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Some considerations concerning the efficiency of forward exchange rates as predictors of future spot exchange rates

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Some Considerations Concerning the Efficiency
of Forward Exchange Rates as Predictors of
Future Spot Exchange Rates

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Serie A - Nr. 136

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I

As a consequence of the growing interest in international monetary economics special attention has been paid recently to the distinction between actual and expected exchange rates. In theoretical considerations, such as those of the Dornbusch variety (Dornbusch (1976)), this distinction is of crucial importance for the effectiveness of monetary policy, for example. The introduction of expected values into purely theoretical discussions does not involve particular problems of identifying, at time $t-1$, the unknown exchange rate for time t . For empirical investigations, however, the question of which variable to use to represent the expected exchange rate is of the same importance as the problem of identifying expected inflation rates in the rational expectation context.

In contrast to the case of expected inflation rates, there do exist observable market figures for expected exchange rates, namely forward rates, and these do seem to provide a satisfactory time series for this expected variable. Several empirical studies follow this approach and use the forward exchange rate as a substitute for the unobservable expected exchange rate.¹⁾

1) For example, Frenkel (1979), Abel et al (1979), Alexander and Loef (1979) and Loef (1980).

An alternative to this approach would be the assumption of random walk behavior by the actual and future exchange rates which leads to an adaptive expectations scheme for the expected exchange rate (see, for example, Levich (1978)). Both these approaches could be subsumed under the heading of the asset market approach.

A third approach extends the ideas of modern international monetary theory and particular those of the monetary theory of the balance of payments and relate the expected exchange rate, under the assumption of rational expectations, to economic forces (e.g., money supply and money demand), using information known at time $t-1$.²⁾

This paper is concerned with the first, and partly with the second, approach and examines the performance of the market forward rate as a predictor of the future spot rate.³⁾ The DM/\$ exchange rate for the period I.1970 to IV.1978 is used as an empirical example. Section two

2) For example, Bilson (1978), Mussa (1979) and Caves and Feige (1980).

3) The recent concern about this special issue seems to be increasing. A more detailed list of references than that contained in my paper is to be found in Levich (1978), Stockman (1978), Fama and Farber (1979), Caves and Feige (1980) and Fratianni and Wakeman (1980).

starts with a statistical inference about the relationship of forward rates and future spot rates. The character of the forward rate as a biased predictor of the future spot rate is examined theoretically in section three. In section four the empirical context is re-entered with an attempt to take the foregoing theoretical considerations into account. Section five summarizes the findings and an appendix contains the data used in the empirical sections.

II

The 'market figure' approach which uses the forward rate FR_{t-1} as a predictor of the future spot exchange rate SR_t can best be understood by looking at the time series of these two variables relative to each other. Fig. 1 shows the behavior of the spot rate at time t (SR_t) and the movement of the forward rate lagged one quarter (FR_{t-1}) for the first quarter of 1970 to the fourth quarter of 1978 for the DM/\$ exchange rate. Both series move very close together, and, moreover, when the exchange rate depreciates the spot rate lies above the forward rate, whereas in periods of appreciation the spot rate lies below.

The forward rate FR_{t-1} known at $t-1$ can be used as a good and efficient predictor of the spot rate SR_t , unknown at



FIG. 1 SPOT EXCHANGE RATE AT TIME T DM/\$
 FORWARD EXCHANGE RATE AT TIME T-1 DM/\$
 'BACKWARDATION'

time $t-1$, if the forward market is an efficient market in the sense described by Fama (1970, 1975, and 1976). FR_{t-1} then contains all available information about SR_t known at time $t-1$.

