Division of Research
Graduate School of Business Administration
The University of Michigan

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THE DETERMINATION OF EUROCURRENCY INTEREST RATES

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by

Gunter Dufey and Ian H. Giddy

The University of Michigan
and Columbia University, respectively

Introduction

Bankers, company treasurers, and others who are in a position to borrow or deposit large sums of money must have a thorough understanding of the factors affecting the cost and availability of funds, particularly those factors that will help them to forecast future interest rates. This paper does not provide a technique for forecasting rates in the international money market, but it does attempt to provide two things essential to an understanding of international interest rates: first, an analysis that identifies and integrates the determinants of Eurocurrency interest rates; second, a framework that enables the borrower or lender of funds to compare effective interest rates in the domestic and external money markets, and also in the external markets to compare funds denominated in dollars, French francs, German marks, and so forth.

The structure of this study is simple. It develops the theme that there are close interdependencies between national and Eurocurrency interest rates, between interest rates in different currencies, and between the spot and forward exchange markets that link those currencies. By describing the basic structure of the system, we hope to dispel the

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The authors wish to acknowledge helpful comments on an earlier draft by Prof. Richard J. Herring of the Wharton School without implicating him in the errors that remain.

major misunderstandings that arise primarily from viewing the Eurodollar market in isolation, rather than in relation to competing domestic and foreign currency credit markets and the foreign exchange markets. We also hope to avoid the numerous misleading research findings that arise from the use of poor data for, as anyone familiar with the day-to-day workings of the Euromarkets knows, the conclusions about costs and returns in Eurocurrency dealings are extremely sensitive to the source and timing of the data used. For the purposes of this exposition, however, we have refrained from describing the technical details of Eurorates, e.g., "weekend" and "two-day delivery" effects (except for the insert on page 11). In addition, the body of this paper avoids discussing the many empirical studies on determinants of Eurocurrency interest rates. (The major findings of these studies are critically surveyed in Appendix 1.)

The dollar portion of the Eurocurrency markets will be the focus of discussion partly because the bulk of Eurocurrency transactions occur in dollars, but primarily for convenience of exposition. Keep in mind, however, that what holds for the relationship between the U.S. and Eurodollar markets also holds in principle for the Swiss national market and the EuroSwiss franc market, the British money market and the Eurosterling market, and so forth.

Factors That Determine Eurocurrency Rates

There is a high degree of interaction between the internal and external (Eurocurrency) credit markets, between the external credit markets in different currencies, and between the Eurocurrency and foreign exchange markets. These interdependencies have increased dramatically over the past two decades as the world's financial markets have become increasingly integrated under the impact of growing international trade and investment, and a more flexible international monetary system. Bankers, corporate treasurers, and others involved in the money markets are rapidly recognizing that they cannot ignore the alternatives available to them and their competitors in foreign and international money markets. Indeed most major banks, as the most active participants in money markets, have recognized these interdependencies by centralizing their domestic and foreign money market and foreign exchange operations in a single trading room.

Eurocurrency interest rates are dominated by two factors: competing credit markets and exchange rate expectations. The relative influence of these two factors and of various credit markets, however, varies between different currencies and with different international monetary conditions. Consider the Eurosterling market, for example. In the absence of controls on capital movements, U.K. domestic rates are closely related to Eurosterling rates, and under completely fixed exchange rates both are influenced by conditions in foreign-currency money markets.

Under conditions of exchange rate uncertainty, the influence of foreign-currency money markets is modified by exchange rate expectations. Both foreign credit conditions and exchange rate expectations have a greater influence on Eurosterling rates when Britain imposes capital controls which reduce the influence of the domestic money market on the external market and vice-versa. Severe uncertainties concerning the soundness of institutions in one particular segment of the international money market tend to break down the normal relationships between that segment and competing domestic (or national) credit markets, as happened during the months following the collapse of Bankhaus Herstatt in the summer of 1974. Similarly, severe exchange rate uncertainties tend to reduce the influence of competing credit conditions and increase that of exchange rate expectations. Finally, the relative size of the various credit markets affect the relative importance of different influences on particular Eurorates; for example, Eurodollar rates are dominated by the huge U.S. money market and U.S. monetary policy but rates in the relatively small guilder credit markets, both internal and external, are much more subject to the influence of conditions in other credit markets (Eurocurrency and national) and in the foreign exchange markets.

All these influences are described more explicitly in later sections. To sum up, however, one may list the following as being the major influences on interest rates in any particular Eurocurrency market (such as the Eurosterling market):

1. domestic credit conditions
2. domestic capital controls
3. exchange rate expectations
4. foreign credit conditions
5. foreign capital controls
6. risk factors
7. transactions costs

This study concentrates on the first five factors since, under normal conditions, the transactions costs and risk factors may be regarded as relatively minor and unchanging. Banks usually eliminate the exchange risk in Eurocurrency borrowing or lending by matching the currency-denomination of their assets and their liabilities or through hedging exposed positions in the forward exchange market. Default risks are insignificant in determining relative interest rates because of the size and stability of the bulk of Eurobanks and also because the choice of deposits or loans in different financial centers frequently involves the same bank--the Chase Manhattan Bank, for example, accepts dollar deposits in London or New York, French franc deposits in Paris or Geneva, and a host of other combinations. The only risks of any importance are those arising from the possibility of government-imposed capital controls and other restrictions that might inhibit the transfer of funds from one country to another or the nonresident convertibility of a particular currency. Conceivably there could be controls to block Eurocurrency deposits in one of the financial centers where such deposits are held. Alternatively, the authorities of the country whose currency is used to denominate Eurodeposits could restrict the use of that currency as a means of payment for nonresidents. Consequently, even in the absence of exchange risk and default risk one cannot regard New York dollar, Eurodollar and hedged Eurosterling deposits as perfect substitutes. In practice, however, Eurocurrency operations tend to be limited to those currencies and financial centers where such risks are minimal. Hence there is little risk to deter Eurobanks from engaging in extensive arbitrage operations that keep rates in different currencies and financial centers strictly in line.

Finally, transactions costs in the Eurocurrency interbank market, where the bulk of the activity occurs, are rather constant and are directly related to rate fluctuations. In addition, these costs are so small in relation to the amounts involved that they exert a negligible influence on arbitrage incentives.[1]

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[1] The total transactions costs, including both the bid-ask spread and the brokerage fee in the interbank deposit market and the cost of foreign exchange transactions, have been estimated to be 0.15 percent or less. See Jacob A. Frenkel and Richard M. Levich, "Covered Interest Arbitrage: Unexploited Profits?" Journal of Political Economy 83, No. 2 (1975): 325-38.

Competing Internal and External Credit Markets

The various segments of the Eurocurrency market are external money markets in which credit is intermediated by financial institutions located outside of the countries where the respective currencies are legal tender. The focus of this section and the next will be the nature of the competition and arbitrage between each national money market (such as the New York market) and the corresponding external market (such as the dollar-denominated portion of the Eurocurrency market). This section compares deposit rates in the internal and external credit markets; it then compares borrowing rates in the two markets; and finally it combines the two to compare domestic banking margins or spreads with those in the Eurobanking markets.

These issues can be approached by asking some very practical questions about the reasons for the growth of the Eurodollar market. First, why would a depositor entrust his dollar-denominated time deposit to a financial institutions outside the United States, when the natural alternative is a bank in the United States?

While familiarity, similar business hours, and, in special circumstances, fear of interference by U.S. authorities may occasionally account for such deposits being offered to financial institutions outside the United States, these factors cannot and do not account for more than a small fraction of the funds that are intermediated in the Eurodollar market. In the absence of perceived differences in risk between institutions inside and outside the United States, the answer becomes a matter of price. In other words, financial institutions outside the United States must offer a higher rate on U.S.-dollar denominated deposits than would be available to depositors from institutions that operate inside the United States.

Second, on the lending side the question is: Why do borrowers go to institutions outside the United States when U.S. financial institutions are the obvious place to obtain a dollar loan?

Foreign institutions can compete successfully in the long run only if they offer a lower effective rate on loans. Again, while factors such as familiarity, business hours, and communications may play a role, in a world of relatively large-scale transactions, usually in units of $1 million or more, where the transactors are large banks and corporations, public entities, and governments, the impact of such factors is minimal, especially in view of modern communication technology and institutions having resident operations in many countries. With the deposit rates higher and effective lending rates lower, financial institutions outside the United States must be able to get by on a lower spread, i.e., a smaller margin between the deposit rate and the lending rate as is shown in Figure 1. Out of this margin the financial institution must cover its various costs including a profit sufficiently large to justify remaining in this kind of banking business.

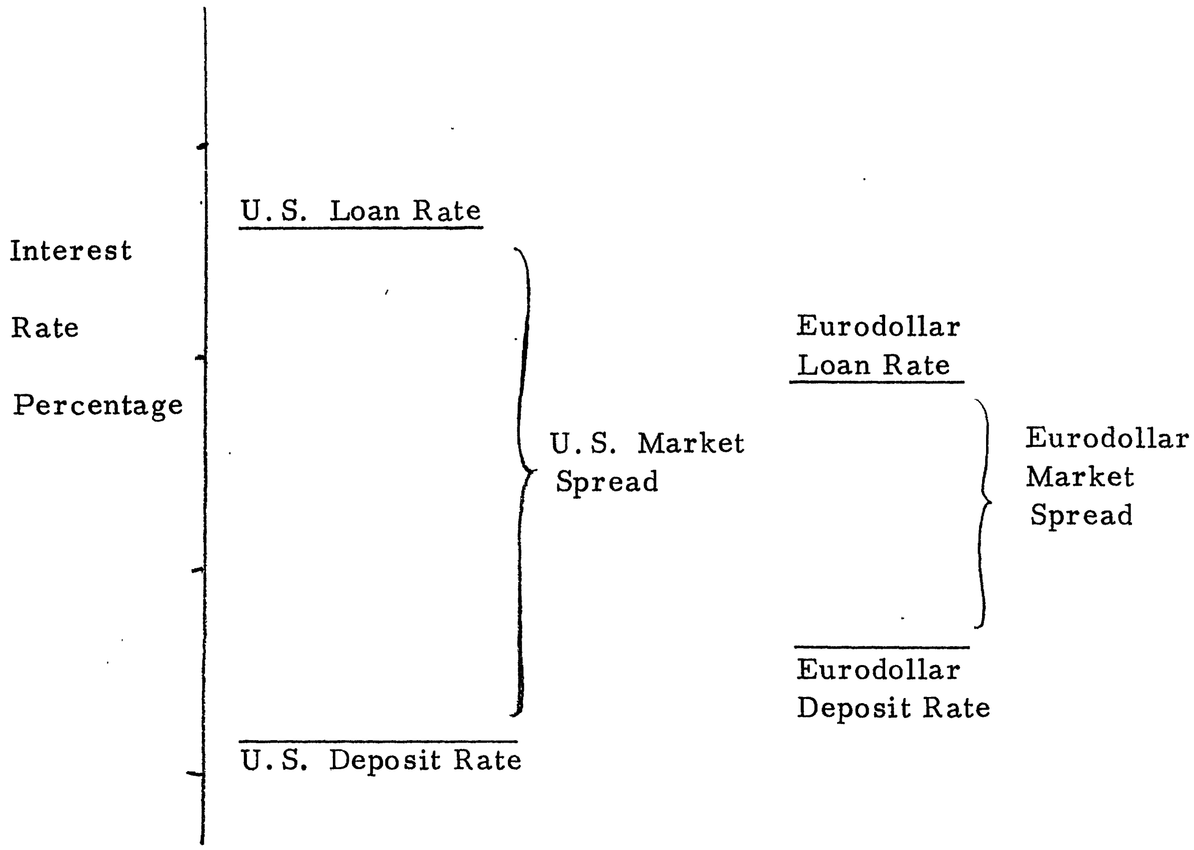

Fig. 1. Eurodollar and national loan and deposit rates.

This raises the question: Why do financial institutions outside the United States seem to be able, systematically, to live on spreads smaller than those operating in the United States when it comes to bidding for dollar-denominated loans?

The factors that enable Eurobanks to operate profitably on narrower margins than domestic banks, and hence to competitively take substantial portions of the financial intermediation business away from domestic banks are discussed in some detail in another paper. They may be summarized as follows:

1. The absence of statutory reserve requirements, official control on the volume of lending by banks, deposit insurance fees, and similar regulations along these lines, which are typically imposed in national markets.
2. The absence of either official restrictions (such as Regulation Q in the United States) or private restraints (such as banking cartels) on the level of interest rates.
3. The high degree of competitiveness in and virtually unrestricted entry to, the international money market.

Hence this section concludes: for the Euromarkets to survive, the spread between Eurocurrency borrowing rates and lending rates must, and can, be narrower than those in national money markets. From this relationship between the national and external sectors of the money market follows the general rule that the theoretical upper limit for the lending rate in the Eurocurrency market is represented by the effective lending rate in the corresponding national market, while the theoretical lower limit for the deposit rate is the corresponding deposit rate in the respective national money market.

In practice, of course, there is no such thing as <u>the</u> interest rate and one must be exceedingly careful to use the correct measure of the effective rates available to particular borrowers or depositors under particular circumstances. Some of the problems of interest rate definition and measurement are summarized in the insert below.

The Myth of "The" Interest Rate

Any examination of interest rates in competing credit markets must of course be concerned with effective, rather than nominal rates. Translating nominal rates into effective rates can introduce conceptual and practical difficulties. To illustrate, while the nominal rate in the United States money market is usually given by the prime rate, the true cost of a loan to a corporate borrower--which in periods of tight money may involve up to 30 percent additional compensating balance requirements, an "equity kicker," and the promise to conduct all business for the next ten years with a particular financial institution--is far beyond that indicated by the prime rate. In contrast, rates in the Eurodollar market are quoted on what is essentially a net basis and the true cost is easier to ascertain.

Even in the Eurodollar market, however, several measurement problems can be identified. The Eurodollar rate most frequently employed is the London interbank rate, or simply the arithmetic average of the interbank bid and offer interest rates. These are the borrowing ("bid") and lending ("offer" or "ask") rates quoted by major banks in the

London wholesale Eurocurrency market, i. e., the rates at which they are willing to borrow and lend dollar funds among themselves. During normal times the interbank bid and offer rates are separated by as little as 1/8 of one percent. Even these rates can be misleading since the biggest institutions sometimes manage to obtain or deposit funds at rates more favorable than the prevailing interbank rates. With the tiering of interbank rates in the months following the uncertainties of early 1974, these rates were hard to pinpoint since the number of really prime banks with unquestioned credit was extremely small, and the membership of that group changed almost hourly depending on the prevailing rumors. Nevertheless, the offer rate has become the fundamental base rate on which actual charges for all but interbank borrowers--the wholesale market--are computed. In the typical corporate loan agreement this is specified as the arithmetic average of the rates at which six major institutions in London would be willing to deposit dollar funds in or lend to each other at a certain time during the morning. This is the well-known London interbank offer rate, or LIBOR. The actual charge to the final borrower would then be fixed at a certain contractually-determined spread above LIBOR. This spread might range anywhere from 3/4 of a percent to 3 percent and more depending on the borrower, general market conditions, the maturity, and other factors.

From a borrower's point of view, then, LIBOR plus the appropriate spread represents the effective lending rate, after special conditions of the loan agreement have been factored in, although Eurodollar loans tend to be rather straight forward as a general rule.

In order to compare Eurodollar borrowing rates with those available in the United States, the prime rate must at least be adjusted for the cost of maintaining interest-free compensating balances, which are generally in the region of 15 to 20 percent of the loan. This may be difficult to do, not only because these required balances vary by borrower and market conditions, but also because borrowers must hold cash balances anyway and hence the interest foregone may not be a good measure of the true opportunity cost of the funds.

As a practical matter, the cost of commercial paper issued by U.S. corporations, plus the cost of maintaining lines of credit to back up the paper, may be the best proxy for the U.S. lending rate. It has the advantage of being objective, although at times it may deviate from loan rates because the commercial paper market becomes very thin in periods when corporate liquidity becomes a major concern of investors.

Similar problems occur on the deposit side. The Euro-deposit rate is usually compared to the rates on large, negotiable Certificates of Deposit (CDs) in the U.S. mone market. This was acceptable for periods when market rates for CDs were below interest rate ceilings, such as Regulation Q, or since ceilings on such CDs have been abolished. However, during other times when interest rates were above such ceilings, even the rates for CDs in the secondary market were not true indicators of domestic deposit rates because of the increasing shortage of such instruments which developed when CDs outstanding matured and new CDs at the artificially low ceiling rate were not acceptable to lenders.

Errors far more serious than those outlined above, however, would result if one were to compare the London interbank rate with rates on securities of a completely different character, such as U.S. Treasury Bills. Yet this is exactly what a number of studies of Eurodollar interest rates have done. Treasury Bills are issued by the U.S. government, a borrower that is hardly representative of U.S. issuing institutions in general. Moreover, since a number of investors are constrained in their investment behavior insofar as they must invest in Treasury Bills for legal and regulatory reasons, this rate is a very poor proxy for "the" U.S. money market.

