.0604	0.4928
0.8	1.0823	0.4899

$\beta_2 = 4.0, \tau = 0.2$

Table 7.8

ϕ_1	Rel. Var.	Over-Shoot
0.1	1.0392	0.5782
0.5	1.1180	0.4541
0.8	1.1578	0.4405

$\beta_2 = 7.0, \tau = 0.2$

Table 7.9

ϕ_1	Rel. Var.	Over-Shoot
0.1	1.0072	0.4712
0.5	1.0282	0.4832
0.8	1.0399	0.5048

$\beta_2 = 1.0, \tau = 0.3$

Table 7.10

ϕ_1	Rel. Var.	Over-Shoot
0.1	1.2123	0.4321
0.5	1.5264	0.3078
0.8	1.6992	0.2897

$\beta_2 = 10.0, \tau = 0.8$

in Tables 7.7-7.10 tend to support the case for arguing that, unless the level of τ is very low, consistent with risk aversion, one would expect to observe that the variance of the spot rate greatly exceeds the variance of the forward rate. Hence, before proceeding to Chapter 8, this would again seem to underline the prima facie evidence against the speculative efficiency hypothesis.

5. Conclusion

A necessary, although not sufficient, condition of speculative efficiency is that the variance of the spot rate exceeds the variance of the forward rate. In this chapter we have investigated the dynamic adjustment paths of spot and forward exchange rates following a monetary disturbance within the framework of the model set out in Chapter 6 above. It has been demonstrated that as the role of speculative activity in the forward market is increased the implied relative variance term greatly exceeds unity. However, at low levels of speculative activity, consistent with risk aversion, the relative variance term accords with casual inspection of the empirical data in the appendix to Chapter 1 above. This result would not appear to hinge critically on assumptions made about the size of other important coefficients within the model and hence provides prima facie evidence against the speculative efficiency hypothesis. In Chapter 8 below we will consider estimates of variances of selected time series of spot and forward exchange rates in the light of these findings.

Appendix

This section sets out the derivation of the roots of the characteristic equation on page 154 above, using the procedure for solving cubic equations in Lewis ((73, pp.531).

Taking the general form of a cubic equation as

(7.1A) $$x^3 + a_1 x^2 + a_2 x + a_3 = 0$$

If we now write

(7.2A) $$y = x + \frac{a_1}{3}$$

then the equation may be reduced to

(7.3A) $$y^3 + \left(a_2 - \frac{a_1^2}{3}\right)y + \left(\frac{2a_1^3}{27} - \frac{a_1 a_2}{3} + a_3\right) = 0$$

or $$y^3 + Ay + B = 0$$

where, from the above,

(7.4A) $$A = -1.252 \quad , \quad B = -0.804$$

Since $B^2/4 + A^3/27 > 0$ this implies the existence of one real and two complex roots (see Lewis, p.533 (73)).

The solutions of the reduced cubic equation are given by

(7.5A) $y_1 = z + v \quad , \quad y_2 = \omega z + \omega^2 v$

$y_3 = \omega^2 z + \omega v$

where $1, \omega, \omega^2$ are the roots of $x^3 - 1 = 0$. That is,

(7.6A) $\omega = -\frac{1}{2} + i\frac{\sqrt{3}}{2} \quad , \quad \omega^2 = -\frac{1}{2} - i\frac{\sqrt{3}}{2}$

In addition,

(7.7A) $$z = \sqrt[3]{\left(-B/2\right) + \sqrt{B^2/4 + A^3/27}} = 0.888$$

$$v = \sqrt[3]{-B/2 - \sqrt{B^2/4 + A^3/27}} = 0.469$$

Thus

(7.8A) $$y_1 = z + v = 1.358$$

$$y_2 = \omega z + \omega^2 v = -0.679 + 0.362i$$

$$y_3 = \omega^2 z + \omega v = -0.679 - 0.362i$$

From equation (7.2A) above we can then solve for the roots on page 154.

Chapter 8.

Relative Variance Tests and Speculative Efficiency

1. Introduction

In this chapter several statistical tests of the speculative efficiency hypothesis are performed. The null hypothesis, consistent with speculative efficiency in the forward market, is that the variance of the spot exchange rate is significantly greater than the variance of the forward rate, when both are measured around the long-run equilibrium exchange rate. An alternative hypothesis is presented by the findings reported in Chapter 7 above. In Chapter 7 model simulations were performed to examine the time paths of spot and forward exchange rates following an increase in the supplies of domestic money and bonds within a general equilibrium framework. It was found that, at low values of elasticity of speculative demand for forward exchange, consistent with risk aversion, the variance of the spot rate did not greatly exceed the variance of the forward rate. The tests are outlined in Section 2 below. The data is described in Section 3 and the results are presented in Section 4. The evidence supports the alternative hypothesis that behaviour of spot and forward rates is consistent with risk aversion in the forward market and a low level of speculative activity. Hence the null hypothesis of speculative efficiency is rejected.

2. Derivation of Variance Tests

In this section we derive tests of the speculative efficiency hypothesis based on the relative variance of spot and forward rates around the expected long run equilibrium value of the exchange rate. The initial discussion draws heavily on Chapter 4, pp. 88-89 above.