To test these characteristics of FR_{t-1} (see Frenkel (1979)), I regress equation (1) below using data for SR (spot rate, DM/\$) and FR (forward rate for three month contracts, DM/\$) for I.1970 to IV.1978, where u_t represents the stochastic terms with the usual properties assumed.

$$(1) \quad SR_t = a_0 + a_1 FR_{t-1} + u_t$$

In this study I use quarterly averages of spot and forward rates rather than the point of time values used by, for example, Stockman (1978). To adopt the latter procedure would involve the problem of exact timing and possible recontracting. Moreover, in empirical studies, like those of Frenkel (1979) and Loef (1980), the emphasis is on expectations about average rates for a period (e.g., a month or a quarter) rather on expectations about exchange rates for a point in time (e.g., the last day of the period in consideration). The alternative procedure, that of taking daily or weekly spot rates and daily or weekly forward rates with three month contracts, would certainly lead to different results from those obtained in this study (see, for example, Stockman (1980)).

If FR_{t-1} is an efficient forecast in the sense of Fama then a_0 must be zero, a_1 must equal one and there should be no autocorrelation in the disturbance terms u_t , that is, $E(u_t u_{t-1}) = 0$. Further, if all available information at $t-1$ is contained in FR_{t-1} , lagged values of FR other than FR_{t-1} should not contribute to the explanation of SR_t .

Testing equation (1) results in:

$$(2) \quad SR_t = \begin{matrix} 0.03541 \\ (0.42) \end{matrix} + \begin{matrix} 0.97635 \\ (33.05) \end{matrix} FR_{t-1} + u_t$$

$$R_{adj}^2 = 0.9680; \text{ F-ratio} = 1092; \text{ SE} = 0.0949; \text{ D.W.} = 1.90;$$

(t-ratios in parantheses below the parameters,

SE = standard error of estimation and D.W. =

Durbin-Watson statistic).

Equation (2) shows that a_0 is not significantly different from zero, a_1 is close to one and there is no autocorrelation as indicated by the Durbin-Watson statistic of 1.90.

Introducing the additional lagged term, FR_{t-2} , into equation (2) yields a coefficient a_2 which is negative and not different from zero as in equation (3).

$$(3) \quad SR_t = \begin{matrix} 0.04259 \\ (0.50) \end{matrix} + \begin{matrix} 1.1092 \\ (7.90) \end{matrix} FR_{t-1} - \begin{matrix} 0.13283 \\ (0.97) \end{matrix} FR_{t-2} + u_t$$

$$R_{adj}^2 = 0.9680; \text{ F-ratio} = 546; \text{ SE} = 0.0950; \text{ D.W.} = 2.12;$$

A Box-Pierce-test or a Q-test would be more appropriate here to test for purely white-noise in the residuals because the Durbin-Watson statistic only tests for first order autocorrelation. Computational problems, however, precluded a Q-test in the present version of the paper. Two similar tests about the efficiency of the currency markets by means of a F-test are easy to perform instead. First, I regressed the residuals of equation (2) to their own lagged values up to eight lags: $u_t = \alpha_0 + \sum_{j=1}^8 \alpha_j u_{t-j}$. All parameters turn out to be insignificant and the adjusted R^2 equals -0.1166. The F-ratio for this regression equation is 0.76 which is considerable below the 95% critical value of 2.48 (8;19 degrees of freedom). It can be concluded therefore that higher order autocorrelation is absent from equation (2) as well as first order autocorrelation. Second, I included in equation (1) additionally lagged values of the forward rate. In order to take care of the lagged forward rate data the new time period runs from I.1972 to IV.1978. If the resulting R^2 is then properly compared with the R^2 of regression equation (1) using only FR_{t-1} as the explanatory variable (besides the constant term) for the same new time period the obtained F-ratio measures the additional influence of the higher lagged forward rates. This F-ratio turns out to be 0.82 and is significantly below the 95% and 99% critical values of the tabulated F-statistics of 2.55 and 3.77, respectively.

Both applied tests, therefore, indicate that the currency markets (spot and forward markets together) are efficient and that the current value of FR_{t-1} contains all available information.

Taking natural logarithms, as Frenkel (1979) does, the results of equations (2) and (3) are not altered essentially.