In summary, then, defining rates requires great care to avoid misinterpretations when analyzing the basic relationship between rates in the national market and those in the corresponding external market.

Capital Controls and Divided Credit Markets

In the absence of restrictions on borrower-arbitrage or depositor-arbitrage between the internal and external markets for credit denominated in a particular currency, Eurorates will fluctuate almost entirely in correspondence with domestic rates and will, as has been shown, be limited by the upper and lower bounds of the effective domestic loan and deposit rates. This section examines two related questions: what happens when arbitrage is inhibited by controls on the movement of funds into or out of a country? And what causes Eurorates to move up or down within the limits set by domestic rates?

Government-imposed capital controls, to the extent that they are effective, impede interest rate arbitrage and allow Eurodollar interest rates to break through the limits set by domestic rates. This is illustrated in Figure 2.

Consider, for example, the effect of U.S. capital controls on Eurodollar rates. The program of Foreign Direct Investment Regulations, which was put in effect in 1965 and abolished at the beginning of 1974, effectively compelled U.S. multinational corporations to finance their overseas operations with funds raised outside the United States. At the same time, banks and financial institutions in the United States were prevented by the Voluntary Restraint Program from increasing the level of loans to foreign entities. The Interest Equalization Tax, finally, discouraged the majority of foreign borrowers from raising funds in the United States bond market. The result of all this was that in effect Eurodollar lending rates could, and did, move above the theoretical limit set by the effective U.S. lending rate as one may see in Figure 2. One way to interpret this phenomenon is to say that as a result of controls, the effective upper limit for Eurodollar rates can be raised above the control-free limit to an extent dependent on the effectiveness of the controls.

In a similar fashion, controls limiting depositor-arbitrage may result in Eurorates falling below corresponding domestic deposit rates. For example; German and Swiss restrictions on deposits by nonresidents --implemented through the imposition of zero or even negative interest rates--make the effective floor for EuroDM and EuroSwiss/franc deposits drop lower than the floor that would exist without such restrictions.

It should not be concluded (as some writers have done) that the enlargement of the limits through restrictions on credit operations between national and international markets implies that such restrictions are a cause for the growth of the external markets. While the general rule holds that the wider the effective limits, the greater the incentive for external intermediation, this effect is offset by the increased difficulties of conducting such operations. The widely alleged reason for the growth of the Eurodollar market specifically and the Eurocurrency market in general, i.e., the various U.S. control programs, has been vastly overestimated in the literature. This observation is verified by the continued growth of the market following the removal of the U.S. capital controls.

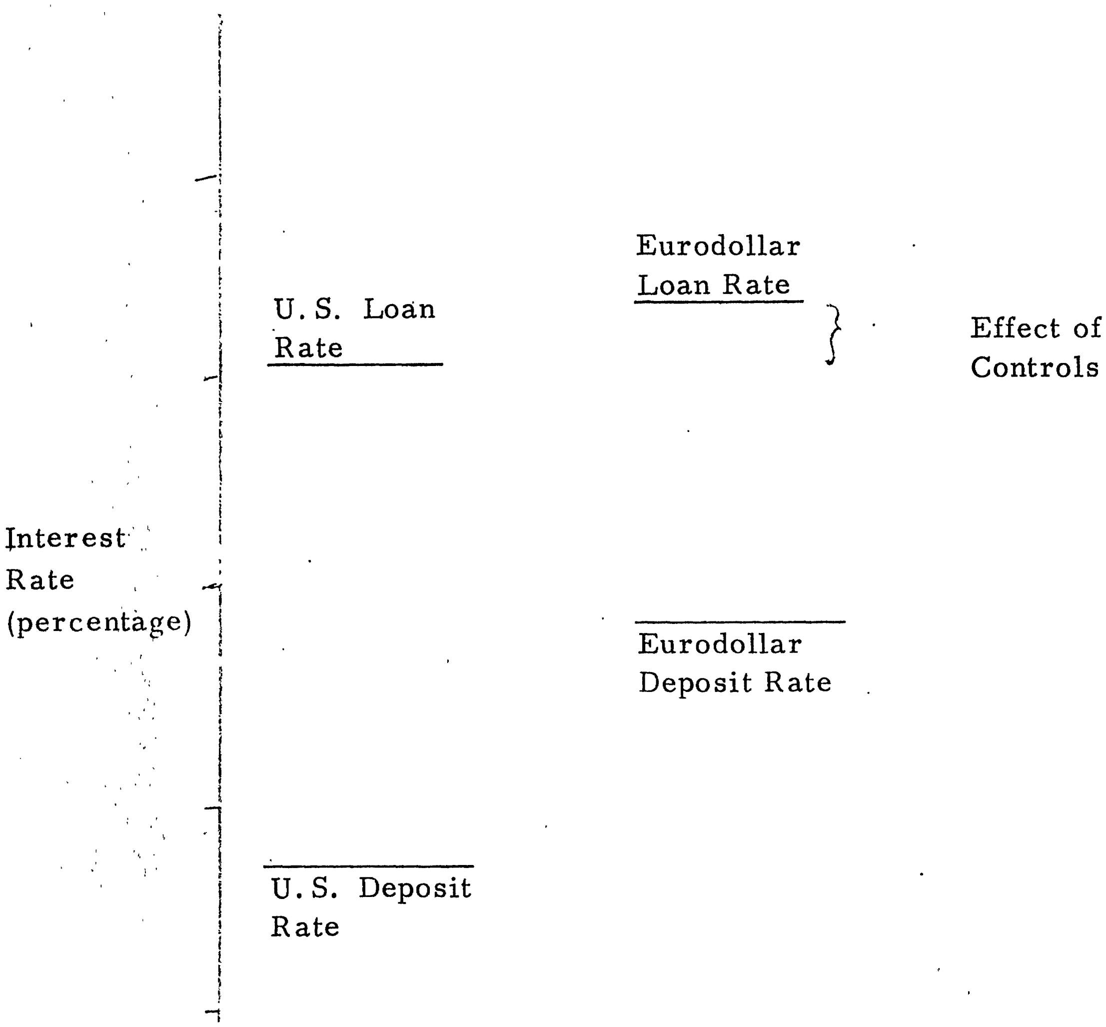

Fig. 2. The effect of capital controls on Eurodollar interest rates.

What determines the movements of Eurorates within the bounds set by domestic rates and capital controls? There are three major influences on these movements:

1. foreign credit conditions,
2. exchange rate speculation,
3. unfamiliarity and risk perceptions that inhibit arbitrage.

In the absence of perceived risk or unfamiliarity, foreign credit conditions and currency expectations would pull Eurodollar rates toward their upper or lower limits. High interest rates abroad or expectations of a relative appreciation of foreign currencies would induce people to borrow Eurodollars in order to buy foreign currencies and so would pull Eurodollar rates up against their effective ceiling. Conversely if foreign rates were low or foreign currencies were viewed as being weak, people would prefer Eurodollar deposits and Eurodollar rates would settle on their effective floor.

If borrowers and lenders were completely indifferent to domestic and external money markets, loan rates and deposit rates in the two sets of markets would tend to be equalized. This is seldom the case, however, as Figure 3 suggests. Eurorates apparently have seldom been close to U.S. loan or deposit rates for long except when capital controls were in effect.[1] One may hypothesize two kinds of perceptual barriers

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[1]Note, however, that the data for this figure rely on the calculation of effective U.S. loan rates assuming 15 percent compensating balances; in many cases, of course, actual loan rates will be higher or lower depending on the marginal cost to the firm of maintaining compensating balances.

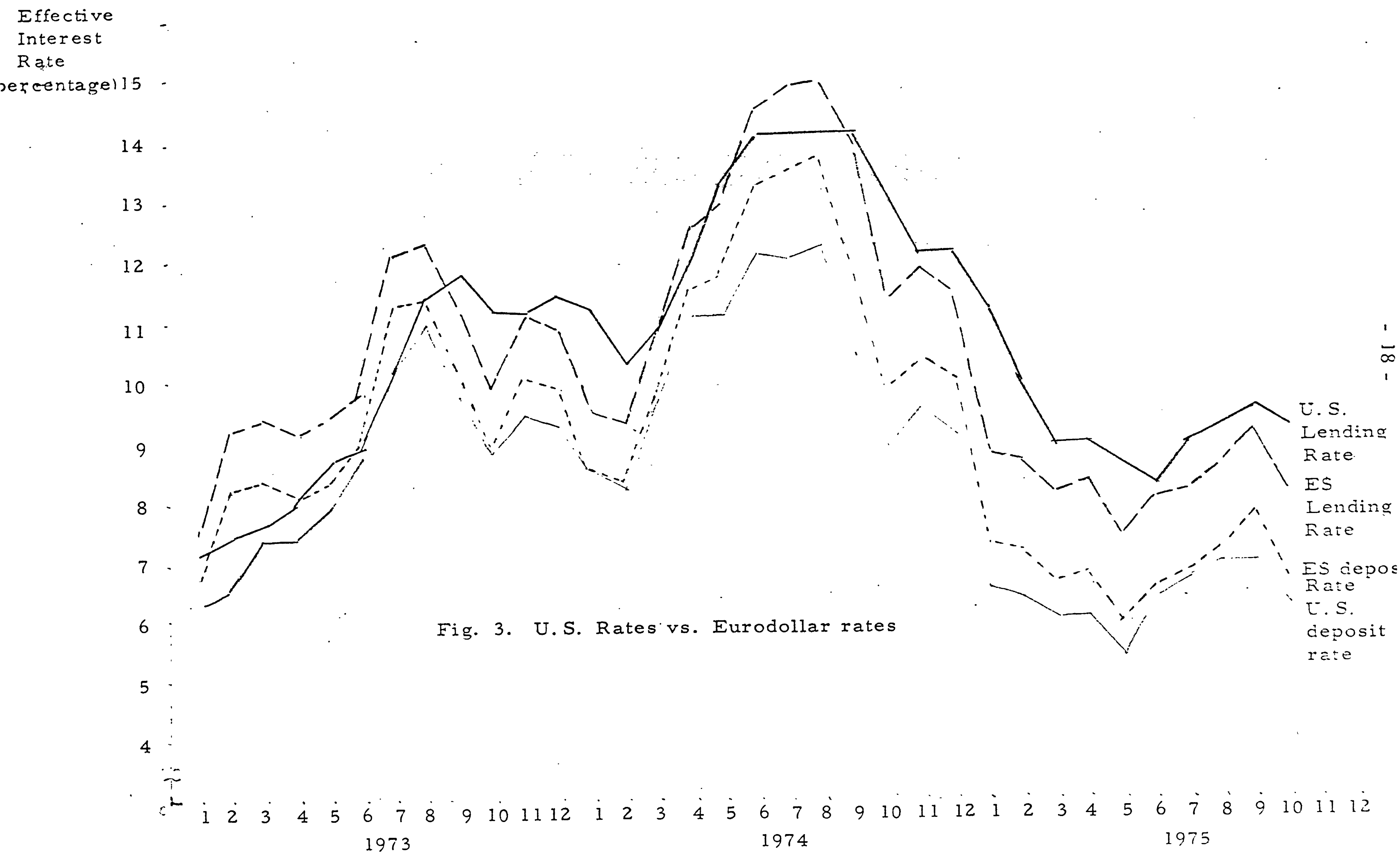


Fig. 3. U.S. Rates vs. Eurodollar rates

Sources: All data are month-end.

U.S. lending rate = U.S. prime rate adjusted by compensating balance requirement (15%)
U.S. prime rates from World Financial Market

Eurodollar lending rate = London Interbank offer rate (LIBOR) + premium
LIBOR from Financial Times
Premiums from World Financial Market

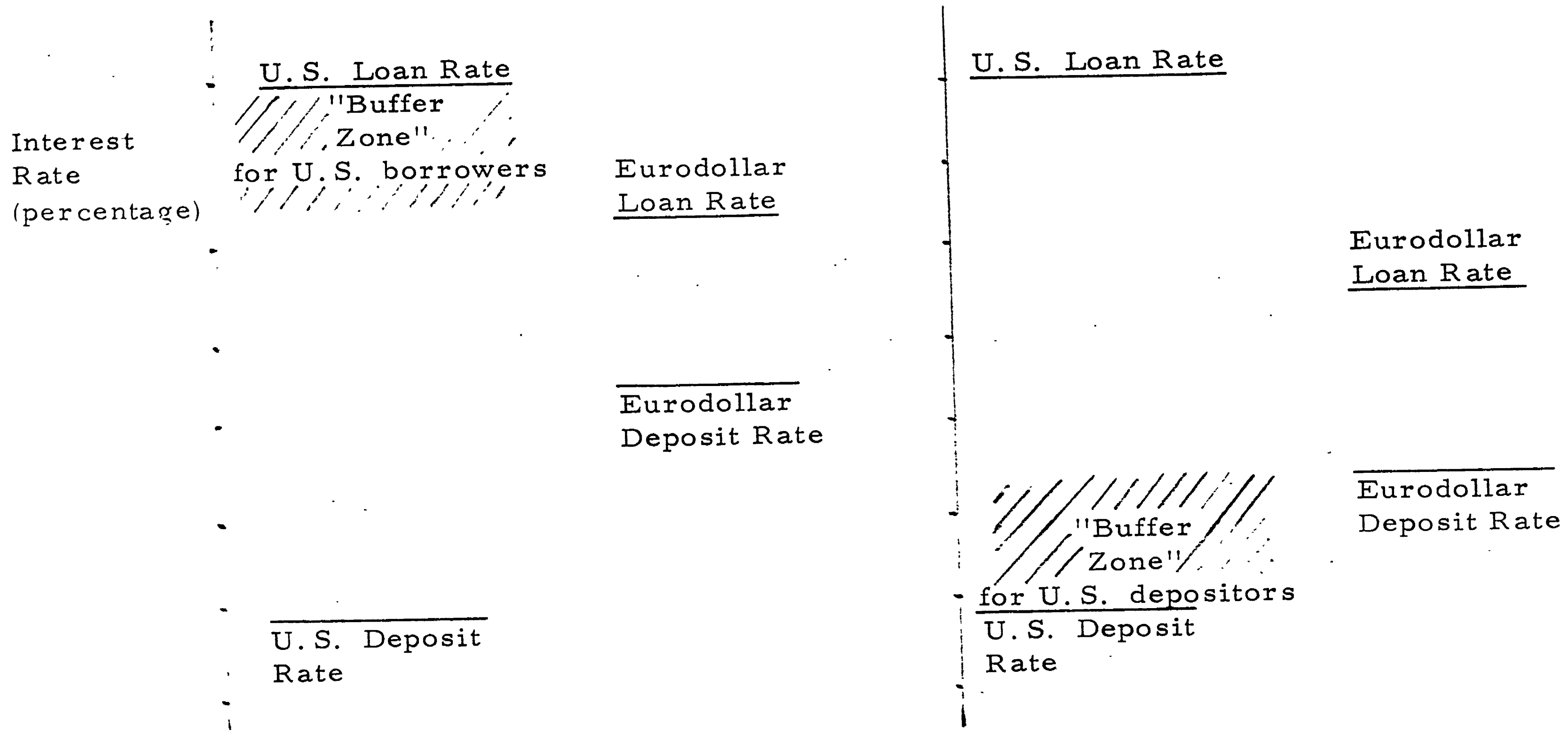
Eurodollar deposit rate = London Interbank bid rate (LIBIR)
LIBIR from Financial Times

U.S. deposit rate = U.S. certificate of deposit rates
USCD rates from Bank & Quotation Record

to arbitrage at the margin, depending on whether one takes the American or foreign point of view.

For U.S. depositors and lenders there may exist ill-defined buffer zones that resist arbitrage at the margin, as is illustrated in Figure 4. On the deposit side, U.S. owners of funds may perceive slighly greater risks or information costs in holding Eurodollar deposits, particularly since the market for the latter is much thinner than the corresponding U.S. money market. And the financial managers of even large international firms often are willing to pay a slightly higher loan rate for traditional U.S. dollar loans. They regard these as being somewhat less risky than Eurodollar loans because the drawdown of U.S. funds does not involve even the remote danger of U.S. government controls or of capital inflows or blockage by the foreign government in whose jurisdiction the Eurobank operates.

However, the converse is not true for foreign entities, such as European corporations. These depositors would not accept lower Eurodollar deposit rates than are available in the United States because U.S. capital controls would affect Eurodollar deposits in exactly the same way as they would affect deposits in New York. The reason is that all dollar deposits have ultimately to be paid through a bank located in the U.S. Thus restrictions on payments to foreigners would prevent foreign Eurodollar depositors from receiving their funds just as much as if their



(a) Eurodollar rates when dollar loans are relatively more attractive than foreign-currency loans.