Let $f_m(s_{i,j,t+1} \mid \Phi_t^m)$ be the joint probability density function for the spot exchange rate between currencies i and j at t+1 based on the information set used by the market at t, Φ_t^m. The set of information available at t, Φ_t, includes past and present values of all relevant variables and knowledge of past, present and perceived future relationships between variables. The joint distribution of exchange rates has mean or expected value $E(\tilde{s}_{i,j,t+1} \mid \Phi_t^m)$, where $\sim$ denotes a random variable. The market is assumed to use Φ_t^m to set the price of forward exchange corresponding to maturity at t+1, ${}_{t+1}F_t$, such that the expected return to forward speculation, $E(\tilde{R}_{i,j} \mid \Phi_t^m)$ is zero where

(8.1) $$E(\tilde{R}_{i,j} \mid \Phi_t^m) = E(\tilde{s}_{i,j,t+1} \mid \Phi_t^m) - s_{i,j,t} = 0$$

and $${}_{t+1}F_t = E(\tilde{s}_{i,j,t+1} \mid \Phi_t^m)$$

The speculative efficiency hypothesis states that where the forward rate is set in this fashion and the market is efficient ($\Phi_t^m = \Phi_t$) then there ought not to be a consistent bias in the prediction error of the forward rate.

A test of the speculative efficiency hypothesis is then provided from the regression equation

$$(8.2) \qquad S_{t+1} = a + bF_t + u_t \text{ , } u_t \sim N(0, \sigma_u^2)$$

If the market is efficient and if the model determining spot and forward exchange rates is correctly specified, then the forward rate should contain all relevant information concerning the market's expectation of the future spot rate. This implies a joint test of speculative efficiency from the regression equation (8.2). The constant term, a, should not be significantly different from zero, the coefficient b should be insignificantly different from unity and there should be no serial correlation between the error terms. Tests of significance require that the time series of spot and forward rates are stationary. Hence an alternative expression of equation (8.2) is often estimated,

$$(8.3) \qquad (S_t - S_{t-1}) = a + b(F_{t-1} - S_{t-1}) + u_t$$
$$u_t \sim N(0, \sigma_u^2)$$

Early research mostly produced evidence which failed to reject the null hypothesis of speculative efficiency. However, more recently, studies which have taken into account a wide range of econometric and data alignment problems in estimating (8.2) and (8.3) have provided more robust tests which have rejected speculative efficiency (see Chapter 4, pp. 101).

An alternative test of speculative efficiency is provided by examining the relative variance of spot and forward rates. From equation (8.2), if the regression results are consistent with speculative efficiency, this would imply the condition,

$$(8.4) \qquad Var\ s_t > Var\ f_{t-1}\ , \text{ since } Var\ u_t > 0$$

However, this provides a necessary but not sufficient condition for the null hypothesis to hold. If $Cov(f_t u_t) > 0$ then the condition set out in (8.4) would hold but correlation between the forward rate and prediction errors would not be consistent with speculative efficiency. Note also that since variances are measured from sample estimates both time series must be stationary. A more appropriate procedure is then to derive a similar condition from (8.3) above;

$$(8.5) \qquad Var(s_t - s_{t-1}) > Var(f_{t-1} - s_{t-1})$$

Huang has concluded that the variance bounds test is not violated (see (56) and Chapter 4, p.102) for equation (8.5). This result is not surprising in the light of the casual empiricism of Chapter 1 which demonstrated that spot exchange rate series are far more unstable than forward premia or discounts. However, in Chapter 4 (see p.103) it was demonstrated that a similar result will be obtained where the forward rate stands at a constant premium or discount to the forward rate. Thus the cost of adjusting for non-stationarity and contemporaneous covariance between the dependent and independent series is that transformation of (8.4) into (8.5) does not provide a meaningful test of the speculative efficiency hypothesis. In this chapter tests of the null hypothesis of speculative efficiency, based on the necessary condition set out in (8.4), are derived from variance terms measured around long-run equilibrium exchange rates. An alternative hypothesis, as explained below, is then provided by the evidence of Chapter 7. Statistical tests with a properly specified alternative are able to explain possible rejection of the null and thus provide a more powerful test of the speculative efficiency hypothesis.

Equation (8.2) can be expanded thus

$$(8.6) \qquad E_t(s_t - E_t(s_t))^2 = E_{t-1}(f_{t-1} - E_{t-1}(f_{t-1}))^2 + E_t(u_t - E_t(u_t))^2$$

In Chapter 7 the variance of spot and forward exchange rates was measured around the fixed expected long run equilibrium value of the exchange rate, such that $E_t(s_t) = E_{t-1}(f_{t-1}) = \bar{m}$. However, empirical measures of the variance terms must allow for the long run equilibrium exchange rate to wander through time. Hence, in equation (8.6), retaining time subscripts, we should substitute $E_t(s_t) = m_t$. Speculative efficiency asserts that $E_{t-1}(f_{t-1}) = m_t$. Thus we can rewrite (8.6).

$$(8.7) \qquad E_t(s_t - m_t)^2 = E_{t-1}(f_{t-1} - m_t)^2 + E_t(u_t - E_t(u_t))^2$$

From (8.7) it will be seen that, under the speculative efficiency hypothesis, $Var(s_t)$ will increase relative to $Var(f_{t-1})$ as $Var(u_t)$ increases. That is, in circumstances where σ^2_u, the variance of prediction errors increases, we should observe an increase in the variance of the spot rate relative to the variance of the forward rate.

In the tests which follow we consider three circumstances in which the variance of forward prediction errors might be expected to increase. Firstly, we compare the prediction errors associated with one and twelve month forward rates. The longer forecast interval implied in the twelve month forward rate might be expected to be associated with larger forecast errors than the one month forward rate. Secondly, we compare the forecast errors of forward rates for volatile exchange rate series with the forecast errors associated with more stable spot and forward rates. The more volatile exchange rates might be expected to have larger forward prediction errors. Thirdly, we might expect to find an increase in forward prediction errors when comparing time periods with high exchange rate variability and periods in which there is low exchange rate variability.