It could be argued that today's spot rate influences today's forward rate and so has a great impact on the future spot rate. This dependency follows, for example, from the theoretical assumption that exchange rate expectations are adaptive or follow a simple random walk hypothesis (Levich (1978) and Bilson (1978)) together with the underlying assumption of efficiency in the spot market. This theory is analogous to the notion that today's weather is the best forecast of tomorrow's weather. If that is correct today's spot rate would explain tomorrow's spot rate as well as does today's forward rate. A test equation, (4) below, corresponding to this hypothesis uses SR_{t-1} as the independent variable.

$$(4) \quad SR_t = 0.01132 + 0.9780 SR_{t-1} + u_t \\ (0.11) \quad (27.06)$$

$$R_{adj}^2 = 0.9530; F\text{-ratio} = 732; SE = 0.1151; D.W. = 1.70;$$

Although the coefficients have the correct value and sign, the summary statistics indicate an inferior performance of this hypothesis as compared to the former one. The standard error of estimation rises to 11.5% points. The adjusted R^2 drops by 1.5% and the Durbin-Watson statistic is now in the indeterminacy region. Furthermore in (4) the independent variable used is in fact a lagged endogenous one so that the Durbin-Watson statistic is expected to be biased towards two. Durbin's h-statistic which is more appropriate here shows a value of 0.92 which, if compared to the value of the normal distribution assuming a 5% error level, does not indicate autocorrelation.

The standard error of estimation rises by more than 2%age points, indicating that market participants using the forward rate as the future spot rate predictor make fewer mistakes than those taking the current spot rate.

Altogether then, it can be concluded that FR_{t-1} contains at least the information contained in SR_{t-1} . Since FR_{t-1} explains SR_t better than SR_{t-1} does, the forward rate must contain more information than SR_{t-1} . Thus, the market value of the forward rate is a better proxy variable for the expected exchange rate than a simple adaptive expectations scheme which uses lagged spot rates to explain future ones.

The inclusion of SR_{t-2} in equation (4) does not improve the statistical findings. The parameter of SR_{t-2} is again not significantly different from zero, indicating the efficiency of the spot market.

The time period used (I.1970 to IV.1978) consists of periods where the German Bundesbank intervened in the exchange market to keep the DM/\$ exchange rate more or less within a prefixed band. In March 1973 the Bundesbank abandoned the fixing of the DM/\$ exchange rate. Therefore, it could be argued that the result of equation (2) is biased in that the intervention period I.1970 to I.1973 shows a closer relationship between SR_t and FR_{t-1} than the period of more freely fluctuating exchange rates. Retesting equation (1) using only data for II.1973 to IV.1978 leads to regression equation (5).

$$(5) \quad SR_t = \begin{matrix} 0.22945 \\ (0.91) \end{matrix} + \begin{matrix} 0.89517 \\ (8.62) \end{matrix} FR_{t-1} + u_t$$

$$R_{adj}^2 = 0.7588; \text{ F-ratio} = 74; \text{ SE} = 0.1086; \text{ D.W.} = 1.89;$$

Time period: II.1973 - IV.1978.

Equation (5) shows inferior results compared to equation (2). The R^2 drops remarkably and - more important - the a_1 coefficient as a point estimate is considerably less one.

Looking at Fig. 1 it can be seen that the more or less steady decline of the DM/\$ exchange rate from I.1970 to I.1973 is replaced by rather volatile fluctuations, at least during III.1973 to IV.1975. These larger variations in the spot (and forward) rate cause the comparatively low correlation coefficient in (5) and might cause the deviation of a_1 from one.

III

Even though the forward rate at $t-1$ predicts the future spot rate at t quite well, one problem arises with respect to the a_1 coefficient in (1). The point estimation of a_1 in regression equations (2) and (5) is about one standard deviation lower than the theoretical value of one. Both results point to the fact that the forward rate overestimated the future spot rate on average. Moreover, Frenkel's results for the German hyperinflation show an underestimation of the forward rate in those period on average. In general, in periods of rising exchange rates (depreciation) the forward rate lies below the future spot rate, thus underpredicting the latter, while in periods of falling exchange rates (appreciation) the forward rate lies above the future spot rate, thus overestimating the actual future exchange rate (see Fig. 1).