(b) Eurodollar rates when dollar deposits are relatively more attractive than foreign currency deposits.

Fig. 4. The movement of Eurodollar relative to U.S. rates.

deposits were in New York. Indeed, dollar deposits in London face the additional risk of controls by the British authorities. Hence Eurorates are unlikely ever to drop below corresponding domestic rates. Convenience, familiarity, and identical operating hours may mitigate the above to some extent, by creating a slight bias for non-U. S. investors in favor of Eurodollar deposits. These influences, however, do not appear to predominate.

Competing Eurocurrency Markets: Interest Rate Arbitrage and Currency Expectations

The last two sections described the relationship between Eurorates and corresponding domestic rates. Although the discussion focused on the U.S. and Eurodollar markets, the same set of relationships applies to the internal and external markets for credit in each major currency. An examination of rates for Eurosterling, EuroSwiss francs, [1] Eurodeutsche marks, Euroguilders, and so forth should reveal how closely these rates are bounded by corresponding domestic rates except when capital controls inhibit arbitrage. The next question, therefore, is: What is the

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[1] The apparently large discrepancies between EuroSwiss and internal Swiss rates do not contradict this statement but provide an example of how careful one has to be in interpreting published rates (see insert, pp. 11-13). Quoted Swiss deposit rates may reflect oligopolistic practices on the part of Swiss banks, the lack of interest sensitivity of a certain class of depositors in Swiss banks, and/or services connected with deposits that are not reflected in quoted rates.

relationship between rates in different segments of the Eurocurrency market? For example, how do Euro-DM rates influence Eurosterling rates and vice versa?

The answer has two parts. First, each Eurorate influences and is influenced directly by the level of interest rates in other Eurocurrency markets, and hence by the level of rates in the corresponding domestic credit markets. Other things being equal, a rise in German interest rates, for example, will immediately result in an equal rise in the EuroDM interest rate which in turn will tend to raise interest rates in other currencies. The second part of the answer concerns the influence of currency expectations as reflected in forward exchange rates. Exchange rate expectations keep different interest rates in different Eurocurrency markets and temper the influence of a change in one currency's rates on those in other currencies. Changes in exchange rate expectations, themselves, cause rates to change. For example, other things being equal, a shift in the market's expected rate of change in the pound/French franc exchange rate will produce an interest rate change in the Eurosterling market, or in the EuroFrench franc market, or (as is more likely) both. These mutual influences are illustrated in Figure 5.

One may study the relationship between Eurocurrency interest rates and the foreign exchange markets by looking at the behavior of borrowers and lenders who are considering the use of alternate Eurocurrency

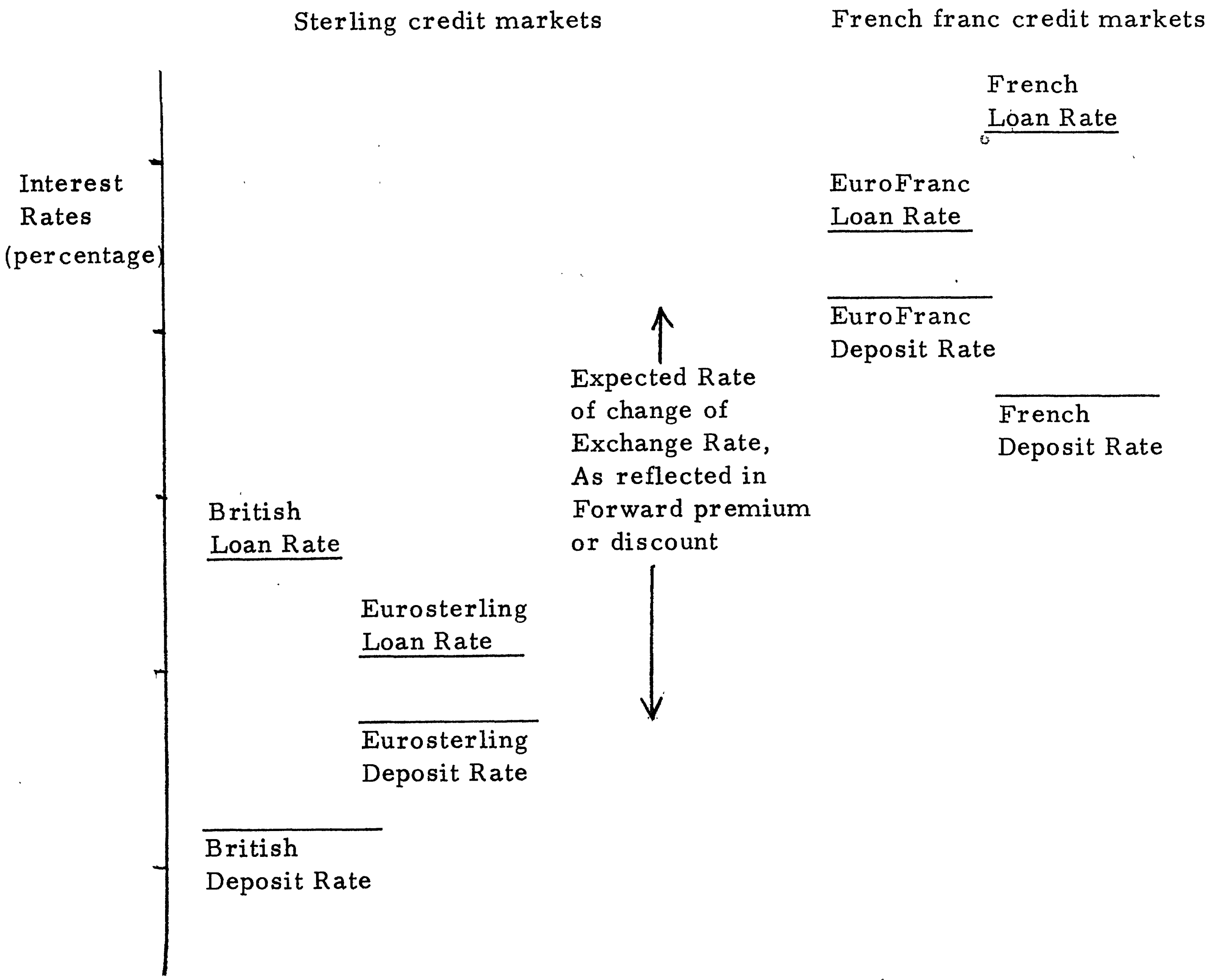


Fig. 5. Interest rate relationships in the Eurocurrency markets.

markets and bankers who are willing at any time to move funds from one market to another in order to make profits. In a world of changing exchange rates, both sets of transactors are fully aware of the possibility of losses or gains from exchange rate changes.

In order to isolate the effect of exchange rate expectations on Eurorates it is initially assumed that there are two markets, Eurodollars and Euro-DM, and that the Euro-DM market is completely cut off from the German credit market by capital controls. (This situation was, in fact, approximated in reality during the summer of 1972. At that time, rates in Germany were considerably higher than elsewhere, but a 100 percent cash deposit requirement and other restrictions were quite effective--temporarily at least--in preventing banks, firms, and individuals resident in Germany from borrowing abroad in any currency, including German marks.)

First, consider the actions of Eurobankers who, it is assumed, readily move funds between the dollar and DM Euromarkets but always do so in such a way as to avoid exchange losses--that is, by hedging their transactions in the forward exchange market (see insert on p. 25). This is referred to as interest rate arbitrage and leads to a well-known relationship between interest rates and spot and forward exchange rates called "interest rate parity." Interest rate parity also results from the fact that Eurobanks stand ready to offer loans or deposits in any

Spot and Forward Exchange Markets

The foreign exchange markets for each pair of currencies consists of two parts, the spot market, where payment (delivery) is made right away (in practice this means usually the second business day) and the forward market. The rate in the forward market is a price for foreign currency set at the time the transaction is agreed to but with the actual exchange, or delivery, taking place at a specified time in the future. This commitment to exchange currencies at a previously agreed exchange rate is usually referred to as a forward contract.

The forward exchange market is used by both banks and companies in order to cover or hedge their future cash flows in foreign currencies. The forward contract guarantees an exchange rate at which currencies will be sold or bought, and so eliminates the chance of exchange rate losses for any particular transaction. The forward rate that the parties agree upon depends on the parties' expectations regarding the future behavior of the exchange rate. Under normal circumstances the forward rate tends to equal the market participants' best guess as to the future spot exchange rate. If this were not the case, and if, for example, many believed that the future spot rate would be below the prevailing forward rate, they would tend to offer more for forward delivery and drive the forward rate down toward the expected future rate.

The extent to which the forward exchange rate represents market's forecast of the future spot exchange rate is a question that continues to occupy the attention of forecasters and students of the foreign exchange market. There appear to be three major views. The first argues that the forward rate is an unbiased predictor of the future spot rate, because speculative transactions always bid the forward rate up or down to the point where it equals the expected spot rate. The second view, a modification of the first, argues that transactions costs are likely to render the forward rate a biased predictor of the future spot rate. Because people will not act upon profit opportunities in the forward market unless the expected profits exceed transactions costs, the forward rate will not always respond immediately to changes in the expected spot rate. Hence the forward rate may underestimate or overestimate the expected spot rate.

A third theory purports that investors will act on speculative profit opportunities only if the expected profits are sufficient to compensate them for bearing risk. The existence of a premium for risk would again make the forward rate a biased predictor of the future spot rate. According to financial theory, the size of the risk premium would be a function of the covariance of returns from forward speculation with returns on some market portfolio of assets. In other words, the supply of speculative funds may not be perfectly elastic because of investors' risk aversion.

We may summarize the second and third views by stating that the forward rate may differ from the expected spot rate by a "transactions premium" arising from transactions costs and a covariance premium. Transactions costs are positive. But the covariance premium may be positive (in which case it would increase the bias), negative (in which case it would decrease the transactions-cost bias) or zero. There exists no empirical evidence that the covariance of returns from forward speculation with a market index is either very large or consistently positive or negative.

The above remarks may be clarified with the aid of the diagram below plotting the forward rate and the expected spot rate for German marks. Assume that transactions costs and the risk premium together constitute a constant transactions premium equal to k. Then, if the spot rate that investors expect to prevail in the future $E(S_{t+1})$ rises above the current forward rate F_t, the forward rate will be bid up until it differs from the expected spot rate only by the transactions premium k:

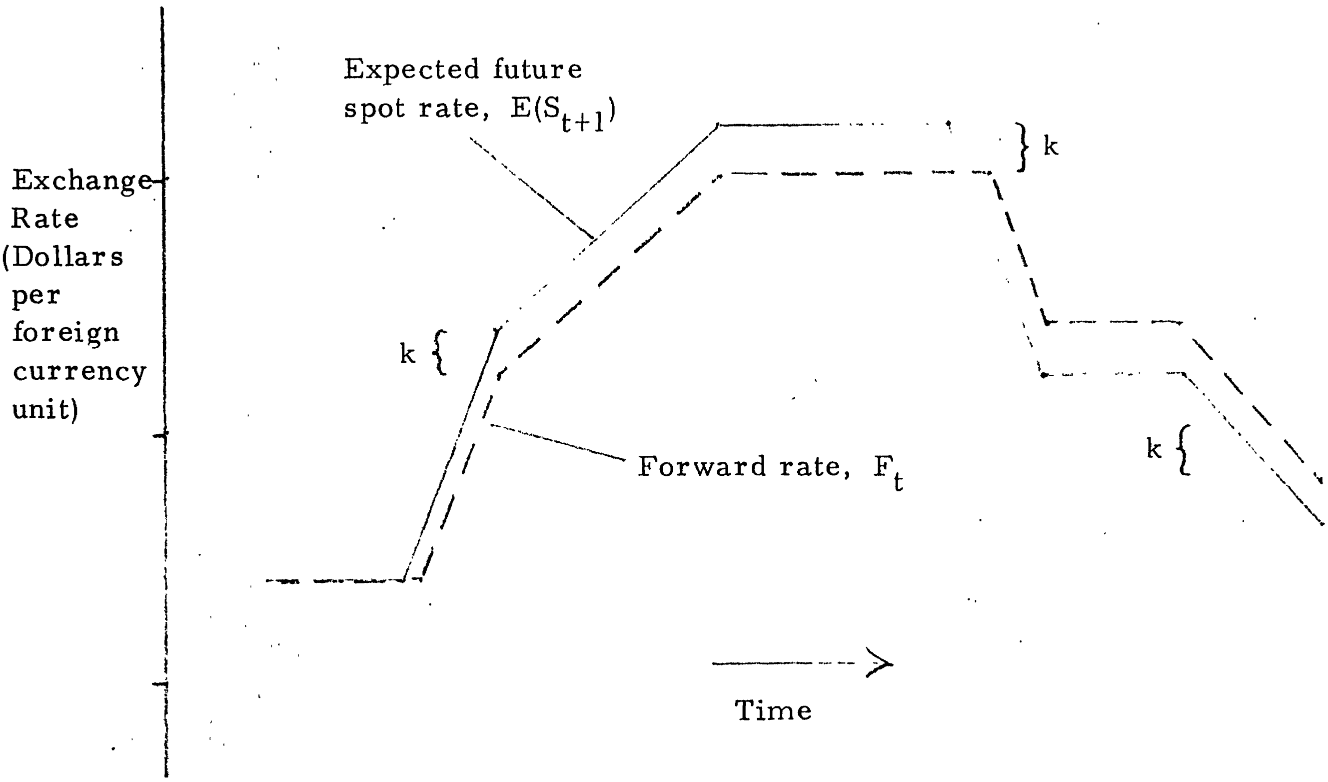
$$E(S_{t+1}) = F_t + k \, .$$

In the diagram, we may see that when the expected spot rate is <u>rising,</u> the forward rate <u>underestimates</u> the expected spot rate by k.

If the expected spot rate then drops below the forward rate, investors will profit from selling German marks forward and the forward rate will be bid down until it is only k above the expected spot rate:

$$E(S_{t+1}) = F_t - k$$

The diagram shows that when the expected spot rate <u>falls</u>, the forward rate <u>overestimates</u> the expected spot rate by k.



Relation over time between forward rate and expected future spot rate with transactions premium of k.

Adapted from: Richard M. Levich, "Tests of Foreign Exchange Forecasting Models and Market Efficiency," NYU Working Paper #75-88, Nov. 1975.

Of course, if either the covariance (risk) premium or transactions costs are not constant, then the bias k may widen or narrow over time. On the other hand, the efficiency and competitiveness of the major foreign exchange markets suggest that transactions costs are likely to be small; and as was suggested above, the covariance premium is unlikely to differ much. Hence one would expect the forward rate to differ little from the expected spot rate. This is borne out by the evidence cited in Appendix 2, and in the remainder of this paper we assume that the forward rate provides a reasonably unbiased estimate of the expected spot rate.

Eurocurrency but they are unwilling to have a net exposed position in loans or deposits. If, for example, a Eurobank offers both Eurodollar and Euro-DM deposits and loans and finds itself with an imbalance of loans and deposits in each currency, it will cover this net imbalance through use of the forward market. Figure 6 illustrates this point. The purpose of covering the net exposed dollar assets in this illustration is, of course, to protect the bank from being adversely affected should the dollar have weakened relative to the German mark by the time the deposits and loans mature. But if the dollar is expected to weaken, the bank will have to pay a premium for the forward purchase of German marks. Hence the bank will only be willing to convert Euro-DM deposits into dollar loans if the Euro-DM deposit rate <u>plus</u> the $/DM forward premium is equal to or lower than the cost of dollar deposits. Similarly, banks hedging a net exposed asset position in German marks will be willing to convert Eurodollar deposits into mark loans only if the Eurodollar deposits rate <u>minus</u> the DM/$ forward discount is equal to or lower than the cost of mark deposits. In equilibrium, then, the forward premium or discount will tend to settle at a rate exactly equal to the interest rate differential between two Eurocurrencies.

This effect also will be brought about through the process of covered interest arbitrage undertaken by large international banks. Covered interest arbitrage involves the rapid movement of funds between

Assets	Liabilities	
Eurodollar loans $60 m.	Eurodollar deposits $50 m.	
		Cover net $10 m. exposed asset position through forward purchase of $10 m. worth of DM.
Euro-DM loans $40 m. equiv.	Euro-DM deposits $50 m. equiv.	
$100 m. equiv.	$100 m. equiv.	

Fig. 6. Eurobank Balance Sheet

securities denominated in different currencies in order to profit from different effective rates of interest in different currencies after taking hedging costs into account:

Effective interest rate on a foreign currency deposit

= Nominal interest rate + cost of forward cover.

= Interest rate + forward premium (+) or discount (-).