In the above we have considered three circumstances in which forward prediction errors might be expected to increase. From equation (8.7), under the null hypothesis of speculative efficiency, we should then expect to observe an increase in the ratio of the variance of the spot rate to the variance of the forward rate. However, note that if speculators are risk-averse then, in circumstances where we are likely to observe high prediction errors, the elasticity of the speculation schedule in the forward market is likely to be low. The evidence of Chapter 7 suggested that, in such circumstances, the variance of the spot rate will not greatly exceed the variance of the forward rate. Hence, this provides an alternative to our null hypothesis.

3. Data

The spot, one month and twelve month forward exchange rates used in this chapter are bid quotations recorded in the New York foreign exchange market at the close of business on the last working day of each month. The data was obtained from Data Resources Incorporated. Data alignment is not precise since forward prices for one and twelve month maturities do not relate to calendar months. However, this does not affect the statistical tests included in this chapter. Six exchange rates are considered. They are the German Mark, Japanese Yen, Swiss Franc and British Pound prices of one U.S. Dollar (the British Pound exchange rate is conventionally quoted in terms of U.S. Dollars per Pound) and the Japanese Yen and Swiss Franc prices of one German Mark. Observations are included over the interval January 1976 to December 1984. Units are converted into natural logarithms.

In addition, two alternative time series are constructed to approximate the unobservable long run equilibrium exchange rate. The first consists of a moving average based on the actual spot rate series. The second is a set of fitted values obtained from regressing the spot exchange rate on the difference between the logarithms of national consumer price indices. Thus, in the second case, the long run equilibrium exchange rate is measured by a simple purchasing power parity relationship. The details of the construction of both series are outlined below.

4. Results

The statistical tests set out briefly above were deemed appropriate in circumstances where the variance of forward prediction errors is increased. It was suggested that an increase in the variance of prediction errors might be observed when firstly, comparing data from a volatile against a more stable exchange rate series, secondly, when considering an increase in the maturity of a forward contract and, finally, when examining time periods in which there is an increase in the general level of exchange rate variability. In this section we first consider whether forward prediction errors are increased in these circumstances before proceeding to examine the relative variance of spot and forward rates.

Tests for significant difference between sample variances are based on the F statistic,

(8.8) $$F_{(n_1-1)(n_2-1)} = \hat{\sigma}_1^2 / \hat{\sigma}_2^2$$

where $\hat{\sigma}_1^2 > \hat{\sigma}_2^2$ and n_1 and n_2 are the number of observations on each time series. The competing hypotheses in the one-tailed test are

(8.9) $H_0: \hat{\sigma}_1^2 = \hat{\sigma}_2^2$

$H_1: \hat{\sigma}_1^2 > \hat{\sigma}_2^2$

From pair-wise tests we find from Tables 8.1 and 8.3a that there is no significant difference between $V(s_t - s_{t-1})$ for the first five series in the table at the 95% level of confidence. However, the sample variance of the Swiss Franc/ Deutsche Mark exchange rate is significantly smaller than all of the others. Moreover, the F statistics in Tables 8.3b and 8.3c reveal that both one and twelve month forward prediction errors are significantly lower for the SF/DM exchange rate than for the others. Secondly, in all cases, the variance of the twelve month forward prediction errors is significantly greater than the variance of the one month forward prediction errors at the 95% level of confidence. Thus Table 8.1 has confirmed that forward prediction errors are increased firstly, when comparing statistically volatile exchange rates with more stable series and, secondly, when increasing the length to maturity of forward contracts. This will provide the basis for our tests of speculative efficiency which follow below.

The observation interval has also been divided into sub-periods January 1976 - December 1979 and January 1980 - December 1984. The sample variance terms $V(s_t - s_{t-1})$ were computed for each exchange rate series in the two sub-periods (see Tables 8.2 and 8.3d). F tests revealed that only in the case of the SF/DM exchange rate was a significant difference found between the variance terms at the 95% level of confidence. On this basis it was decided not to examine whether prediction errors are increased when the general level of exchange rate variability is increased.

Table 8.1 Variance of Spot Rate Changes and Forward Errors

Per U.S. Dollar

	$Var(s_t - s_{t-1})$	$Var(s_t - f_{t-1})$	$Var(s_t - f_{t-12})$
British Pound	0.00114	0.00101	0.02625
German Mark	0.00115	0.00110	0.01583
Japanese Yen	0.00120	0.00127	0.02454
Swiss Franc	0.00153	0.00148	0.02419
Per German Mark			
Japanese Yen	0.00122	0.00151	0.02494
Swiss Franc	0.00039	0.00040	0.00596
	$n_1 = 107$	$n_2 = 107$	$n_3 = 96$

Observation interval January 1976 - December 1984.
Variances calculated with n-1 degrees of freedom.

Table 8.2

	$Var(s_t - s_{t-1})$	
Per U.S. Dollar	Jan 1976-Dec 1979	Jan 1980-Dec 1984
British Pound	0.00096	0.00116
German Mark	0.00092	0.00114
Japanese Yen	0.00122	0.00119
Swiss Franc	0.00144	0.00142
Per German Mark		
Japanese Yen	0.00109	0.00123
Swiss Franc	0.00047	0.00031

Table 8.3 F-Statistics for Tests of Relative Variance

(a) Variance of Spot Rate Changes Relative to the Variance of the SF/DM Exchange Rate

Per U.S. Dollar	
British Pound	2.92
German Mark	2.95
Japanese Yen	3.08
Swiss Franc	3.92
Per German Mark	
Japanese Yen	3.92

The critical value for the F statistic at the 95% level of significance is approximately 1.39.

(b) Variance of Prediction Errors Relative to the Variance of Prediction Errors for SF/DM

Per U.S. Dollar	One Month	Twelve Months
British Pound	2.53	4.40
German Mark	2.75	2.66
Japanese Yen	3.18	4.12
Swiss Franc	3.70	4.06
Per German Mark		
Japanese Yen	3.78	4.18

The critical value of the F statistic at the 95% level of significance is approximately 1.39.