There exist several theoretical arguments which provide possible explanations for the forward rate being a biased forecast for the future spot rate. Before turning to these theoretical considerations it is worthwhile to distinguish between four exchange rates (for the same two currencies) and the relationship between them (Fig. 2).

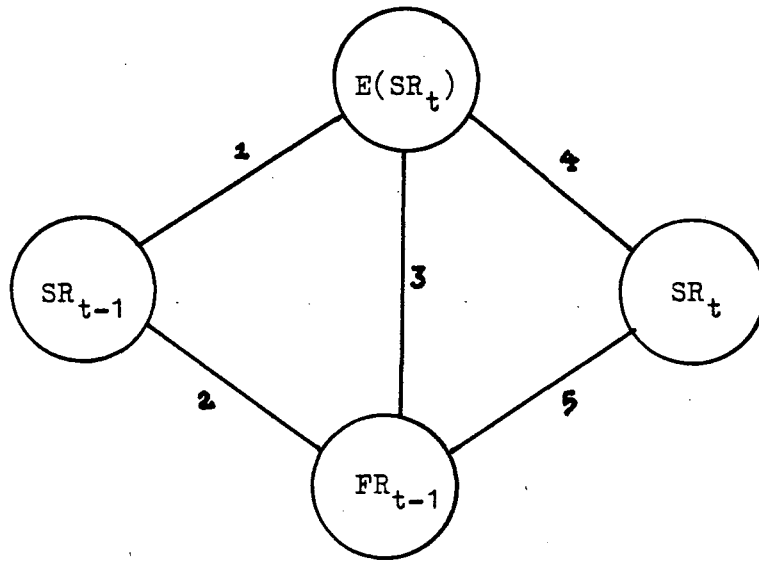


Fig. 2

Possible Relationships
Among Exchange Rates

In Fig. 2 SR_{t-1} and FR_{t-1} represent the spot and forward rate known and observed with certainty at time $t-1$.

$E(SR_t)$ is the unobservable expectation at time $t-1$ for the future unknown spot rate SR_t .

Direct empirical testable relationships are the links 2 and 5 (and the link between SR_{t-1} and SR_t according to

the random walk hypothesis, which is not shown in Fig. 2, however). In the present paper the major empirical concern is about link 5. Deviations of the forward rate FR_{t-1} from the future spot rate SR_t could be purely random. In this case the forward rate could be an unbiased predictor of the future spot rate. If, however, besides stochastic disturbances, both rates deviate systematically from each other (as Fig. 1 suggests) the forward rate would be a biased predictor.

The bias could be attributed to two general sources, separately or jointly. First, the forward rate might be a poor and therefore a biased operator for the unknown expected future spot rate (link 3). Judging from the literature, this source seems to be the major one.

Second, the expectations about the future themselves could be systematically wrong (link 4). This phenomenon could be described in terms of the modern theory of the balance of payments as overshooting/undershooting or inelastic expectations (e.g., Dornbusch (1976)). Another possibility could be irrational expectations. In these cases the forward rate would be a biased forecast of the future exchange rate (link 5) although (or better because) the forward rate exactly mirrors the expected exchange rate.

Most theoretical explanations about the forecast bias, however, are attributed to link 3 in Fig. 2 which can be labeled "backwardation" in Keynes's terminology (Keynes (1930, p. 143 and 144)).

Before turning to these issues it should be mentioned that link 2, which, again in Keynes's terminology, is named "contango" (Keynes (1930, p. 144)), predicts that for rising exchange rates (depreciation) the forward rate FR_{t-1} is higher than the actual spot rate at time $t-1$ while for falling exchange rates (appreciation) FR_{t-1} is smaller.