The cost of forward cover is, if we ignore transaction costs, simply the forward premium or discount. If the foreign currency is at a premium, the cost is positive and the effective rate is higher than the nominal rate. A typical arbitrage transaction would be the following:

A foreign exchange trader in the course of constantly monitoring international interest rates and exchange rates observes the following constellation:

90-day interest rates

Euromark: 4.75 (bid) 5.00 (offer)

Eurodollar: 6.625 (bid) 6.75 (offer)

Exchange rates (dollars per German mark)

spot: .3801 (bid) .3802 (ask)

90-day forward: .3821 (bid) .3823 (ask)

Realizing that when he borrows funds or buys a currency he will have to pay the higher (offer or ask) of the two rates, and realizing that when he deposits funds or sells a currency he will receive the lower of the two rates, the trader makes the following calculation:

Cost of borrowing Eurodollars = 6.75 percent per annum

Return from buying marks in the spot market, depositing them in the Euromark market, and simultaneously selling them in the forward market

$$= \text{Euromark rate} + \text{forward premium}$$

$$= 4.75 + \frac{.3823 - .3802}{.3802} \times \frac{365}{90} \times 100$$

$$= 4.75 + 2.24$$

$$= 6.99 \text{ percent per annum}$$

Hence by borrowing Eurodollars and depositing them in the Euromark market while covering them forward, the bank can earn 0.24 percent per annum which, for a million-dollar transaction, is \$600.

Since banks take advantage of such covered interest arbitrage opportunities as soon as they arise, they seldom last very long. In the above example, Euromark deposit rates would be driven down, \$/DM spot rates bid up, and \$/DM forward rates bid down to the point at which the arbitrage opportunity no longer exists once the (small) bid-offer spreads and transactions costs were taken into account. In other words, interest rate parity would soon prevail (to a close approximation):[1]

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[1] The precise formulation of the interest rate parity theorem is as follows:

$$I_{E\$} = I_{EDM} + F_{\$/DM}$$

where $I_{E\$}$, I_{ED} are the Eurodollar and Euromark interest rates and $F_{\$/DM}$ is the forward premium or discount in the dollar/German mark foreign exchange market. This, in essence, is the "interest rate parity theorem."

Value at t+n of \$1 earning dollar interest rate $I_{E\$}$ = Value at t+n of \$1 converted into foreign currency and earning foreign currency interest rate I_{EDM}, until t+n when it is converted back into dollars at the pre-arranged forward rate, F_t^n.

$$\$1(1+I_{E\$}) = \$1/S_t(1+I_{EDM})F_t^n$$

where S_t is the spot exchange rate (dollars per German mark) and F_t^n is the forward rate.

$$\frac{1+I_{E\$}}{1+I_{EDM}} = \frac{F_t^n}{S_t}$$

Subtracting 1 from each side gives

$$\frac{I_{E\$} - I_{EDM}}{1 + I_{EDM}} = \frac{F_t^n - S_t}{S_t}$$

and if I_{EDM} is small then, to a close approximation,

$$\frac{F_t^n - S_t}{S_t} = I_{E\$} - I_{EDM}$$

i.e., forward premium or discount = interest rate differential.
For a review of empirical work on the interest rate parity theorem the reader is referred to Lawrence H. Officer and Thomas D. Willett, "The Covered-Arbitrage Schedule: A Critical Survey of Recent Developments," Journal of Money, Credit and Banking (1970); 247-57.

The forward premium or discount reflects not only covered interest arbitrage but also exchange rate expectations. This is because commercial and financial transactors who expect to receive future revenues in currencies other than that which they wish to hold will tend to agree to future currency exchanges only at an exchange rate close to that which they expect to prevail in the future. The forward exchange rate therefore equals the market's expected future exchange rate (however, note the insert on page 25). In general, as people's currency expectations change as the result of new information, the forward premium or discount will adjust to equal the expected rate of change of the exchange rate. Hence:

forward premium or discount = expected rate of change of the exchange rate or $F_{\$/DM} = E(R_{\$/DM})$

where $F_{\$/DM}$ is the dollar/German mark forward premium or discount as before and $E(R_{\$/DM})$ is the annual rate at which the market expects the dollar/German mark exchange rate to change.

The relationship between the forward rate and exchange rate expectations may be termed the "unbiased forward rate theorem." The reader may readily see that, together with the interest rate parity theorem, the unbiased forward rate theorem suggests that the Eurodollar interest rate usually equals the Euromark interest rate plus the expected rate of change of the dollar/mark exchange rate. This is indeed the logical conclusion, as will now be shown.

Consider the corporate treasurer of one of the many large, international corporations which place funds on deposit for short periods in the Eurocurrency markets. These companies are well-informed about international credit and foreign exchange conditions, constantly compare the yields available in different markets, domestic and international, and so will readily transfer funds into or out of domestic markets or between Eurocurrency markets in order to maximize the return on excess short-term funds that they hold. In contrast to the bank example, however, it is now assumed that the treasurer does not necessarily hedge his deposits in various Eurocurrencies. How, then, will he compare effective yields? Simply by taking into account the expected rate of change of the exchange rate between two currencies. For example, if the three-month Eurodollar interest rate is 6 percent and the Euromark rate 4 percent, he will prefer to hold his funds in Eurodollar deposits unless the lower Euromark rate is offset by an expected appreciation of the dollar/mark exchange rate at an annual rate of 2 percent (that is, by 8 percent over the three-month period) or more. Similarly, borrowers of three-month funds will prefer to borrow German marks <u>unless</u> the mark is expected to appreciate at a rate of 2 percent p. a. or more: Assume the market expects the DM to rise at a 1 percent rate or more. The actions of these and many other companies, then, will tend to bid the Euromark rate up (as depositors move funds out of Euromarks into

Eurodollars and borrowers borrow more Euromarks and fewer dollars) since the Euromark rate is not, by assumption, constrained by German domestic interest rates. At the same time the sale of marks to obtain dollars by both sets of transactors will bid the dollar/mark spot exchange rate down. If for convenience transactions costs are ignored, the incentive for this choice of depositing and borrowing currencies will disappear only when the Euromark rate has been bid up and the dollar/mark exchange rate bid down to the point at which the Euromark rate plus the expected rate of appreciation of the mark approximates the Eurodollar rate.

Since any pair of Eurocurrencies will quickly adjust to borrowing and depositing pressures of the kind just described, one would expect that the following relationship would normally hold to a close approximation:

Interest rate in one currency market

= Nominal interest rate in other Eurocurrency market

+ Expected annual rate of change of exchange rate.

Or for dollars and German marks,

$$I_{E\$} = I_{EDM} + E(R_{\$/DM})$$

where $I_{E\$}$ and I_{EDM} are the dollar and mark Eurorates and $E(R_{\$/DM})$ is expected rate of change of the exchange rate on an annual basis.

This relationship can be restated to say that the Eurocurrency interest rate differential equals the expected rate of change of the exchange rate, and so may be termed the "unbiased interest rate differential theorem."

The three theorems that have been described may now be brought together and summarized in a single statement of the normal relationship between Eurocurrency rates, spot and forward exchange rates, and exchange rate expectations:

The borrowing, lending, and hedging actions of banks and corporations tend to ensure that the interest rate differential between two Eurocurrency markets equals the forward premium or discount and also equals the expected exchange rate change expressed as an annual rate. For the Eurodollar and Euromark markets, then:

$$I_{E\$} - I_{EDM} = F_{\$/DM} = E(R_{\$/DM}) \, .$$

This conclusion is unchanged if one now relaxes the assumption, introduced at the beginning of this section, that the German national market was cut off from all other credit markets. If the barrier is now removed, investment and borrowing arbitrage will rapidly eliminate any major interest rate differentials between the German and Euromark credit markets. The final situation will resemble that illustrated in Figure 5.

Influences on Eurocurrency Rates: How They Actually Work

Thus far we have identified the major interest rate relationships and influences that normally prevail in the Eurocurrency markets. This section and the two that follow will complement those by examining in more detail how these influences are transmitted in order to produce the equilibrium relationships between internal credit markets, external credit markets, and foreign exchange markets. The framework will involve six major variables in the dollar and German mark markets:

Two internal interest rates

(1) the domestic U. S. interest rate

(2) the domestic German interest rate

Two external interest rates

(1) the Eurodollar interest rate

(2) the Euromark interest rate

Two exchange rates

(1) the spot exchange rate (dollars per mark)

(2) the forward exchange rate

All these interact with one another. There are, however, two major sets of independent, or exogenous, variables affecting Eurocurrency rates. These are (1) domestic credit conditions in the U. S. and Germany, as influenced by national growth rates, monetary policies, and so forth and (2) exchange rate expectations, influenced by inflation rates, trade flows, and government policies, among other things. The remaining variables are generally dependent, or endogenous, variables and change in response to changes in the independent variables. A change in U.S. interest rates, for example, usually produces changes in Eurodollar rates, dollar/mark exchange rates, and mark-denominated interest rates. From time to time, however, the reverse may happen--that is, the changes in Eurocurrency and foreign exchange rates produced by a domestic interest rate change may, in turn, produce a feedback effect on domestic interest rates.

The following two cases will show how changes in these two major independent variables, domestic credit conditions and exchange rate expectations, make themselves felt in the Eurocurrency and foreign exchange markets.

Case one: the effect of a change in credit conditions

A change in credit conditions or interest rates in the domestic credit market of one country immediately induces arbitrage until rates in the external market are in line with domestic rates. Next covered interest arbitrage tends to restore the relationship between Eurocurrency and spot and forward exchange rates. Finally the impact is felt on (as well as constrained by) other domestic credit markets. Assume, for example, an initial position showing interest rates at internal-external equality and foreign exchange rates at interest rate parity:

U.S. 90-day rate = Eurodollar rate = 8 percent p.a.

German 90-day rate = Euromark rate = 4 percent p.a.

Spot exchange rate, dollars per German mark = .400

90-day forward exchange rate = .404

$$\text{Hence forward premium} = \frac{.404 - .400}{.400} \times \frac{360}{90} \times 100$$

$$= 4$$

$$= \text{interest rate differential.}$$

Now suppose that the actions of the U.S. monetary authorities raise the U.S. interest rate to 10 percent. Since the U.S. interest is no longer aligned with Eurocurrency and foreign exchange rates, arbitrage and expectational forces described in earlier sections will effect changes in interest and exchange rates that will restore the equilibrium relationships.

First, internal-external equality will be restores, i.e., borrowers will switch to the Eurodollar market and depositors to the U.S. money market. Because the U.S. market is larger than the Eurodollar market, and is more directly subject to U.S. monetary policy, Eurodollar rather than U.S. rates will adjust. Hence one may expect to see Eurodollar rates move rapidly up to 10 percent. A similar process would occur for any pair of markets in which the internal money market is large relative to foreign money markets. Relatively small domestic money markets, such as the Swiss one, are much more subject to external influences such as changes in foreign credit conditions or currency expectations.

Next, interest rates and exchange rates in the external markets will adjust to conform to the interest rate parity and the unbiased interest rate differential theorems. Any or all of four variables--the Eurodollar rate, the Euromark rate, the spot exchange rate, and the forward exchange rate--may bear the brunt of the adjustment:

(a) The Eurodollar rate may move down as investors find dollar interest rates more than compensating for the forward premium on the dollar/mark exchange rate and banks borrow marks to make dollar loans. In this particular case, however, Eurodollar rates are largely constrained by the upper and lower limits set by U.S. rates and are likely to move little because of the size of the dollar credit market relative to that of other Eurocurrency and domestic credit markets (the United States' money stock constitutes almost 40 percent of the total of the ten major industrial countries). In general, the Eurocurrency interest rate will adjust to arbitrage only to the extent that (1) the domestic monetary authorities are unwilling or unable to fix corresponding internal rates, or (2) capital controls widen the effective limits within which Eurorates can move relative to domestic rates.

(b) Euromark interest rates will tend to rise, as arbitrage and speculative transactions become attractive and this moves funds out of Euromarks and into Eurodollars, even after the forward premium and expected rate of change of the exchange rate are taken into account. Again, Eurorates will be constrained by domestic rates; Euromark rates will move to the upper limit provided by domestic German rates, which themselves may be pulled up because of the relatively small size of the German money market.

(c) The spot exchange rate, i.e., the price of German marks, will be bid down as investors and arbitrageurs sell marks in order to buy dollars and invest them in Eurodollar deposits. The spot rate often will bear much of the brunt of an interest rate change, except when the authorities are willing and able to fix the exchange rate by buying all the marks offered at a fixed dollar price.

(d) The forward dollar/mark exchange rate may be bid up as more and more investors enter contracts to purchase marks forward in order to hedge their dollar investments. The forward rate also usually absorbs much of the impact of an interest rate change because this forward market is seldom influenced directly by government intervention. Because of the unbiased forward rate theorem, however, the forward rate is constrained to equal the market's expected value for the future spot exchange rate; hence when investors' exchange rate expectations are unaltered by the interest rate change, the forward premium will adjust through changes in the spot rate rather than changes in the forward rate.

To sum up, when the interest rate differential widens as a result of changed credit conditions, arbitrage and speculation will tend to narrow the interest rate differential and widen the differential between forward and spot exchange rates in order to restore interest rate and expectations parity. In the above example, the following adjustments might have followed the 2 percent rise in U.S. rates:

Eurodollar rate: from 8 percent to 10 percent

Euromark rate: from 4 percent to 4-1/2 percent

German rate: from 4 percent to 4-1/4 percent

Spot exchange rate: from .400 \$/DM to .399 \$/DM

Forward exchange rate: from .404 \$/DM to .4045 \$/DM

$$\text{Hence, new forward premium} = \frac{.4045 - .399}{.399} \times \frac{360}{90} \times 100$$

$$= 5.5$$

$$= \text{Eurocurrency interest rate differential.}$$

Case two: the effect of a change in currency expectations

A change in the international financial community's exchange rate expectations will alter the forward exchange rate which will widen or narrow the forward premium (or discount) which may change interest rates in one or more Eurocurrency and domestic credit markets. As before, the impact of a change in currency expectations may be examined by assuming an initial set of interest and exchange rates at interest rate parity in the dollar and German mark markets:

U.S. 90-day rate = Eurodollar rate = 10 percent p.a.

German 90-day rate = 4-1/4 percent p.a.

Euromark rate = 4-1/2 percent p.a.

Spot exchange rate = .399 $/DM

90-day forward rate = .4045 $/DM

As was shown in the previous section, the forward premium of 5.5 percent equals the Eurocurrency interest rate differential. Now suppose that statistics indicating a sudden jump in the inflation rate are released in Germany; as a result, investors expect a deterioration in the German trade balance and a lower demand for German marks. The consensus now is that the mark will rise over the next three months to only .402 instead of the present expected .4045 $/DM. The markets are now in disequilibrium and will undergo adjustments of the following nature:

(a) The forward exchange rate will tend to adjust to match the new expectation: that is the forward rate will drop from .4045 to .402. This will result from the actions of speculators who will be willing to sell German marks forward at .4045, hoping to profit in three months time by purchasing marks in the spot market at .402 and selling them at the contracted rate of .4045. In addition, investors will be less willing to hold uncovered mark deposits and so will seek to hedge them by selling marks forward. These actions will continue until the forward rate equals the expected future spot rate, .402 $/DM.

(b) The Euromark interest rate will tend to rise. With a lower forward rate, the forward premium on the mark will have dropped (from 5.5 percent to 3 percent) and will not be sufficient to compensate for the lower Euromark interest rate. Arbitrageurs will therefore move funds out of Euromarks and into dollars, thus bidding the Euromark interest rate up to the extent that it is not constrained by German domestic interest rates. The Euromark rate may even pull internal interest rates up with it to a minor degree.

(c) Eurodollar rates will tend to drop. By buying spot dollars, depositing them in the Eurodollar market, and selling them forward at .402 for marks, investors can earn 10 percent - 3 percent = 7 percent, much higher than the 4-1/2 percent available on Euromark deposits. As more funds are deposited in the Eurodollar market, rates will drop unless they are completely constrained by the U.S. domestic credit market.

(d) The spot exchange rate will tend to drop. As investors seek to liquidate Euromark deposits and purchase dollar deposits, they will sell marks for dollars on the spot market and bid the price of marks down. Normally, the spot rate will undertake most of the adjustment necessary to restore interest rate parity once expectations have altered the forward rate. If the government intervenes to fix the exchange rate, however, the spot rate can adjust very little at all and interest rate parity must be restored through interest rate changes.

In this situation, opportunities for profits will rapidly disappear as the forward rate moves down followed by a rise in the Euromark rate and a drop in the Eurodollar and dollar/mark exchange rate. If interest rates change much, the spot rate will adjust less and the altered interest rates may affect currency expectations and thus feed back to the forward rate. If it is assumed, however, that in the absence of capital controls the monetary policies of national authorities prevent interest rates from moving much, if at all, the change in currency expectations just described may result in the following changes to restore parity:

Forward exchange rate: from .4045 $/DM to .402 $/DM

Euromark rate: from 4-1/2 percent to 5 percent

German rate: from 4-1/4 percent to 4-3/4 percent

Eurodollar rate: unchanged at 10 percent

U.S. rate: unchanged at 10 percent

Spot exchange rate: from .399 to .397

$$\text{Hence, new forward premium} = \frac{.402 - .397}{.397} \times \frac{360}{90} \times 10$$

$$= .5 \text{ percent}$$

$$= \text{Eurocurrency interest rate differential.}$$

In the past, when capital controls were in effect and the Bretton Woods system kept spot rates fixed, much of the adjustment took place in Eurorates, particularly in those of the smaller Eurocurrency markets. The result could even be negative interest rates, as actually occurred in the Euromark market during the summer of 1972.