Table 8.3 (continued)

(c) Variance of Twelve Month Forward Prediction Errors Relative to the Variance of One Month Forward Prediction Errors

Per U.S. Dollar

British Pound	25.99
German Mark	14.39
Japanese Yen	19.32
Swiss Franc	16.34

Per German Mark

Japanese Yen	16.52
Swiss Franc	14.90

The critical value of the F statistic at the 95% level of significance is approximately 1.39.

(d) Variance of Spot Rate Changes in Period II Relative to Period I

Per U.S. Dollar

British Pound	1.21
German Mark	1.24
*Japanese Yen	1.025
*Swiss Franc	1.014

Per German Mark

Japanese Yen	1.13
*Swiss Franc	1.52

* Variance of spot rate changes in period I relative to period II.

The critical value of the F statistic at the 95% level of significance is approximately 1.39

Summing up, the evidence from Tables 8.1-8.3 is that the variance of forward prediction errors is increased if we compare the SF/DM exchange rate with our five remaining series and if we compare one and twelve month forward rates for all exchange rate series. From the above, if speculative efficiency holds then we should find an increase in the relative variance of spot and forward rates as prediction errors are increased.

(i) Moving Average

In the first series of tests of speculative efficiency, based on the relative variance of spot and forward rates, the long run equilibrium exchange rate is approximated by a five period moving average of the spot exchange rate series. The moving average is centred on the relevant observation point. Thus

$$(8.10) \quad MA_5 = (s_{t-2} + s_{t-1} + s_t + s_{t+1} + s_{t+2}) / 5$$

The variance of spot, one month and twelve month forward rates are calculated, for each exchange rate series, around the five period moving average. The results are presented in Table 8.4. The implication of the speculative efficiency hypothesis, from equation (8.7) above, is that we should observe that the ratio of the variance terms for spot and twelve month forward rates exceeds the ratio of variance terms for spot and one month forward rates for all exchange rate series. In addition, we should observe higher relative variance terms for the sub-set of five exchange rate series excluding the

Table 8.4 Variance of Spot and Forward Rates Around Long-Run Equilibrium (Moving Average)

Per U.S. Dollar	$\sum(s_t - m_t)^2$	$\sum(f_{t-1} - m_t)^2$	$\sum(f_{t-12} - m_t)^2$
British Pound	0.0366	0.0674	1.8774
German Mark	0.0414	0.0672	1.6573
Japanese Yen	0.0528	0.0828	2.2217
Swiss Franc	0.0509	0.0979	2.3728
Per German Mark			
Japanese Yen	0.0436	0.2885	2.9697
Swiss Franc	0.0172	0.0288	0.5254
	$n_1 = 104$	$n_2 = 104$	$n_3 = 94$

m_t is a moving average of the spot rate series, such that $m_t = (s_{t-2} + s_{t-1} + s_t + s_{t+1} + s_{t+2})/5$.

Table 8.5 Relative Variance Tests Using the Moving Average Measure of the Long Run Equilibrium Exchange Rate

(a) Variance of One Month Forward Rate Relative to Variance of Spot Rate

Per U.S. Dollar	
British Pound	1.84
German Mark	1.62
Japanese Yen	1.57
Swiss Franc	1.92
Per German Mark	
Japanese Yen	6.62
Swiss Franc	1.67

(b) Variance of Twelve Month Forward Rate Relative to Variance of One Month Forward

Per U.S. Dollar	
British Pound	27.85
German Mark	24.66
Japanese Yen	26.83
Swiss Franc	24.24
Per German Mark	
Japanese Yen	10.29
Swiss Franc	18.24

The critical value of the F statistic at the 95% level of significance is approximately 1.39

Swiss Franc/ Deutsche Mark exchange rate. The evidence from Chapter 7 suggested that failure to find any significant difference between the relative variance terms might be consistent with the existence of risk aversion in the forward market.

F tests reveal that for every exchange rate series the variance of the one month forward rate significantly exceeds the variance of the spot rate. Similarly, the variance of the twelve month forward rate significantly exceeds the variance of the one month forward rate in each case. These results lead us to reject the null hypothesis of speculative efficiency. Similarly, tests reveal no significant difference between the pattern of relative variance terms for the Swiss Franc/ Deutsche Mark exchange rate and the other exchange rate series. This is again inconsistent with the null hypothesis of speculative efficiency in the forward market. Thus the conclusion of this section is that evidence rejects the null hypothesis that the forward rate is an unbiased predictor of the future spot rate. The evidence is perhaps consistent with an alternative model framework in which there is risk-aversion in the forward market and the supply of speculative funds at the forward rate equal to the expected future spot rate is less than perfectly elastic.

(ii) Purchasing Power Parity

In the second set of tests the long run equilibrium exchange rate is approximated by the fitted values of s from the regression equation;

(8.11) $s_t = \alpha + \beta (p^d - p^f) + u_t$

where p^d and p^f denote the domestic and foreign consumer price indices, u_t is a random error term and all variables are measured in natural logarithms. Consumer price indices were obtained from the OECD Main Economic Indicators database. The variance of spot, one month and twelve month forward rates around the fitted values of s were calculated for each exchange rate series. The results are reported in Table 8.6.

F tests reveal that for every exchange rate series there is no significant difference between the variance of the spot and one month forward rates around the long run equlibrium exchange rate (see Table 8.7). Moreover, in all cases there is no significant difference between the variance of one and twelve month forward rates around the long run equilibrium exchange rate. Similarly, as in the first set of results noted above, there is no significant change in the pattern of relative variance terms for the the more stable exchange rate series, the Swiss Franc/ Deutsche Mark rate, as compared with the other exchange rates. This evidence again leads us to reject the null hypothesis of speculative efficiency.