The relationship between actual spot rate SR_{t-1} , forward rate FR_{t-1} and expected spot rate $E(SR_t)$ will, therefore, be the following:

$$SR_{t-1} < FR_{t-1} < E(SR_t) \quad \text{for rising exchange rates and}$$
$$SR_{t-1} > FR_{t-1} > E(SR_t) \quad \text{for falling exchange rates,}$$

if "contango" dominates link 2 and "backwardation", which I discuss below in terms of risk aversion, influences link 3 in Fig. 2.⁴⁾

4) Keynes, in describing rising future spot prices at the commodity market, writes "..., the quoted forward price, though above the present spot price, must fall below the anticipated future spot price by at least the amount of the normal backwardation; and the present spot price, since it is lower than the quoted forward price must be much lower than the anticipated future price." (Keynes (1930, p. 144)).

The presence of "contango" in the foreign exchange market is supported by Fig. 3, which shows the behavior of SR and FR for the same time period: in cases of falling (rising) exchange rates the forward rate is below (above) the spot rate.

In the absence of risk aversion, and with perfect foresight and efficient market behavior in the spot and forward market, the use of the forward rate FR_{t-1} as a predictor of the future spot rate SR_t might be biased if transaction costs are nonzero. In this case the forecast point estimate of SR_t becomes a neutral band with upper and lower bounds (Levich (1978, p. 132)).

Though transaction costs will obliterate the exact point estimate of the exchange rate their influence is neutral in that deviations are in general symmetrical. Therefore the existence of transaction costs can hardly be used to explain overprediction (underprediction) in periods of appreciation (depreciation).

The most important argument to explain the observed bias of the forward rate in predicting the future spot rate is risk aversion or "backwardation". Keynes's (1930, p. 143) description of backwardation, though dealing with commodity future markets, applies for currency future markets as