It is easy to see that under a system of fixed exchange rates, interest rate changes or currency expectations can have significant effects on domestic credit markets and thus reduce the independence of national monetary policies. Fixed rates in conjunction with covered interest arbitrage facilitate the international transmission of interest rates and monetary policies. While this transmission has been described as occurring most naturally and conveniently through the Eurocurrency markets, it can, of course, take place directly between national credit markets. This fact allows the interdependence between internal and external rates to continue even in the presence of effective capital controls.

To illustrate, consider the situation in which German residents are prohibited from borrowing or lending Euromarks. If the German authorities tighten monetary policy thereby raising interest rates on domestic securities, the forward rate for marks will tend to fall as foreign investors increase their purchases of German securities and hedge their investments by selling marks forward. Covered interest arbitrage between the Eurodollar and Euromark markets will then cause Euromark rates to rise approximately by the amount that German internal rates have risen.

The Term Structure of Eurocurrency Interest Rates

The discussion so far has focussed on interest rates on Eurocurrency deposits or loans of a particular maturity. Each maturity's interest rate, however, is related to rates for all other maturities: if rates on short-term deposits rise, for example, rates on securities of all other maturities, medium- and long-term, denominated in the same currency tend to rise, too. Long rates are, of course, much less volatile than those on short-term securities.

The basic theory of the term structure of interest rates, internal or external, is that the interest rate on a long-term bond reflects the market's expectations about future short-term interest rates. Investors tend to switch to long-term investments if they think interest rates will drop; this will raise the price of long-term securities, raising the long-term yield to maturity. The term structure of interest rates will be consonant with the market's interest rate forecasts if, and only if, the yield on a long-term bond equals the expected yield obtained from investing in short-term securities and reinvesting the proceeds later in short-term securities at the interest rate expected to prevail at that time.

If this expectation theory of the term structure holds for the domestic market, it will hold for the external or Euromarket regardless of the existence of capital controls. In the absence of capital controls, arbitrage would ensure the virtual equality of internal and external rates at each maturity and whatever held for the domestic market would hold identically for Eurorates. In other words, there is normally no independent Eurodollar term structure of interest rates.

If capital controls were in place and affected all maturities equally, the internal term structure might not be identical to the external one, but since Eurorates would tend to be at the same position relative to internal rates at each maturity, a nearly identical term structure would hold. If capital controls affected some maturities but not others, the term structure should still be identical as long as expectations of future rates were the same, since the expectations theory along with arbitrage in one maturity would bring external rates in other maturities into alignment with internal rates. If, for example, internal-external arbitrage were possible between short-term deposits but not long-term deposits, identical forecasts for future short-term rates in both the internal and external credit markets should result in identical long-term rates in both markets.

What about the relationships between the term structures of interest rates in different Eurocurrency markets? Because there can be no capital controls separating the Euromarkets, all that keeps the yield structures different is expectation of exchange rate changes. The relationship between the term structures of two Eurocurrency markets, such as the Eurodollar and Euromark term structures, reflects the forward premium of discount and currency expectations at each period in the future. In other words, by comparing the term structure of interest rates in two Eurocurrency markets one may readily derive the term structure of exchange rate expectations.

Of course, if well-developed forward markets exist for all maturities, the term structure of exchange rate expectations may be derived directly from the series of forward exchange rates, since these equal the expected future spot rates. For most markets, however, longer-term forward markets are nonexistent or too thin to be reliable. In such cases it may be useful to employ the term structure of interest rates in two Euromarkets to deduce the term structure of exchange rate expectations. Simply subtracting the Euromark rate from the Eurodollar rate available on deposits of various maturities, for example, will yield a good approximation of the term structure of expected rates of change of the dollar/mark exchange rate. This will reveal not only how much the currency may be expected to appreciate or depreciate over a given period, but also how rapidly the market expects the change to occur--suddenly or gradually.

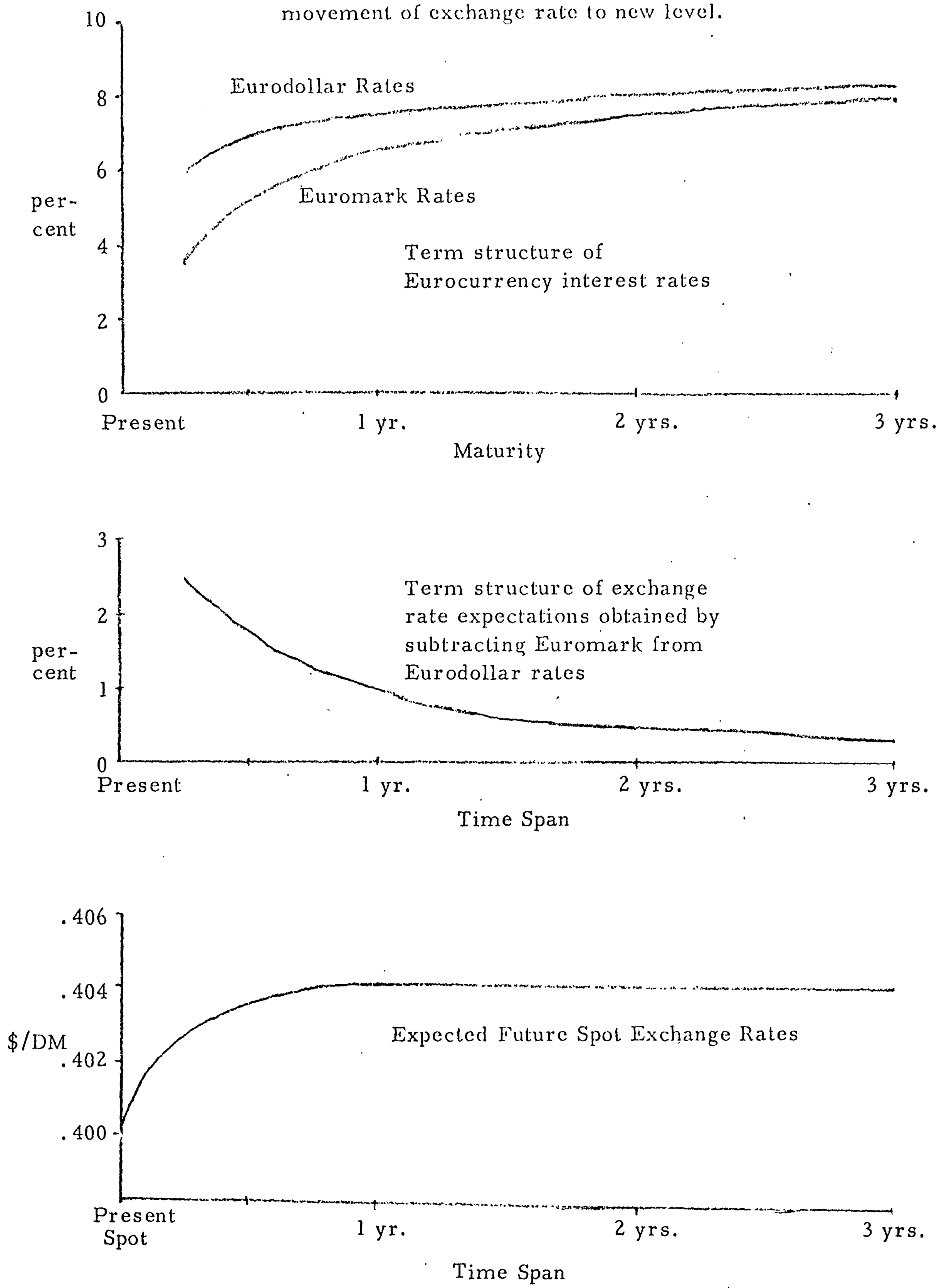
Figure 7 shows three examples of the term structure of exchange rate expectations implied by Eurocurrency yield curves. In each the mark is initially at an exchange rate of .400 dollars per German mark. The simplest case, not shown here, would be one in which the exchange rate is expected to remain stationary at its current spot value: one should then observe identical interest rates at all maturities in both Eurocurrency markets. Case one in Figure 7 depicts the term structure of Eurorates in which the market expects an increase in the dollar/mark exchange rate to a new level of .404; here the Eurodollar and Euromark interest rates converge with increasing maturities. In case two, where the two Eurorates are separated by two percentage points at all maturities, the market expects a steady appreciation of the mark at a rate of 2 percent per annum. Finally, case three shows the term structures of Eurorates that would prevail if the dollar/mark exchange rate were expected to rise gradually at first, then more and more rapidly over the three-year period. Of the three cases, this situation is least likely to occur in practice.

Summary

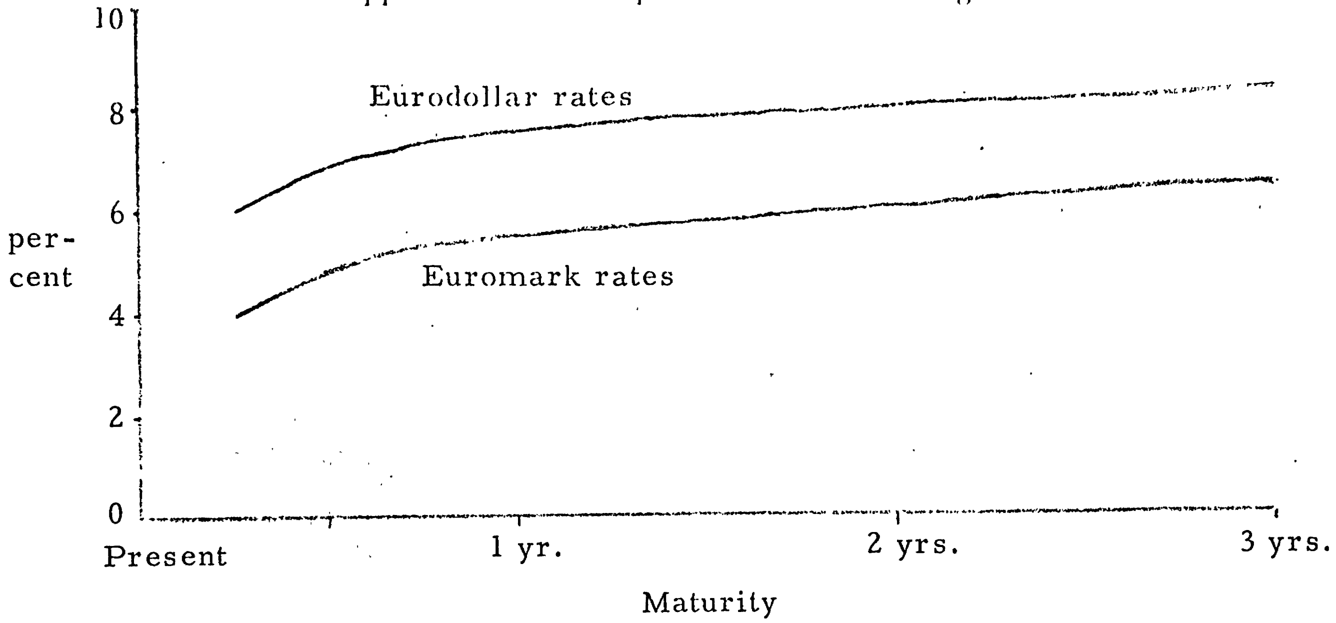
In this paper the major determinants of Eurocurrency interest rates were identified as: domestic and foreign credit conditions, forward exchange rates and exchange rate expectations, and three sets of factors

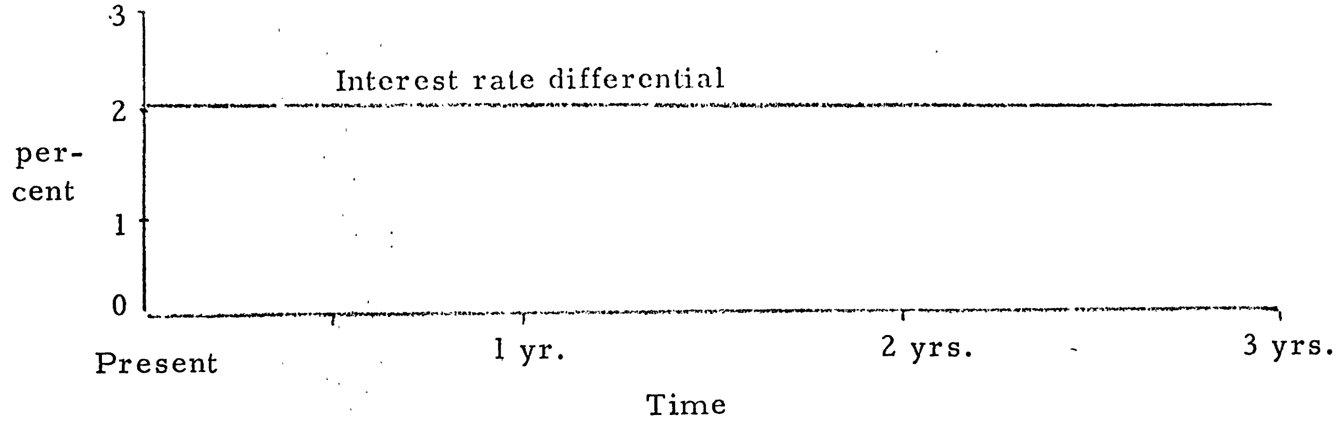
Fig. 7. The term structure of Eurocurrency rates and exchange rate expectations.

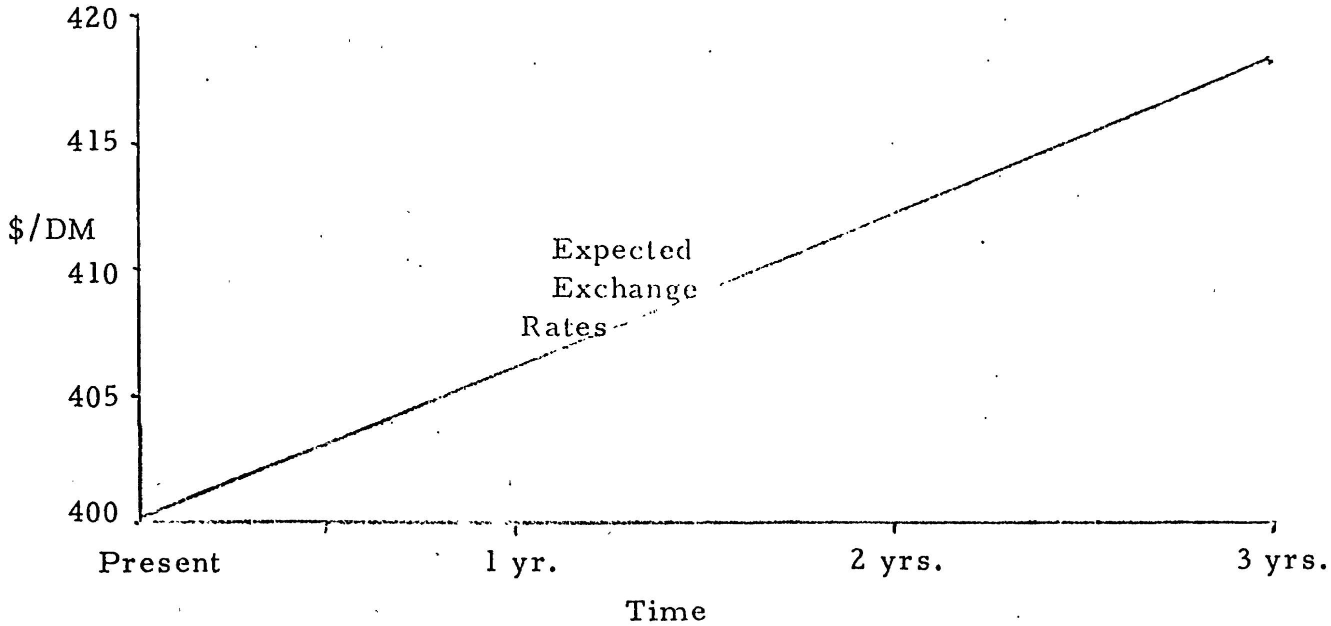
Case 1: Converging Eurocurrency interest rates imply movement of exchange rate to new level.