Table 8.6 Variance of Spot and Forward Rates Around Long-Run Equilibrium (Purchasing Power Parity)

Per U.S. Dollar	$\sum(s_t - m_t)^2$	$\sum(f_{t-1} - m_t)^2$	$\sum(f_{t-12} - m_t)^2$
British Pound	2.786	2.651	2.323
German Mark	2.430	2.383	2.744
Japanese Yen	1.397	1.418	1.751
Swiss Franc	2.406	2.346	2.655
Per German Mark			
Japanese Yen	2.376	1.997	1.627
Swiss Franc	0.351	0.351	0.458
	$n_1 = 108$	$n_2 = 107$	$n_3 = 96$

$m_t = \hat{s}_t$, where $\hat{s}_t = \hat{\alpha} + \hat{\beta}(p^d - p^f)$ and $\hat{\alpha}, \hat{\beta}$ are estimated from the regression equation $s_t = \alpha + \beta(p^d_t - p^f_t) + u_t$ using OLS.

Table 8.7 Relative Variance Tests Using Purchasing Power Parity Measure of the Long Run Equilibrium Exchange Rate

(a) Variance of Spot Rate Relative to Variance of One Month Forward

Per U.S. Dollar

British Pound	1.05
German Mark	1.02
*Japanese Yen	1.02
Swiss Franc	1.03

Per German Mark

Japanese Yen	1.19
Swiss Franc	1.00

* Variance of one month forward relative to variance of spot.

(b) Variance of Twelve Month Forward Relative to Variance of One Month Forward

Per U.S. Dollar

*British Pound	1.14
German Mark	1.15
Japanese Yen	1.23
Swiss Franc	1.13

Per German Mark

*Japanese Yen	1.23
Swiss Franc	1.30

* Variance of one month forward relative to variance of twelve month forward

The critical value of the F statistic at the 95% level of significance is approximately 1.39

Conclusion

The speculative efficiency hypothesis states that the forward rate is set equal to the expected future spot rate and that expectations are formed using all readily available information. The implication of speculative efficiency is that the forward rate should be an unbiased predictor of the future spot rate. Tests of the speculative efficiency hypothesis in the literature have been inconclusive.

A further avenue of research is provided by the implication of speculative efficiency for the relative variance of spot and forward rates. An increase in the variance of spot rates relative to the variance of forward rates ought to be witnessed in circumstances where the variance of forward prediction errors increases. An alternative hypothesis is provided by the evidence of Chapter 7 in which it was demonstrated that, within a simple portfolio balance model, risk-averse behaviour with inelastic supply of speculative funds at the forward rate equal to the expected future spot rate may lead to no significant difference between the variance of spot and forward rates around the (fixed) long run equilibrium exchange rate.

In this chapter we have presented statistical evidence that, over the interval January 1976 - December 1984, forward prediction errors were increased for six exchange rate series when increasing the length to maturity of the forward contract. Secondly, prediction errors were increased when comparing five exchange rate series with the statistically more stable Swiss Franc/ Deutsche Mark exchange rate. However, in two alternative sets of tests, based on different measures of a long run equilibrium exchange rate which wanders through time, no statistically significant pattern of relative variances of spot and forward rates could be found consistent with the speculative efficiency hypothesis. Thus the conclusion of this chapter is that statistical evidence must lead us to reject the null hypothesis of speculative efficiency and accept the alternative hypothesis of risk-averse behaviour in the forward foreign exchange market.

Chapter 9.

Conclusion.

This study set out to provide a new test of the null hypothesis that speculative efficiency holds in the forward market for foreign exchange. Speculative efficiency has important implications for the theory of exchange rate determination, the conduct of exchange rate policy and the management of exchange rate exposure. A growing literature has evolved in recent years to examine whether the forward exchange rate is an unbiased predictor of the future spot rate. However, previous tests have been inconclusive. This argued the case for a new line of research to be followed.

Previous research has mostly concentrated on the statistical properties of the forward rate as a predictor of the future spot rate. There has been little attempt to explicitly model forward market behaviour. Hence, an alternative to the null hypothesis, based on rigorous analysis of forward market behaviour, has rarely been stated. The original contribution of this study is to consider the joint determination of spot and forward exchange rates within a general equilibrium framework. The adjustment paths of spot and forward exchange rates are examined under alternative assumptions about behaviour in the forward market.

Model simulations demonstrated that, following a monetary disturbance, the variance of the spot rate around its long-run equilibrium path greatly exceeded the variance of the forward rate as the role of speculative activity increased in the forward market. This result did not appear to hinge on the values of other key parameters of the model. These model simulations provided an alternative to the null hypothesis of speculative efficiency in tests based on the relative variance of spot and forward exchange rates. Statistical evidence rejected the null hypothesis of speculative efficiency in favour of the alternative hypothesis that forward market participants are risk-averse.

The principal limitations of this study are twofold. Firstly, the model which forms the core of the paper in Chapter 6 is highly simplistic. Secondly, the number of exchange rate series and the time-period considered restricted the observations available in preparation of the statistical evidence in Chapter 8. Some aspects of the model in Chapter 6, for example the lack of a "supply side" and the simplistic treatment of savings behaviour, are unlikely to have altered the conclusions. However, explicit consideration of expectations formation might have permitted a more thorough specification of an alternative to the null hypothesis. Speculative efficiency is a joint hypothesis of rational expectations and risk-neutrality in the forward market. The assumption of perfect foresight in the model meant that rejection of the null hypothesis could not be explained in terms of possible alternatives which might rule out rational expectations.