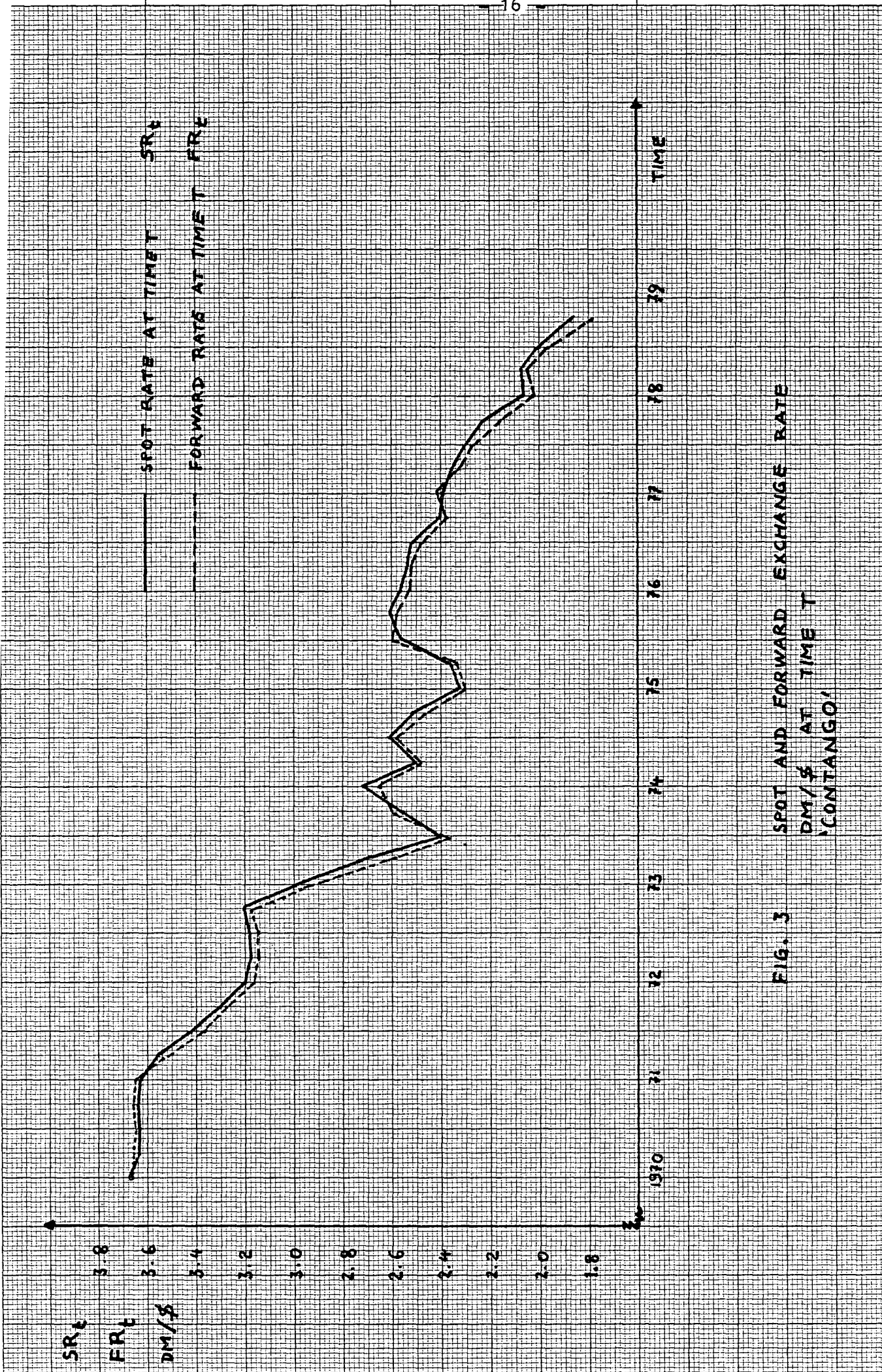


FIG. 3 SPOT AND FORWARD EXCHANGE RATE
DM/\$ AT TIME T
'CONTANGO'

well. He views futures markets as an insurance scheme in which speculators underwrite the risks of price fluctuations of the spot commodity (Dusak (1973, p. 1388)). Thus hedgers, or nonspeculators, must pay on average a premium to the speculator for this insurance service.

In direct contrast to the interpretation of a futures market as an insurance market is Hardy's gambling interpretation (Hardy (1940)). According to Hardy a futures market is a gambling casino. Therefore speculators should be willing to pay for the privilege of gambling. For commodity markets the issue is still controversial. As Dusak puts it: "despite many empirical studies, the conflict between the insurance interpretation and the gambling interpretation of returns to speculators in futures markets remains unresolved". (Dusak (1973, p. 1388)).

Keneys' argument concerning backwardation receives support from the modern theory of finance (e.g., Fama (1976)). Applying these ideas to currencies markets (e.g., Fama and Farber (1979) and Stockman (1978)) risk aversion on part of the participants in futures exchange markets leads to a diversion between expected and observed forward exchange rates on average. The central idea underlying this proposition is that uncertainty concerning the future money supply attaches risk to the purchasing power of future money. In domestic bonds markets this

purchasing power risk of the money supply can be allocated across investors according to their willingness to bear risk in exchange for a return (Fama and Farber (1979, p. 643)). The positive risk premium is then associated with the nominal interest rate on bonds. Different countries with their own money supplies will, in general, have different degrees of risk associated with the purchasing power of their individual currencies. However, unrestricted international capital movements raise the possibility of the purchasing power risk of one country's money supply being borne by residents of other countries. Moreover, differences in purchasing power risks as between individual currencies can lead to premiums in forward exchange rates (Fama and Farber (1979, p. 639)).