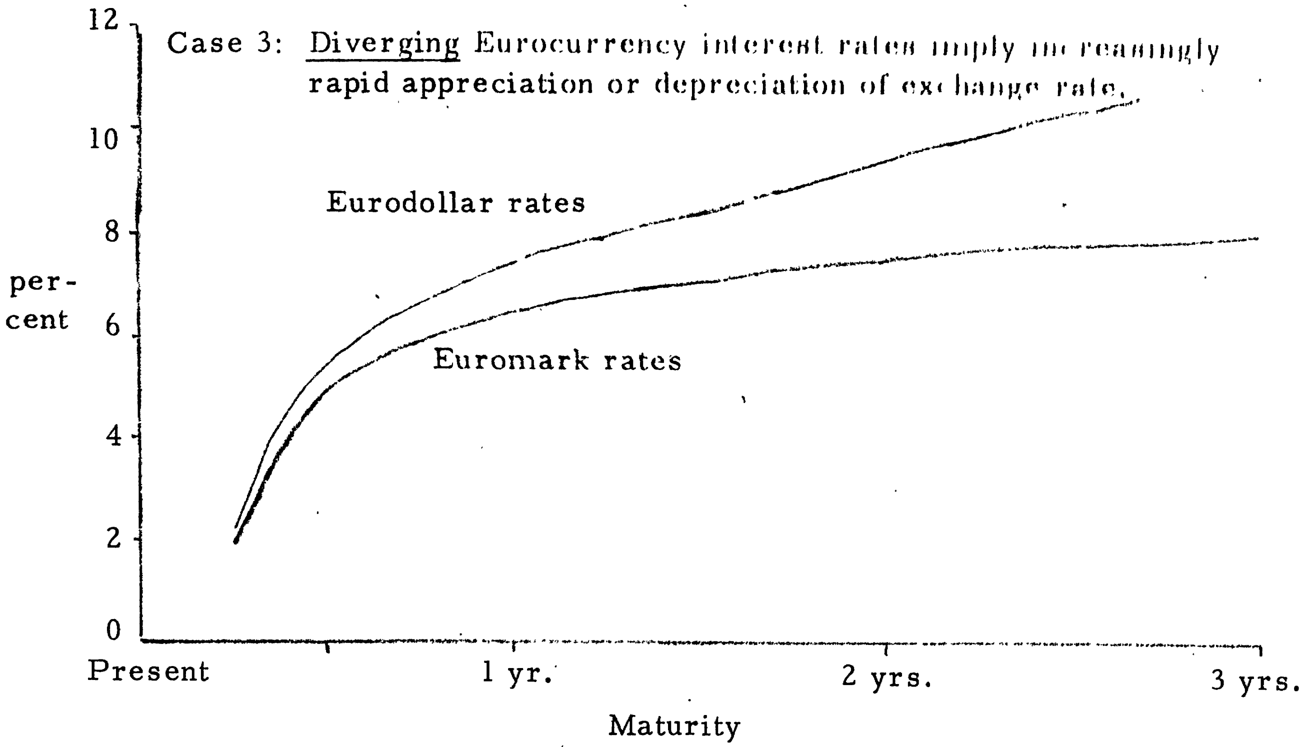
Case 2: Parallel Eurocurrency interest rates imply steady appreciation or depreciation of exchange rate.

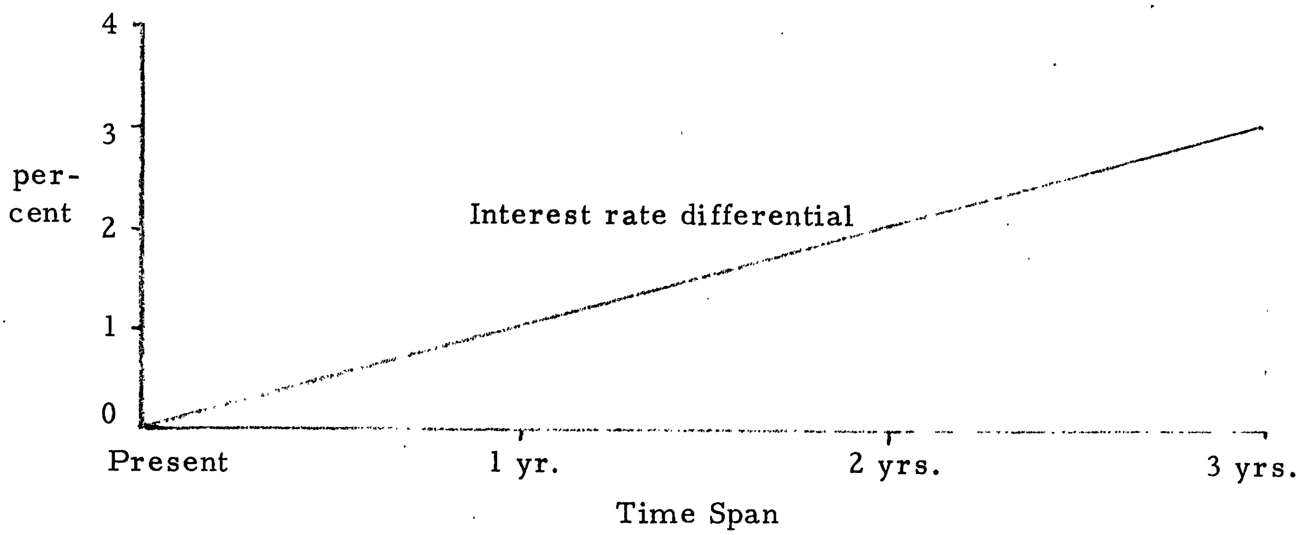


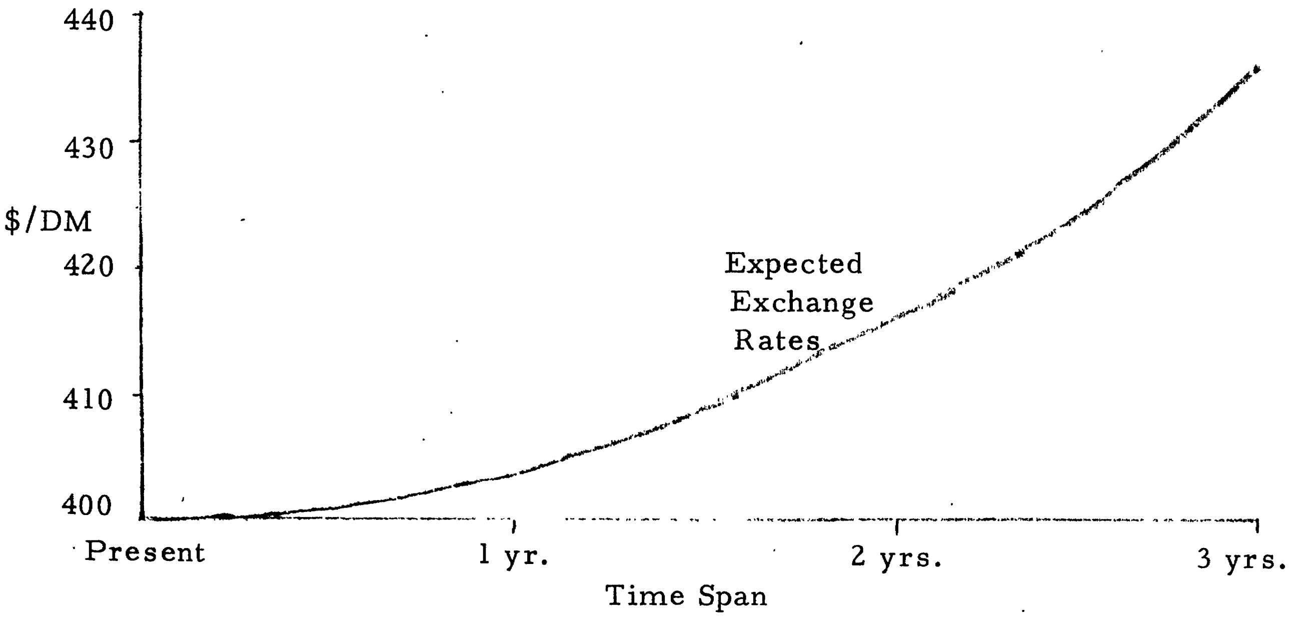




Case 3: Diverging Eurocurrency interest rates imply increasingly rapid appreciation or depreciation of exchange rate.







Summary of Data for Figure 7

	Eurodollar int. rate (in percentage)	Euromark int. rate (in percentage)	T.S. of exch. rate expect (% p.a.)	Expected future spot exch. rate
Case 1				
Spot				.400
3 mo.	6	3-1/2	2-1/2	.4025
6 mo.	7	5-1/4	1-3/4	.4035
1 yr.	7-1/2	6-1/2	1	.404
1-1/2 yr.	7-2/3	7	2/3	.404
2 yr.	8	7-1/2	1/2	.404
3 yr.	8-1/3	8	1/3	.404
Case 2				
Spot				.400
3 mo.	6	4	2	.4015
6 mo.	7	5	2	.403
1 yr.	7-1/2	5-1/2	2	.406
1-1/2 yr.	7-2/3	5-2/3	2	.409
2 yr.	8	6	2	.412
3 yr.	8-1/3	6-1/3	2	.418
Case 3				
Spot				
3 mo.	2-1/4	2	1/4	.40025
6 mo.	5-1/2	5	1/2	.401
1 yr.	7-1/2	6-1/2	1	.404
1-1/2 yr.	8-1/2	7	1-1/2	.409
2 yr.	9-1/2	7-1/2	2	.416
3 yr.	11	8	3	.436

that might inhibit arbitrage--capital controls, risk factors, and transactions costs.

External or Eurocurrency interest rates, it was argued, are always linked through arbitrage to internal rates, although capital controls can weaken this linkage. In the absence of capital controls, external loan and deposit rates are bounded by loan and deposit rates in the internal credit market. Eurocurrency rates are linked to one another through covered interest arbitrage in such a way that the interest rate differential equals the forward premium or discount between two currencies and also equals the market's expected rate of change of the exchange rate changes that the market expects can be deduced by comparing the term structures of interest rates in two Eurocurrency markets.

All the relationships between credit and foreign exchange markets described in this chapter result from a continual process of simultaneous interaction. Any deviation from interest rate parity, for example, will set in motion a number of transactions which will change interest rates and exchange rates and this change will trigger further transactions until interest rate parity between Eurocurrency and foreign exchange is reestablished. The interest rate parity theorem describes an ex post relationship towards which rates will tend to move. However, which part of the total readjustment is actually accomplished by changes in which rate cannot be determined a priori; this depends on the relative sizes of the credit markets involved, on exchange rate expectations, on the degree of institutional flexibility and efficiency in the market, and, of course, on government regulations and intervention.

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See also the various footnotes and references cited in the Appendices to this paper.

APPENDIX 1

Empirical Studies on Eurodollar Interest Rates

I. Term structure of Eurodollar interest rates

Empirical studies on the term structure in the Eurodollar market have focused on two different issues. Santomero [12] used Eurodollar interest rates to provide empirical evidence regarding the yet unsettled controversy that surrounds the expectations hypothesis of the term structure of interest rates. Meiselman's empirical study of the U. S. term structure using error-learning model provided considerable support for the expectations hypothesis. However, the absence of two-month securities in the U. S. and the resulting need to smooth the yield curve has cast doubts on the Meiselman results regarding the error-learning hypothesis. Using Eurodollar interest rates, Santomero claimed that his empirical study "offers results using the first complete and unsmoothed data set investigating the pure Meiselman expectations hypothesis."

On the other hand, both Kaen [6] and Findlay and Kleinschmidt [4] analyzed the Eurodollar term structure to test the efficiency of the Eurodollar market itself. Kaen's stated objective was "a test of the trans-maturity efficiency in the Eurodollar market," while Findlay's

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This appendix was drafted by Sangkee Min under the direction of the authors.

tested hypothesis was "whether the Eurodollar market does behave as if it predicts future interest rates, such that the forward rates impounded in the term structure is a function of expected future rates." However, not surprisingly, all three studies used Meiselman's error learning model to test their respective hypotheses because it is the only available methodology yet devised.

<u>Meiselman's error-learning test</u>

In its pure form, the expectations hypothesis contends that the interest rate on the long-term security will be equal to the geometric mean of intervening expected short-term interest rates:

$$(1+{}_tR_{n,t}) = \sqrt[n]{(1+{}_tR_{1,t})(1+{}_{t+1}r_{1,t})(1+{}_{t+2}r_{1,t}) \cdots (1+{}_{t+n-1}r_{1,t})} \qquad (1)$$

where R = actual interest rate, and

r = future short-term interest rate implied by present yield curve

on a security with a maturity of n (first postscript) beginning at time t (prescript), available or expected at time t (second postscript). Thus ${}_tR_{n,t}$ is the actual interest rate on a security of maturity n that begins at time t and is available at time t. ${}_{t+n}r_{1,t}$ is the short-term (1-period) interest rate beginning at time t+n that is expected at time t. (Here we employ Meiselman's notation.)

In other words, the expectations hypothesis states that the short-term rates implied by the present long-term interest rate equal the market's expected future short-term rates. When there is any disequilibrium in the sense that the interest rate on a long-term security is higher or lower than the geometric mean of the expected intervening short term rates, the expectations hypothesis contends that interest arbitragers will act on the profit opportunities until the market returns to equilibrium.

In contrast to the expectations theory, the market segmentation hypothesis contends that lenders (and borrowers) have specific preferences in terms of maturity and, therefore, the interest rate on each point on a yield curve is determined by the interaction of supply and demand in that segment of the market. The liquidity preference hypothesis provides a third explanation of the term structure. The liquidity preference hypothesis basically agrees with the expectations hypothesis, but argues that investors will demand a higher rate on a long-term security (because of its illiquidity) than that implied by the pure expectations hypothesis, the geometric mean of expected intervening short-term rates.

Although the expectations hypothesis has a clearly-defined theoretical formulation, it is not easily subject to direct empirical testing. Several studies have compared the yield-curve implied short-term interest rate with actual short-term rates; these studies, however, measured the market's ability to forecast future interest rates, which was not an integral part of the expectations theory.

In 1962 a methodological breakthrough was achieved by Meiselman [10], who distinguished for the first time between the issue of the market's <u>ability</u> to forecast and the issue of the market's <u>attempt</u> to forecast. Given the information that investors made errors in forecasting short-term interest rates for time t (right hand side of the equation (2)), Meiselman's error learning model tested whether the yield curve implied short-term interest rates for time period t+n were revised in a manner consistent with the expectations hypothesis.

$$\underbrace{{}_{t+n}r_{1,t} - {}_{t+n}r_{1,t-1}}_{\text{degree of forecast revision}} = a + b\underbrace{({}_{t}R_{1,t} - {}_{t}r_{1,t-1})}_{\text{previous forecast error}} \qquad (2)$$

If investors actively revise their expectations on the basis of previous forecast errors, the coefficient "b" and the explanatory power (coefficient of determination) of equation (2) would be significantly different from zero. In addition, if the constant "a" is significant, it would imply that the revision of interest rate expectations could be explained by some additional, constant, factor as well as error-learning. According to Meiselman, this additional factor would reflect the liquidity preference of investors.

The empirical results regarding the error learning model by Meiselman and three other researchers are presented in Exhibit 1. Meiselman's data base was Durand's annual United States corporate bond yield curve for the period 1901-1954. Three other studies, by Santomero [12], Kaen [6], and Findlay-Kleinschmidt [4], have applied Meiselman's tests to the Eurodollar market, using monthly Eurodollar yield curves covering roughly the same period: from 1966 to 1972.

As was the case with the Meiselman test, all three studies of Eurodollar yield curves produced values for b and R^2 which were statistically significant, supporting the error learning model. Each study concluded that the constant term was not statistically significant at the 95 percent confidence level and so failed to support the existence of a liquidity premium.

Compared to the results for the U.S., however, the coefficients of error adjustment and coefficients of determination were lower in the studies of Eurodollar yield curves and faded much faster as the time span of forecasts was lengthened. Santomero's study, for example, revealed that only 51 percent of the revision of the expectation of future interest rate was explained by the current forecasting error. Meiselman had found that 90 percent of the revision was explained by the error learning model. And as the forecasting time span was lengthened to 4 months, Santomero's empirical results found that only

EXHIBIT 1

Error Learning Model

$$({}_{t+n}r_{1,t}) - ({}_{t+n}r_{1,t-1}) = a + b({}_{t}R_{1,t} - {}_{t}r_{1,t-1})$$

	Meiselman			Kaen			Santomero			Findlay & Kleinschmidt		
n	a	b	R^2	a	b	R^2	a	b	R^2	a	b	R^2
1	.00 (.02)	.703	.906	.0026 (.0006)	.556	.37	.094 (.065)	.675	.514	.0001 (.0004)	.833	.657
2	.00 (.03)	.526	.752	.0004 (.0006)	.641	.52	-.035 (.098)	.532	.556	-.0004 (.0005)	.644	.495
3	-.01 (.04)	.403	.590	.0862 (.1217)	.652	.62	-.110 (.098)	.252	.215	-.0002 (.0005)	.677	.460
4	-.03 (.04)	.326	.465	-.0005 (.0005)	.631	.50	-.080 (.133)	.193	.081	.0004 (.0005)	.652	.471
5	-.02 (.04)	.277	.412							.0006 (.0005)	.663	.455
6	-.01 (.03)	.233	.391							.0009 (.0005)	.648	.393
7	-.02 (.03)	.239	.398							.0007 (.0004)	.616	.339
8	.01 (.03)	.208	.348							.0007 (.0004)	.531	.288
9										.0004 (.0005)	.344	.185
10										.0006 (.0006)	.201	.128

Source: Meiselman [10], Santomero [12], Kaen [6], and Findlay & Kleinschmidt [4].