Further research might seek to address these criticisms. Firstly, the model might be extended and simulations performed under alternative assumptions about expectations formation. Secondly, statistical tests might be applied to a greater number of observations. Finally, in line with other research, the model might be used to simulate the adjustment paths of spot and forward exchange rates with a time-varying risk premium. The latter might provide new insights and tests of the speculative efficiency hypothesis.

References

1) Adler M, and Dumas B., "Optimal International Acquisition", Journal of Finance, 70, March 1975, pp. 1-20.

2) Adler M. and Dumas B., "Portfolio Choice and the Demand for Forward Exchange", American Economic Review, 66, 1976-2, pp. 332-339.

3) Agmon T. and Amihud Y., "The Forward Exchange Market and Prediction of the Future Spot Rate", Journal of Business Finance, 1981-5, pp.425-437.

4) Aliber R.Z. "The Interest Rate Parity Theory: A Reinterpretation", Journal of Political Economy, 1981-6, pp.1451-1459.

5) Argy V. and Hodjera Z., "Financial Integration and Interest Rate Linkages in Industrial Countries", IMF Staff Papers 1973, 20, March. pp. 1-71.

6) Baillie R.T., Lippens R.E. and McMahon P.C. "Testing Rational Expectations and Efficiency in the Foreign Exchange Market", University of Birmingham Discussion Paper, Series A, No.267.

7) Beenstock M., "The Foreign Exchanges", St. Martin's Press, New York, 1978.

8) Begg D.K.H., "The Rational Expectations Revolution in Macroeconomics", Philip Allan, Oxford, 1982.

9) Bhandari J.S., "A Theory of Exchange Rate Determination and Adjustment", Weltwirtschaftliches Archiv, 4, 1981 pp. 605-621.

10) Bhandari J.S., "Exchange Rate Determination and Adjustment", Praeger, New York, 1982.

11) Bilson J.F.O., "Rational Expectations and the Exchange Rate", in "The Economics of Exchange Rates", Frenkel J.A. and Johnson H.G. (eds.), Addison-Wesley, 1978, p.75-96.

12) Bilson J.F.O., "The Speculative Efficiency Hypothesis", Journal of Business, July 1981, pp. 435-451.

13) Blackhurst R., "The Relation Between the Current Account and the Exchange Rate: A Survey of Recent Literature", in "Multi Country Econometric Models", de Grauwe P. and Peeters T. (eds.), Macmillan, 1983.

14) Branson W.H., "The Minimum Covered Interest Differential Needed for International Arbitrage Activity", Journal of Political Economy, November-December, 1969, pp. 1028-35.

15) Branson W.H., "Asset Markets and Relative Prices in Exchange Rate Determination", Sozial Wissenschaftliche Annalen, Vol. 1, 1977, pp. 69-89.

16) Branson W.H., Haltunnen and Masson P., "Exchange Rates in the Short Run", European Economic Review, 10, 1977, pp. 303-324.

17) Brown B., "The Forward Market in Foreign Exchange", Chapter 4, Croom Helm, 1983.

18) Buiter W.H. and Miller M., "Monetary Policy and International Competitiveness", in Eltis W.A. and Sinclair P.J.N., "The Money Supply and the Exchange Rate", Clarendon Press, 1981.

19) Burt J., Kaen F.R. and Booth G.G., "Foreign Exchange Market Efficiency Under Flexible Exchange Rates", Journal of Finance, 1977, Vol.32, No.4, pp.1325-30

20) Chiang A.C., "Fundamental Methods of Mathematical Economics", McGraw-Hill, 1984.

21) Cornell W.B. ,"Spot Rates, Forward Rates and Exchange Market Efficiency", Journal of Financial Economics, 5, 1977, pp.55-65.

22) Cornell W.B. and Dietrich ,"The Efficiency of the Market for Foreign Exchange Under Floating Exchange Rates", Review of economics and Statistics, February 1978, pp. 111-120.

23) Deutsch H. ,"Arbitrage", Second edition, Pitman, London, 1910.

24) Dooley M.P. and Shafer J.R., "Analysis of Short-Run Exchange Rate Behaviour: March 1973-November 1981", International Monetary Fund, Department Memorandum, 1982/22.

25) Dornbusch R., "Expectations and Exchange Rate Dynamics", Journal of Political Economy, 84, No.6, December 1976, pp.1161-76.

26) Dornbusch R., The Theory of Flexible Exchange Rate Regimes and Macroeconomic Policy" in Frenkel J.A. and Johnson H.G. (eds.) "The Economics of Exchange Rates", Addison-Wesley, 1978, pp. 27-46.

27) Driskill R.A., "Exchange Rate Dynamics, Portfolio Balance and Relative Prices", American Economic Review, September 1980, pp.776-83.

28) Driskill R.A., "Exchange Rate Dynamics: An Empirical Investigation", Journal of Political Economy, Vol.89 No.2, April 1981, pp. 357-71.

29) Driskill R.A., "Exchange Rate Overshooting, the Trade Balance and Rational Expectations", Journal of International Economics, September 1981, pp.361-371.

30) Eaton J. and Turnovsky S.J., "Covered Interest Parity and Exchange Rate Dynamics", Economic Journal, September 1983, pp.555-575.

31) Einzig P., "Some Theoretical Aspects of Forward Exchange", Economic Journal, September, 1936.

32) Einzig P., "A Dynamic Theory of Forward Exchange", London, McMillan, 1961.

33) Fama E.F., "Efficient Capital Markets: A Review of Theory and Empirical Work", Journal of Finance, No.2, May 1970, pp.387-417.

34) Fama E.F., "Foundations of Finance", Basic Books, 1976.