The application of these issues in international finance to the present problem can be stated in terms of equation (6).

$$\begin{aligned}
 (6) \quad FR_{t-1} &= \frac{1 - \phi \operatorname{cov}(\tilde{\pi}_{j,t}; P_{A,t})/E(\tilde{\pi}_{j,t})}{1 - \phi \operatorname{cov}(\tilde{\pi}_{i,t}; P_{A,t})/E(\tilde{\pi}_{i,t})} E(SR_t) \\
 &= \Psi \cdot E(SR_t)
 \end{aligned}$$

where FR_{t-1} and $E(SR_t)$ denote the forward exchange rate at $t-1$ and the expected spot exchange rate for t respectively. $\operatorname{cov}(\tilde{\pi}_{.,t}; P_{A,t})/E(\tilde{\pi}_{.,t})$ measures the contribution of the

uncertainty about the real value of a unit of money (of country i or j) carried forward to t to the risk of total invested real wealth (P_A) at t ($\text{cov}(\tilde{\pi}_{.,t}; P_{A,t})$) relative to the expected future purchasing power of the money of country j or i ($E(\tilde{\pi}_{.,t})$). ϕ could be interpreted as a discount factor or a risk premium factor.

If, for example, domestic money j is more risky in purchasing power terms than foreign money i, then the ratio of the covariance expression to the expected purchasing power of money j is higher than those for money i, leading to a ratio ψ smaller than one.

Expression (6) then indicates that the forward rate at t-1 is smaller than the expected spot exchange rate for t. This theoretical conclusion coincides with the empirical observation of the forward rate being below the future spot exchange rate in periods of depreciation of the home currency.

In conclusion then, risk aversion on the part of forward market's participants may lead to a deviation of the forward rate from the expected future exchange rate whenever the purchasing power risk of the future monies in question deviate. Consequently, the market forward

exchange rate will be a biased predictor of the future spot exchange rate in those cases.⁵⁾

IV

The preceding section explained theoretically how risk aversion or backwardation may cause the forward rate to be a biased predictor of the future spot rate. If the fact that risk aversion is present in futures exchange markets is known, however, then the direction of the bias will also be known, since when the home currency is depreciating (appreciating) the forward rate underestimates (overestimates) the future spot rate. Therefore, the bias of the forward rate (that is the deviation of the a_1 parameter in equations (2) and (5) from one) might be reduced if this information is taken into account.

In order to test this proposition I constructed a backwardation dummy variable (called BW_1) which takes a value of -1 in periods of falling and of +1 in periods

5) Another explanation for the deviation of forward and expected future exchange rates, even when risk attitudes are neutral, is provided by Siegel's paradox which rests on a statistical relationship, called Jensen's inequality (see Siegel (1972), Roper (1975) and McCulloch (1975) on this subject). Siegel's paradox, however, is only of empirical interest in the very long-run. McCulloch has shown that the implied deviation of forward and expected exchange rates will be empirically relevant after 340 years (McCulloch (1975, p. 172)).

of rising spot rates in period t . This variable is included in equation (1) to account for the influence of risk aversion in the exchange market. For the whole period (I.1970 to IV.1978) the modified equation (1) results in regression equation (7).

$$(7) \quad SR_t = \begin{matrix} 0.01783 \\ (0.30) \end{matrix} + \begin{matrix} 0.99445 \\ (46.84) \end{matrix} FR_{t-1} + \begin{matrix} 0.07429 \\ (5.85) \end{matrix} BW_{1t}$$

$$R_{adj}^2 = 0.9838; F\text{-ratio} = 1097; SE = 0.0675; D.W. = 2.01;$$

Equation (7) shows that the dummy variable for risk aversion is highly significant judged by the t-ratio (99% level). Moreover, the point estimate of the a_1 parameter rises to 0.994 indicating that the risk aversion bias present in equation (2) is eliminated in equation (7) by the inclusion of BW_1 . Compared to equation (2) the summary statistics are improved, too. The adjusted R^2 increases by 1.58% points and the standard error of estimation (SE) drops by 2.74% points. The Durbin-Watson statistic improves to an ideal figure of 2.008 (compared to the "good" value of 1.90 in equation (2)).