8 percent of the revision could be explained by the current forecasting error, while Meiselman's test indicated that 75 percent of revision was explained by the current forecasting error even at the forecasting time span of one year.

Drawing inferences from the empirical results, one might be tempted to conclude that the Eurodollar term structure showed different characteristics from the U.S. term structure. As noted, the extent of the revision of future interest rate expectations based on the current error was much lower for Eurodollar rates and faded much faster as forecasting horizons were lengthened. One should, however, have some reservations concerning these apparent discrepancies. First, the results of the three Eurodollar studies themselves disagree with one another. While covering approximately the same period (from 1966 to 1972), the three studies found values for b and for R^2 that differed by 50 percent or more. These disparities may be attributed to the different sets of data employed and suggest that data problems may be significant. A second and more important reason for interpreting the above studies with caution is that, in the absence of controls or even when capital controls provide some segmentation of domestic and external markets, there really is no distinct Eurodollar term structure. As will be demonstrated in detail in the next section, the Eurodollar interest rate is largely determined by the U.S. interest rate for comparable securities. Eurodollar interest rates of each maturity on the yield curve are determined by the U. S. interest rates of corresponding maturities, and thus theoretically the Eurodollar term structure will be a duplicate of the U. S. term structure, with only minor deviations possible.

II. Relationships between Eurodollar and U. S. interest rates

The first empirical study of the relationship between Eurodollar and U. S. interest rate was carried out by Hendershott in 1967. Relating the Eurodollar deposit rates to 3-month U. S. Treasury Bill rates, he concluded that "the U. S. bill rate is seen to be the primary determinant of the equilibrium Eurodollar rate" [5]. Hendershott employed a stock adjustment equation of the Koyak-Nerlove type to produce empirical results with the following form:

$$\Delta\, r^{EU} = .105 + .140\, r^{\overline{US}} - .131\, r^{\overline{EU}} + \sum_{i=1}^{11} S_i \tag{3}$$

where r^{EU} = changes in Eurodollar interest rates;

$r^{\overline{US}}$ = average of 3 month U. S. Treasury Bill rates;

$r^{\overline{EU}}$ = average Eurodollar interest rates;

$\sum_{i=1}^{11} S_i$ = seasonal adjustment terms.

From his empirical results, Hendershott further concluded that "the U. S. bill rate coefficient indicated that the Eurodollar rate will increase by .14 percentage points during the current <u>month</u> in response to a one percentage point rise in the mean U. S. bill rate. The monthly speed of adjustment, K, is .131 implying that the eventual increase in the Eurodollar rate will be $\frac{.140}{.131}$ = 1.07 percentage points."

Hendershott also discussed the possible influence of non-U. S. interest rates on Eurodollar interest rates. However, to keep the empirical study reasonably simple, he hypothesized that the non-U. S. interest rates are largely determined by U. S. Treasury Bill rates, which left the U. S. Treasury Bill rate as a sole determinant of the Eurodollar interest rate.

In 1971, Sung Y. Kwack [7] extended Hendershott's tests using the same methodology only putting non-U. S. interest rates into the equation. Kwack's empirical results are shown in equation (4).

$$\Delta(RM_{E\$})_{-1} = -0.100 + 0.414\,RM_{GB3} + 0.272\,RMFS_{CA} + 0.148\,RMFS_{UK} + 0.131\,RMFS_{WG} - 0.808(RM_{E\$})_{-1} \quad (4)$$

where $\Delta(RM_{E\$})_{-1}$ = changes in Eurodollar interest rates;

RM_{GB3} = 3 month U. S. Treasury Bill rates;

RMFS = rate on short term funds in foreign countries. (Subscripts are for Canada, United Kingdom, and West Germany.)

When foreign interest rates were included in the equation, Kwack concluded that the Eurodollar rate would increase by 0.512 percent in the first quarter as a result of a maintained increase of 1 percent in the U.S. rate, and that 99 percent of the adjustment of the Eurodollar rate would be accomplished in four quarters. In fact, even with the introduction of foreign interest rates, which were not adjusted for exchange risk, Kwack's results were basically in agreement with the Hendershott's results in the extent and speed of Eurodollar interest adjustment to the changes in the U.S. Treasury Bill rate.

Research into the determinants of Eurodollar interest rates took a turn in 1973. Instead of simply regressing Eurodollar interest rates with U.S. and foreign interest rates, Rodney H. Mills, Jr. [11] developed Eurodollar supply-and-demand equations which in turn were reduced and solved for Eurodollar interest rates. In this fashion Mills developed an equation showing the determinants of Eurodollar rates that included, in addition to the U.S. and foreign interest rates, dummy variables for Regulation Q, reserve requirements and the quantity of CDs. For foreign interest rates, Mills modified the nominal rates by the forward premium in order to account for exchange risk. The equation that Mills tested was

$$\begin{aligned} EDR = {} & K + b(TBR) + C(BLAR) + d(GILR) + e(SBDR) + f(FPS) \\ & + g(FDM) + h(FSF) + r(RRD) + m(RQD) + n(QCD) \end{aligned} \tag{5}$$

where EDR = Eurodollar interest rate;

TBR = U.S. 3-month Treasury Bill rate;

BLAR = British 3-month local authority deposit rate;

GILR = German 3-month interbank loan rate;

SBDR = Swiss 3-5 month bank deposit rate;

FPS = Forward pound sterling premium;

FDM = Forward Deutsche Mark premium;

FSF = Forward Swiss Franc premium;

RRD = Reserve Requirement dummy;

RQD = Regulation Q dummy;

QCD = Quantity of CDs.

The empirical results of Mills' study are reproduced in Exhibit 2. Stratifying the data series between 1966-68 and 1969-70, Mills showed that the adjustment of Eurodollar interest rates to the changes in U.S. interest rates was only .24 in 1966-68 and increased to .61 in 1969-70. Mills attributed this difference in the degree of adjustment to the structural changes in Eurodollar market induced by the increased arbitrage by U.S. banks between two markets in 1969-70.

Employing the supply-and-demand framework that Mills used, Argy and Hodjera [3] tested the relationship between Eurodollar and U.S. Treasury Bill rates covering the period from January 1961 to March 1971. The importance of the U.S. Treasury Bill rate was reaffirmed by this empirical study, which revealed a .622 coefficient for U.S. Treasury Bill rates.

EXHIBIT 2

Empirical Results of Mills Test

Eurodollar rate as function of Variables	1966-68 (N = 156) Coefficient	t-ratio	1969-70 (N = 96) Coefficient	t-ratio
Constant	1.00	2.36	3.37	0.93
TBR	.24	2.44	.61	3.07
BLAR	.16	2.74	.29	1.72
GILR	.33	7.36	.04	0.30
SBDR	.18	2.42	.10	0.21
FPS	-.02	1.06	-.06	1.56
FDM	.30	6.98	-.01	0.53
FSF	.02	0.45	.07	0.99
RRD	--	--	-.28	0.81
RQD	.11	1.73	--	--
QCD	--	--	-.09	1.51
S.E.E.	.17		.32	
R^2	.93		.92	
D.-W.	2.10		1.91	

Source: Mills [11], p. 11.

The above four empirical studies of the relationships between the Eurodollar and U. S. interest rates, make it abundantly clear that changes in the U. S. interest rate have a great influence on changes in Eurodollar interest rates. The only surprising fact is that the coefficient for the U. S. interest rate at the highest was only .622. The relatively low levels for the coefficient may be the result of some methodology problems in these empirical studies.

The first and most obvious problem of all four studies is the use of the U. S. Treasury Bill rate as a proxy for U. S. interest rates. Eurodollar deposits are liabilities of commercial banks whose risk characteristics are different from that of the issuer of Treasury Bills. Comparison of interest rates on two different securities would significantly erode the value of the four studies' results.

A second, and methodologically more intriguing, is the problem pertaining to effective foreign interest rates. Since Hendershott excluded foreign interest rates and Kwack used nominal foreign interest rates, these two studies are of little interest. However, both Mills and Argy & Hodjera tried to adjust for the exchange risk without producing higher results. Both empirical studies appear to have relied on the so-called modern theory of the forward rate which states that the forward differential is determined by interest arbitrage and speculative forces:

Forward premium = interest differential + speculation term (6)

Therefore when the forward premium or discount differed from the interest differential, they concluded that the speculation favored one currency over the other.

The modern theory is correct in that speculative forces are important determinants of the level of the forward premium or discount. However, as presented in equation (6), the modern theory neglects the fact that speculative forces affect not only the forward premium but also the interest differential. The interest differentials in equation (6) are not exogenously determined but are simultaneously determined with the forward premium and speculation and adjust to a point where the forward premium equals the interest differential and there is no longer a covered-interest arbitrage profit. As a result, ex post data on interest differentials does not separate interest rate and expectational influences. At interest rate parity, foreign rates minus domestic rates should equal the forward premium or discount. Any observed discrepancy between the forward premium and the interest rate differential must be attributed not to market speculation but to factors that prevent perfect arbitrage, such as transactions costs (see Agmon and Bronfeld [1]) or political risk (see Aliber [2]). The latter would suggest a relationship such as the following:

Forward premium = interest differential + risk (7)

The significant difference between equations (7) and (6) is that while the equation (6) tends to conclude one currency is favored over the other and is often used as an indicator of the direction of future short term capital flows, equation (7) does not make such a judgment. All equation (7) says is that the market is in equilibrium at a certain point in time with a given market-perceived risk level. If the market perceived risk goes down for one currency, say German marks, then capital will flow into German mark deposits. However, since we do not know whether perceived risks will rise or fall in the future, we cannot make an a priori assumption about the direction of the future short-term capital flow. Hence, empirical studies using the difference between forward premium and the interest differentials to predict future direction of the short-term capital movement will yield questionable results.

Third, the test periods of all four studies, between 1961 to 1971, were affected by the varied extent of U.S. capital control programs. Had the capital control programs been totally effective, the Eurodollar market would have been isolated from U.S. markets and therefore there would be no reason to expect any relationship between U.S. and Eurodollar interest rates. On the other hand, had there been no capital controls, there would have been a perfect arbitrage between two markets and therefore the coefficient of the U.S. interest rate would have been much higher than .622. The problem with empirical studies for these periods was that the capital control program was there but very often circumvented by investors. To some extent, then, what the four empirical studies measured was not the true relationships between two interest rates but partially the ingenuity of the investors in circumventing the capital control programs.

Hence a meaningful study of the relationships between U. S. and Eurodollar interest rates has not yet been produced, although Lutz [8] has provided a point of departure. He hypothesizes that when there are no capital control programs, the Eurodollar lending rate will be lower than the U. S. lending rate and the Eurodollar deposit rate will be higher than the U. S. deposit rate. Given these theoretical upper and lower limits to Eurodollar interest movements, one may proceed to study the determinants of the interest differentials between two lending or deposit rates.

III. Relationships between interest rates on Eurodollars and other Currencies

The first empirical study of the relationship between interest rates on Eurodollars and other Eurocurrencies was carried out by Kaen [6]. Regressing forward premium for sterling against the interest differentials between Eurodollar and Eurosterling, Kaen's empirical study produced very high regression coefficients and coefficients of determination (Exhibit 3).

EXHIBIT 3

Forward Sterling-U. S. Dollar Premia Regressed Upon
Three-Month Eurosterling-Eurodollar
Interest Rate Differentials
(January 1963 - May 1971)

Time Period	Constant Term	Regression Coefficient	R^2	Durbin-Watson
1963-1971	.015 (.024)	.993 (.010)	.989	2.1592
1963-1965	.072 (.034)	1.02 (.023)	.982	2.2906
1965-1967	-.131 (.049)	.937 (.025)	.976	2.3245
1967-1969	.068 (.052)	.976 (.016)	.991	2.3444
1969-1971	.073 (.055)	1.002 (.018)	.991	2.8614

Source: Kaen [6], p. 243.

Kaen also tested the relationships between Eurodollar and Euromark interest rates and found a regression coefficient which was very close to unity (1.0397) and an R^2 which was very high (.992). Kaen's empirical results were supported by subsequent empirical studies by Marston [9] and Aliber [2] which also produced regression coefficients near unity and high R^2s. Agmon and Bronfeld [1] went a little further. Based on the actual covered interest arbitrage model they concluded that any deviation of regression coefficient and R^2 from unity in empirical studies of the relationships of the interest rates among Eurocurrencies was simply the result of neglecting the difference between bid and offer rates on Eurocurrencies and forward contracts.

In short, all the empirical studies are in agreement that short-term arbitrage capital in the Eurocurrency market is perfectly mobile and therefore interest rates among Eurocurrencies are tied to each other through forward premia.

In addition to providing explanations about relationships of interest rates among Eurocurrencies, these studies provided strong support for the interest parity theory of the forward exchange rate. The modern theory stated that the forward premium would be different from the interest differentials between two currencies by the amount of market speculation. If the modern theory were correct, the above empirical studies should have shown consistent and significant deviations from unity during highly speculative periods. However, because the speculative forces were accommodated by corresponding movements either in the forward premium or in the interest differential, the empirical work showed regression coefficients near to unity and high R^2s. Therefore any empirical study that yielded a consistent and significant difference between the forward premia and the interest differentials did not show the impact of speculative forces but only the selection of interest rates on two securities which were not compatible in terms of risk, i.e., a data problem.

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APPENDIX 2

Empirical Studies of Interest Rates, Forward Rates and Exchange Rate Expectations

The body of this paper has relied primarily on a framework in which the forward rate is assumed to equal approximately the expected future exchange rate. This appendix discusses this issue in the context of recent theory and empirical work on exchange rate expectations, interest rates, and forward exchange rates. As was noted in the insert on pp. 25-27, there exist three major theories about the relation between forward exchange rates and expected spot rates. The first hypothesizes that the forward rate is an unbiased estimator of the expected future spot rate:

$$E(S_{t+n}) = F_t^n \tag{1}$$

where $E(S_{t+n})$ is the value of the spot rate at time t+n that the market expects at time t and F_t^n is the n-period forward rate prevailing at time t. Discussions of this hyopthesis (sometimes referred to as a "Fisherian model" after Irving Fisher[1] whose work published in 1930 laid the foundation for this theory) may be found in Aliber [3], Frenkel [5], and Giddy [6].

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[1] Irving Fisher, The Theory of Interest (New York: Macmillan, 1930).

If interest rate parity prevails, then providing evidence in favor of equation (1) also supports the hypothesis of the forward differential being an unbiased predictor; this is because in that case the forward premium or discount equals the interest rate differential (see Aliber and Stickney [2]). Some empirical support for the unbiased forward rate hypothesis is provided in Frenkel [5], Bilson [4], Stockman [14], and Kohlhagen [8]. Some of Kohlhagen's results are reproduced in Exhibit 2-1.

A second approach is to argue that equation (1) would hold were it not for transactions costs that in practice cause the forward rate to deviate from the expected future spot rate by an amount reflecting such costs. This theory, upon which work by Kaserman [7] and Levich [9] is based, states quite simply that any change in the expected spot rate, $dE(S_{t+n})$, will be accompanied by a change in the forward rate, dF_{t+n}, in an amount equal to the change in the expected spot rate <u>less</u> the transactions cost of forward speculation (say, T). If the change in the expected spot rate is not sufficiently large to offset the transactions cost of acting upon one's expectations, no change in the forward rate will occur, as was suggested by the diagram on page 27. Thus, the theory may be stated in the following form:

$$\frac{dF_t}{dE(S_{t+n})} = 1 \quad \text{when} \quad \left| F_t - E(S_{t+n}) \right| \nless T$$

Exhibit 2-1

The Predictive Power of the Forward Exchange Rate

Country	Exchange Regime†	$\left[\frac{\Sigma(x'-x_{+90})}{n}\right]$ Mean	S.D.	Degrees of Freedom	t	F
Canada	Floating 1	-0.1006	1 089	100	-0.928*	–
Canada	Floating 2	0.0819	1.482	83	0.507*	–
Canada	Combined	-0.0177	-	1,183	–	0.929**
Denmark	Fixed	-0.4921	1.06	100	-4.667	–
Denmark	Floating	-0.6426	2.566	83	-2.295*	–
Denmark	Combined	-0.5604	–	1,183	–	0.288**
France	Fixed	-0.2962	0.691	100	-4.307	–
France	Floating	-0.1015	1.573	83	-0.592*	–
France	Combined	-0.2078	–	1,183	–	1.258**
Germany	Fixed	-0.6028	1.046	100	-5.79	–
Germany	Floating	-0.5077	3.476	83	-1.338*	–
Germany	Combined	-0.5596	–	1,183	–	0.068**
Switzerland	Fixed	-0.5255	1.097	100	-4.816	–
Switzerland	Floating	-0.8478	2.64	83	-2.944	–
Switzerland	Combined	-0.6718	–	1,183	–	1.248**
U.K.	Fixed	-0.1451	8.044	83	-0.165*	–
U.K.	Floating	-2.1111	10.727	109	-2.064*	–
U.K.	Combined	-1.2598	–	1,192	–	1.973**
Canada	1952-1961 flexible	-.3262	1.334	113	-2.611*	–
Canada	1962-1970 fixed	-.031	5.97	93	-.504*	–
Canada	Combined	-.1564	–	1,206	–	1.361**

x' = weekly averages of 90-day forward exchange in U.S. cents per unit of currency.