35) Fama E.F. and Farber A., "Money, Bonds and Foreign Exchange", American Economic Review, Vol.69, No.4, September 1979, pp.639-649.

36) Frankel J.A., "Tests of Rational Expectations in the Forward Exchange Market", Southern Economic Journal, April 1980, pp.1083-1101.

37) Frankel J.A., "Money and Portfolio Balance Models of Exchange Rate Determination", in "Economic Inter-Dependence and Flexible Exchange Rates", Bhandari, J.S., and Putnam B.H. (eds.), MIT, 1983.

38) Frenkel J.A., "Elasticities and the Interest Parity Theory", Journal of Political Economy, May-June, pp. 741-47.

39) Frenkel J.A., "Flexible Exchange Rates, Prices and the Role of News: Lessons from the 1970's", in "Economic Interdependence and Flexible Exchange Rates", Bhandari J.S. and Putnam B.H. (eds.), MIT, 1983.

40) Frenkel J.A. and Levich R.M., "Covered Interest Arbitrage: Unexploited Profits?", Journal of Political Economy, April 1975, pp.325-338.

41) Frenkel J.A. and Levich R.M., "Transactions Costs and International Arbitrage: Tranquil Versus Turbulent Periods", Journal of Political Economy, 86, 1977, pp. 1209-1226.

42) Fratianni M. and Wakeman L.M., "The Capital Asset Pricing Model and International Finance", Unpublished Draft.

43) Geweke J. and Feige E., "Some Joint Tests of the Efficiency of the Market for Forward Foreign Exchange", Review of Economics and Statistics, August 1979, pp.334-341.

44) Giddy I. and Dufey G., "The Random Behaviour of Flexible Exchange Rates, Implications for Forecasting", Journal of International Business Studies, Spring 1975, pp. 1-32.

45) Goodman S., "Technical Analysis Still Beats Econometrics", Euromoney, August 1981 (subsequent annual surveys)

46) Granger C.W.J. and Newbold P., "Spurious Regressions in Econometrics", Journal of Econometrics, Vol.2, 1974, pp.111-120.

47) Grauer F.Z.A., Litzenberger R.H. and Stehle R.E., "Sharing Rules and Equilibrium in International Capital Markets Under Uncertainty", Journal of Financial Economics, June 1976, pp. 233-256.

48) Gray M.R. and Turnovsky R.H., "The Stability of Exchange Rate Dynamics Under Perfect Myopic Foresight", International Economic Review, October 1979, pp. 643-660.

49) Haas R.D. "More Evidence on the Role of Speculation in the Canadian Forward Exchange Market", Canadian Journal of Economics, August 1974, pp.496-501.

50) Hakkio C.S. "Expectations and the Forward Exchange Rate", International Economic Review, Vol. 22, No. 3, October 1981, pp.663-678.

51) Hansen L.P. and Hodrick R.J. "Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis", Journal of Political Economy, Vol. 88, No. 5, pp.829-853.

52) Helliwell J. "A Structural Model of the Foreign Exchange Market", Canadian Journal of Economics, February 1969, pp.90-105.

53) Herring R.J. and Marston R.C. "National Monetary Policies and International Financial Markets", North Holland.

54) Hodrick R.J. "International Asset Pricing with Time Varying Risk Premia", Journal of International Economics, II, 1981, pp.573-587.

55) Hutton J.P. "A Model of Short Term Capital Movements, the Foreign Exchange Market and Official Intervention in the United Kingdom, 1963-1970", Review of Economic Studies, 44, February 1977.

56) Huang R.D. "Some Alternative Tests of Forward Exchange Rates as Predictors of Future Spot Rates", Journal of International Money and Finance, 3, 1984, pp.153-167.

57) Jasay A.E. "Bank Rate and Forward Exchange Rate Policy", Banco Nazionale del Lavaro Quarterly Review, 12, March 1958.

58) Johnston R.B. "Some Aspects of the Determination of Euro-Currency Interest Rates", Bank of England Quarterly Bulletin, March 1979.

59) Kaserman D.L. "The Forward Exchange Rate: Its Determination and Behaviour as a Predictor of the Future Spot Rate", Proceedings of the American Statistical Association, 1973, pp.417-422.

60) Kenen P.B. and Allen P.R. "Asset Markets and Exchange Rates: Modelling An Open Economy", Cambridge University Prss, 1980.

61) Kesselman J. "The Role of Speculation on Forward Rate Determination: The Canadian Flexible Dollar, 1953-1960", Canadian Journal of Economics, August 1971, pp. 279-298.

62) Keynes J.M. "The Forward Market in Foreign Exchange", Manchester Guardian Reconstruction Supplement, April 20, 1922.

63) Keynes J.M. "A Tract on Monetary Reform", London, MacMillan, 1923.

64) Kouri P.J.K. "The Exchange Rate and the Balance of Payments in the Short Run and in the Long Run: A Monetary Approach", Scandinavian Journal of Economics, 1976.

65) Kouri P.J.K. "Balance of Payments and the Foreign Exchange Market: A Dynamic Partial Equilibrium Model", in "Economic Interdependence and Flexible Exchange Rates", Bhandari J.S. and Putnam B.H. (eds.) MIT, 1983.

66) Kohlhagen S.W., "The Performance of the Foreign Exchange Markets: 1971-74", Journal of International Business Studies, Fall, 1975.

67) Kohlhagen S.W. "The Behaviour of Foreign Exchange Markets - A Critical Survey of the Empirical Literature", New York University Graduate School of Business Administration, Monograph 1978-83.

68) Laidler D. "The Demand for Money: Theories and Evidence", International Textbook Company, 1970.

69) LeRoy S. and Porter R. "The Present Value Relation: Tests Based on Implied Variance Bounds", Mimeograph, Board Governors Federal Reserve System, 1979.

70) Levich R.M. "Tests of Forecasting Models and Market Efficiency in the International Money Market", in "The Economics of Exchange Rates", Frenkel J.A. and Johnson H.G. (eds.), Addison-Wesley, 1978, pp.129-158.

71) Levich R.M. "Analysing the Accuracy of Foreign Exchange Advisory Services: Theory and Evidence", Working Paper 336, NBER, April 1979.

72) Levich R.M. "Empirical Studies of Exchange Rates: Price Behaviour, Rate Determination and Market Efficiency", NBER Working Paper 1122.

73) Lewis J.P., "An Introduction to Mathematics for Students of Economics", Second Edition, MacMillan, 1969.

74) Lintner J., "The Valuation of Risky Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets", Review of Economics and Statistics, February, 1965.

75) Llewellyn D.T. "International Financial Integration", MacMillan, 1980.

76) Logue D.E., Sweeney R.J., and Willett T.D., "Speculative Behaviour of Foreign Exchange Rates During the Current Float", Journal of Business Research, 6, 1978, pp. 159-174.

77) Lotz W. "Die Wahrungsfrage in Osterreich - Ungarn und ihre Wirtshaftliche und Politische Bedeutung", Schmollers Jahrbutch, vol. 13, 1889.

78) MacDonald R. "Some Tests of the Rational Expectations Hypothesis in the Foreign Exchange Market", University of Manchester Discussion Paper, Number 25, March 1982.

79) McCallum B.T. "The Role of Speculation in the Canadian Forward Exchange Market: Some Estimates Assuming Rational Expectations", Review of Economics and Statistics, May 1977, pp.145-151.

80) Meese R.A. and Singleton K.J. "Rational Expectations, Risk Premia and the Market for Spot and Forward Exchange", International Finance Discussion Papers, Number 165, July 1980.

81) Markowitz H., "Portfolio Selection: Efficient Diversification of Investments", New York, 1959.

82) Meltzer A.H. and Cuckierman A. "What Do Tests of Market Efficiency Show?", Draft Discussion Paper, September 1981.

83) Mussa M., "The Exchange Rate, the Balance of Payments and Monetary Policy Under a Regime of Controlled Floating", in "The Economics of Exchange Rates", Frenkel J.A. and Johnson H.G. (eds.), Addison-Wesley, 1978.

84) Muth J.F. "Rational Expectations and the Theory of Price Movements", Econometrica, 29, 1961, pp.315-355.

85) Niehans J. "Exchange Rate Dynamics With Stock/Flow Interaction", Journal of Political Economy, 1977, vol.85, No.6, pp.1245-57.

86) Officer L.H. and Willett T.D., "The Covered Arbitrage Schedule: A Critical Survey of Recent Developments", Journal of Money, Credit and Banking, March, 1970, pp. 247-257.

87) Papadia F. "Forward Exchange Rates as Predictors of Future Spot Rates and the Efficiency of the Foreign Exchange Market", Journal of Banking and Finance, June 1981, pp.217-240.

88) Pippenger J.E. "The Case for Freely Fluctuating Exchange Rates: Some Evidence", Western Economic Journal, September 1973, pp.314-326.

89) Poole W. "Speculative Prices as Random Walks - An Analysis of Ten Time Series of Flexible Exchange Rates", Southern Economic Journal, April 1967, pp.468-478.

90) Prachowny M.F.J., "A Note on Interest Parity and the Supply of Arbitrage Funds", Journal of Political Economy, May, 1970, pp. 540-45.

91) Reading B., "The Forward Pound", Economic Journal, 1960.

92) Roll R. and Solnik B., "A Pure Foreign Exchange Asset Pricing Model", Journal of International Economics, May 1977.

93) Samuelson P.A., "Proof that Properly Anticipated Prices Fluctuate Randomly", Industrial Management Review, Spring 1965, pp. 41-49

94) Sharpe W.F., "Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk", Journal of Finance, September, 1964.

95) Shiller R.J., "The Volatility of Long Term Interest Rates and Expectations Models of the Term Structure", Journal of Political Economy, 1979, Vol.87, pp. 1190-1219.

96) Singleton K.J., "Expectations Models of the Term Structure and Implied Variance Bounds", Journal of Political Economy, December 1980, pp. 1159-1176.

97) Spraos J., "The Theory of Forward Exchange and Recent Practice", Manchester School of Economic and Social Studies, May 1953.

98) Stein J.E., "The Dynamics of spot and Forward Prices in an Efficient Foreign Exchange Market", American Economic Review, August 1981, pp.656-583.

99) Stein J., "The Forward Rate and Interest Rate Parity", Review of Economic Studies, 32, April 1965.

100) Stockman A.C., "Risk, Information and Forward Exchange Rates", in "The Economics of Exchange Rates", Frenkel J.A. and Johnson H.G. (eds.), Addison-Wesley, 1978.

101) Stoll H.B., "An Empirical Study of the Forward Exchange Market Under Fixed and Flexible Exchange Rate Systems", Canadian Journal of Economics and Political Science, August 1971.

102) Theil H., "Applied Economic Forecasting", North-Holland, 1966.

103) Tobin J., "Liquidity Preference as Behaviour Towards Risk", Review of Economic Studies, February, 1958.

104) Tsiang S.C., "The Theory of Forward Exchange and the Effects of Government Intervention in the Forward Exchange market", IMF Staff Papers, 6, April 1959.

105) Wilson C., "Anticipated Shocks and Exchange Rate Dynamics", Journal of Political Economy, June 1979, pp. 639-647.

106) Wynn and Holden, "An Introduction to Applied Econometric Analysis", MacMillan, 1974.