$x'-x_{+90}$ = profit from forward purchase of currency, closed out at maturity.

$$S.D. = \sqrt{\frac{SSR}{n-1}}$$

$$t = \text{mean}\sqrt{\frac{n(n-1)}{SSR}} = \frac{\text{mean}\sqrt{n}}{S.D.}$$

†Canada had a floating exchange rate in both periods; the U.K. had a fixed exchange rate and a floating rate from January 1971 to August 1972 and September 1972 through December 1974 respectively; for all other countries, the two periods were January 1971 through December 1972 and April 1973 through December 1974 respectively.

**At the .99 confidence level, we cannot reject the hypothesis that the mean for each exchange rate regime is the same.

*At the .99 confidence level, we cannot reject the hypothesis that the mean equals zero.

Source: Kohlhagen [8].

$$\frac{dF_t}{dE(S_{t+n})} = 0 \qquad \text{when } \left| F_t - E(S_{t+n}) \right| < T \tag{2}$$

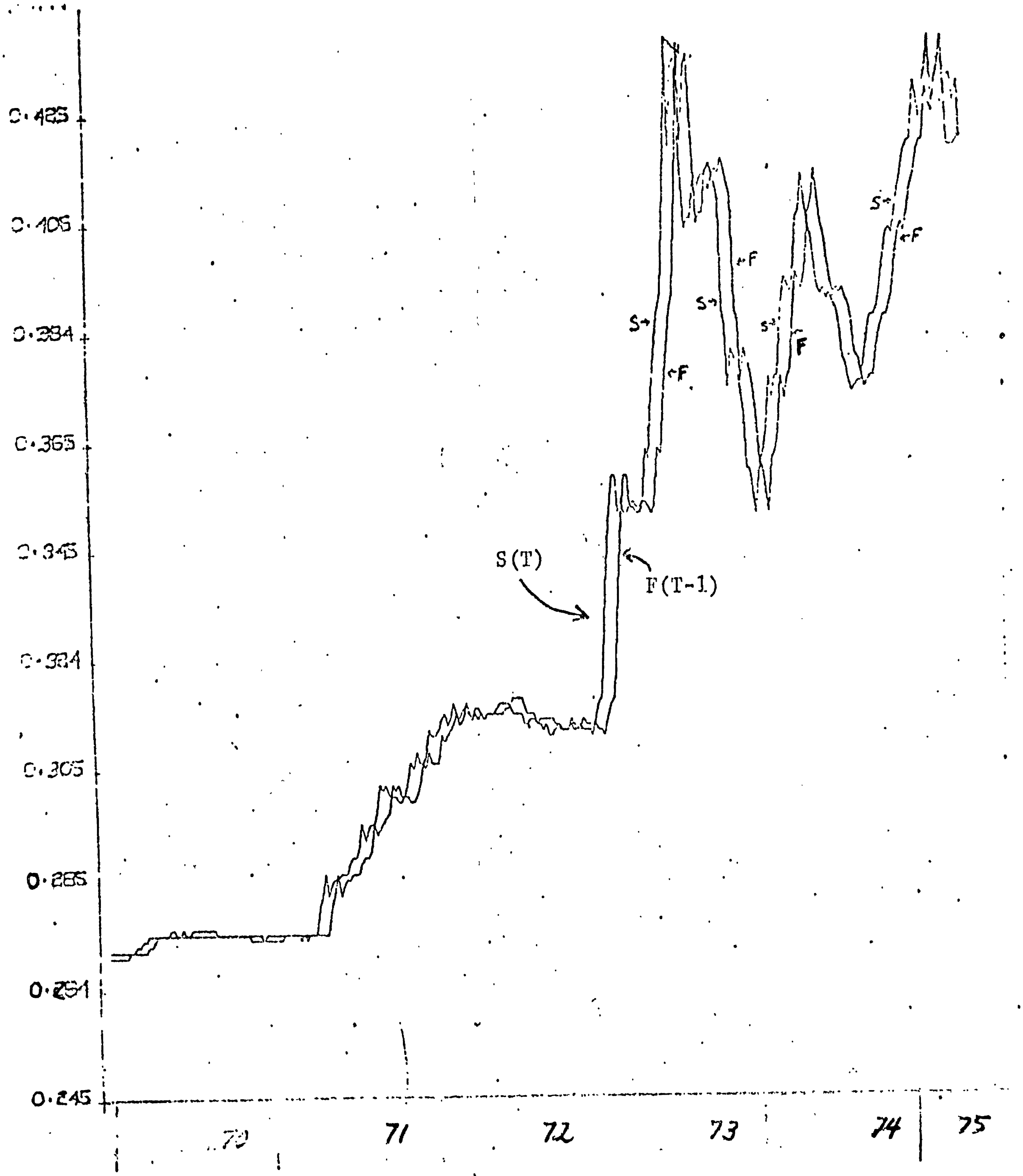
The implication of this hypothesis is that the forward rate will be consistently higher than the expected spot rate whenever the latter is falling, and will remain below when it is rising, so long as the change in the expected future rate is larger than the transaction cost.

Both Kaserman [7] and Levich [9] present evidence to support this hypothesis. Some of Levich's results are shown in Exhibit 2-2. These results are somewhat more convincing than those in support of equation (1). Several of the studies testing the latter hypothesis do find slight deviations from the expected relationship, but attribute them to data errors or market inefficiencies. Since both Levich and Kaserman find the transactions costs to be small relative to the fluctuations in rates, minor deviations from equation (1) may well be associated with transactions costs.

A third set of theories (see Solnik [12], Adler and Dumas [1]) argues that investors may be deterred from profiting fully from a gap between the forward rate and the expected future spot rate because of perceived currency risk. In other words, the riskiness of so-called speculative transactions may mean that the demand for forward currency by investors is not infinitely elastic at the forward rate that equals the expected future spot rate. Unfortunately, it is very difficult to specify the nature of this risk, since foreign exchange transactions that are influenced by currency expectations frequently reduce rather than increase risk for the investor. Nor is a single currency necessarily the

Exhibit 2-2

Plot of Spot Rate and 1-Month Forward Rate Forecast, Dollar/German Mark Exchange Rate, 1970-75



Source: Levich [9].

best base from which to measure exchange risk, since an investor's welfare is affected by the cost of imports as well as by returns in his own currency.

The following represents a typical formulation of this category:

$$E(S_{t+n}) = F^n_t + \frac{Cov(S, R_m)}{Var(R_m)} (E(R_m) - RF) \tag{3}$$

where R_m is the return on some world market portfolio;

RF is a domestic risk-free interest rate;

$Cov(S, R_m)$ is the covariance between the exchange rate and returns on the world market portfolio;

$Var(R_m)$ is the variance of returns on the world market portfolios.

Empirical tests purporting to support such theories have been undertaken by Solnick [13] and Roll and Solnick [11]. The difficulty of specifying and measuring the correct covariance term (i. e., the risk-free rate and an appropriate portfolio index), however, makes the evidence that has appeared to date of dubious value.

In fact, to date no empirical work has come to our attention that would provide convincing evidence for or against the three approaches described above. The reason is that each theory contains an unobservable-variable, i. e., the expected future exchange rate, as a determinant of the forward rate. Hence none of the studies done so far have tested the theories directly; all have examined whether the forward rate is a biased estimator of the actual future spot rate instead of the expected future spot rate. Since the forecasting accuracy of speculation is not an integral part of the unbiased forward rate theory, we can only conclude that the issue remains essentially unresolved, although most of the evidence suggests that the forward rate is a reasonably unbiased estimator of the future spot rate.

In a seminal study, Michael Porter [10] has explored the term structures of interest rates and of exchange rate expectations. The remainder of this appendix draws on his work to show how the term structures of international interest rates can be used to make inferences as to the expected time path of the exchange rate between two currencies and how exchange rate risk affects the term structure of interest rate differentials. Porter's tests, using Canadian and U.S. interest rates and exchange rates, provide some support for the notion that both exchange rate expectations and foreign exchange risk (measured as simple standard deviations) explain interest rate relationships, and suggest that interest rate ratios predicted future exchange rates reasonably well while the Canadian dollar was floating (1953-60). His results, however, are of less interest to us here than is the theoretical framework employed which we believe can be profitably applied to Eurocurrency rates.

First, let us derive Eurocurrency interest rate relationships under the assumption of negligible risk aversion. As in the interest rate parity theorem (see footnote on p. 31),

Value at t+n of \$1 earning interest rate $I_{n,E\$}$	=	Value at t+n of \$1 converted into foreign currency and earning interest rate $I_{n,EDM}$ until t+n when it is converted back into dollars at the expected future spot rate, $E(S_{t+n})$. Thus

$$\$1(1+I_{n,E\$})^n = (\$1/S_t)(1+I_{n,EDM})^n E(S_{t+n}) \tag{4}$$

where $I_{n,E\$}$ and $I_{n,EDM}$ are the interest rates on n-period Euro-deposits denominated in dollars and German marks, respectively, at time period t. S_t is the spot rate and $E(S_{t+n})$ is the spot rate expected to prevail at time t+n; both rates are expressed in dollars per foreign currency unit. Rearranging (4):

$$\frac{(1+I_{nE\$})^n}{(1+I_{n,EDM})^n} = \frac{E(S_{t+n})}{S_t} \tag{5}$$

Next, from the expectations theory of the term structure of interest rates (see Appendix 1, p. 58), we obtain

$$(1+I_{n,E\$})^n = (1+I_{1,E\$})(1+{}_{t+1}i_{E\$})(1+{}_{t+2}i_{E\$}) \cdots (1+{}_{t+n-1}i_{E\$}) \tag{6}$$

where $I_{1,E\$}$ is the 1-period Eurodollar interest rate available at time t and ${}_{t+j}i_{E\$}$ is the <u>expected</u> 1-period Eurodollar interest rate available at time t+j. In other words, the interest rate on a long-term deposit equals the geometric mean of intervening expected short-term deposits.

From this, we can derive a market expected short-term deposit rate in any future period, say n, as follows:

$$(1+{}_{t+n}i_{1E\$}) = \frac{(1+I_{nE\$})^n}{(1+I_{n-1E\$})^{n-1}} \tag{7}$$

By deriving a similar relationship for Euromark interest rates, and dividing, we obtain the following:

$$\frac{(1+{}_{t+n}i_{1E\$})}{(1+{}_{t+n}i_{1EDM})} = \left(\frac{1+I_{nE\$}}{1+I_{nEDM}}\right)^n \bigg/ \left(\frac{1+I_{n-1E\$}}{1+I_{n-1EDM}}\right)^{n-1} . \tag{8}$$

Substituting (5) into (8), we arrive at

$$\frac{(1+{}_{t+n}i_{1E\$})}{(1+{}_{t+n}i_{1EDM})} = \frac{E(S_{t+n})}{E(S_{t+n-1})} = 1 + E({}_{t+n}r_1) \tag{9}$$

where $E({}_{t+n}r_1)$ is the market expected 1-period exchange rate change in period t+n.

Applying the equation (6) to Euromark interest rate and dividing, we can also obtain the following:

$$\frac{1+I_{n,E\$}}{1+I_{n,DEM}} = \frac{\sqrt[n]{(1+I_{1,E\$})(1+{}_{t+1}i_{E\$})(1+{}_{t+2}i_{E\$})\cdots(1+{}_{t+n-1}i_{E\$})}}{\sqrt[n]{(1+I_{1,EDM})(1+{}_{t+1}i_{EDM})(1+{}_{t+2}i_{EDM})\cdots(1+{}_{t+n-1}i_{EDM})}}$$

$$= \left[\left(\frac{1+I_{1,E\$}}{1+I_{1,EDM}}\right)\cdot\left(\frac{1+{}_{t+1}i_{E\$}}{1+{}_{t+1}i_{EDM}}\right)\left(\frac{1+{}_{t+2}i_{E\$}}{1+{}_{t+2}i_{EDM}}\right)\cdots\left(\frac{1+{}_{t+n-1}i_{E\$}}{1+{}_{t+n-1}i_{EDM}}\right)\right]^{\frac{1}{n}} . \tag{10}$$

Substituting (9) into (10) for all periods,

$$\frac{1+I_{n,E\$}}{1+I_{n,EDM}} = [(1+E({}_t r_1))(1+E({}_{t+1}r_1))(1+E({}_{t+2}r_1))\cdots(1+E({}_{t+n-1}r_1))]^{\frac{1}{n}} . \tag{11}$$

This suggests that under the condition of no risk-aversion and at equilibrium, the international interest rate ratio for n-period deposits equals the geometric mean of the intervening expected 1-period rates of change of the exchange rate. From this result and equation (5), we derive an expectations theory of the term structure of exchange rate expectations.

$$\frac{E(S_{t+n})}{S_t} = (1+E({}_t r_1))(1+E({}_{t+1} r_1))(1+E({}_{t+2} r_1)) \cdots (1+E({}_{t+n-1} r_1)) \tag{12}$$

From the above relationships -- in particular, equation (5) -- we may infer the expected spot rate for various future time points from the ratio of international interest rates for various maturities. The following cases (which correspond roughly to those depicted in Figure 7 on pp. 51-53) exemplify how values of $E(S_{t+n})$, the expected future spot rate, may be obtained from various term structure relationships.

Case 1: the market expects no change in the exchange rate.

$$\frac{1+I_{nE\$}}{1+I_{n,EDM}} = 1 \text{ (i.e. } I_{n,E\$} = I_{n,EDM}\text{) for all values of n implies}$$

$$\frac{E(S_{t+n})}{S_t} = 1 \text{ (i.e. } E(S_{t+n}) = S_t\text{)}$$

Case 2: the market expects an immediate change of the exchange rate to a new level.

$$\frac{1+I_{n,\,E\$}}{1+I_{n,\,EDM}} = e^{\frac{a}{n}} \quad \text{implies } E(S_{t+n}) = S_t\, e^{a}$$

Case 3: the market expects a constant rate of depreciation or appreciation of the exchange rate.

$$\frac{1+I_{n,\,E\$}}{1+I_{n,\,EDM}} = a \quad \text{implies } E(S_{t+n}) = S_t a^{n}$$

Case 4: the market expects the exchange rate to converge asymptotically to a new level.

$$\frac{1+I_{n,\,E\$}}{1+I_{n,\,EDM}} = e^{\frac{a}{n}(1-\frac{1}{n})} \quad \text{implies } E(S_{t+n}) = S_t e^{a(1-\frac{1}{n})}$$

Next, we shall explore the way in which the introduction of exchange risk will complicate the analysis of the term structure of Eurocurrency interest rate differentials. If investors seek to minimize risk as well as to maximize return, it is no longer possible to assume that the market will be in equilibrium when expected yields from Eurocurrency deposits are equal. Instead we must assume that yield differentials will settle at the levels that equalize the expected marginal utility from holding each Eurocurrency deposit. In other words for the equilibrium term structure of international yield differentials to prevail, investors must perceive no gain, at the margin, from switching their deposits (loans) from one currency into deposits (loans) denominated in the other currency. Porter employed such a framework to show that the actual yield differentials would then be a function of the expected exchange rate, the yield's variances, the variance of the exchange rate, and the covariances between yields and exchange rates. Even in a simple three-asset framework the resulting formula becomes cumbersome and will not be reproduced here. Suffice it to say that foreign exchange risk may cause yield ratios to differ from the expected rate of change of the exchange rate, so that (6) takes the form

$$\frac{(1+I_{n, E\$})^n}{(1+I_{n, EDM})^n} = [1+E(R_{t+n})] + \text{risk factor} . \qquad (11)$$

And if the risk factor specified in (11) increases with the investment time horizon, yield ratios will diverge from exchange rate expectations more, the greater the maturity of the securities.

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