If the subperiod II.1973 to IV.1978, which is better characterized by more freely fluctuating exchange rates, is used instead, equation (8) results.

$$(8) \quad SR_t = 0.17041 + 0.93370 FR_{t-1} + 0.08820 BW_{1t}$$

(1.04) (13.89) (5.53)

$$R_{adj}^2 = 0.8999; \quad F\text{-ratio} = 105; \quad SE = 0.0700; \quad D.W. = 1.92;$$

Time period: II.1973-IV.1978;

Again, compared to equation (5) for the subperiod, equation (8) shows the same remarkable improvements as those demonstrated by (7), based on data for the whole period. The a_1 coefficient, however, is still biased downwards (0.934 compared to 0.895 in equation (5)). This outcome can be attributed to the fact that the dummy variable BW_1 implicitly assumes constant risk for the whole period. This might not be the case. It could be that the risk associated with future exchange rate movements is non-symmetrical in the sense that there may be differences in the degree of risk associated with the future purchasing power of different currencies. In this case positive and negative forward premiums could be different in absolute value.

Moreover, and more important, in periods of volatile exchange rate fluctuations the associated risk will be different and usually be greater than in periods of zero or steady exchange rate movements. Fig. 1 above shows that, during the first quarters of the period when the German Bundesbank stopped its intervention in the DM/\$ exchange market, the spot exchange rate fluctuates sharply

as compared to the more or less steady decline before that period and thereafter. The deviation of the lagged forward rate, FR_{t-1} , from the spot rate, SR_t , is indeed greatest during the period III.1973 to IV.1975. This observation can be interpreted in terms of risk behavior as indicating higher risk and therefore higher risk premiums in the volatile period III.1973 to IV.1975 as compared to the more steady periods I.1970 to II.1973 and I.1976 to IV.1978.

In order to account for this latter possibility, I created another dummy variable (called VP) taking values of one for the quarters III.1973 to IV.1975 and zero elsewhere. Including the variable VP, as well as the backwardation variable BW_1 , in equation (1) and using the data for the subperiod (9) emerges.⁶⁾

$$(9) \quad SR_t = 0.06533 + 0.99194 FR_{t-1} + 0.10923 BW_{1t} \\ (0.39) \quad (13.51) \quad (5.50) \\ - 0.06457 VP_t \\ (1.66)$$

$R_{adj}^2 = 0.9080$; F-ratio = 77; SE = 0.06711; D.W. = 1.97;
Time period: II.1973-IV.1978

6) The inclusion of VP into equation (1) using the whole period does not improve equation (7). The t-ratio for the parameter of VP is about one and the now positive parameter of VP reduces econometrically the a_1 parameter of the lagged forward rate to 0.988.

Even though the parameter of VP is statistically significant only at the 90% level the inclusion of this variable, which assumes higher risk premiums for volatile periods, increases the parameter of the lagged forward rate to 0.992, which, as a point estimate, is close to one.

The backwardation (dummy-) variable BW_1 used in this section has one serious shortcoming for possible forecasting: its value is only known with certainty when the future (to be forecast) spot rate is known. Although it may, at first, seem that the relatively simple requirement, that it be known whether the rate will rise or fall in future, is easily met, it is not clear how this information could be obtained. This additional information could not come from the forward market because the forward rate itself contains no information about risk aversion, risk premiums and the sign of the latter. However, if no other market figures exist which contain the backwardation information at time $t-1$, the forward market can still be described as efficient even though the forward rate is a biased forecast of the future spot rate in the way analysed in the previous section.

If a backwardation dummy variable BW_2 is constructed from the time series of FR_{t-1} , known at $t-1$, instead of using the, at $t-1$, unknown future spot rate as in

equations (8) and (9) the result in (10) indicates that the forward rate itself does not contain the backwardation information.

$$(10) \quad SR_t = \underset{(0.31)}{0.02668} + \underset{(32.72)}{0.97698} FR_{t-1} + \underset{(0.58)}{0.01928} BW_{2t}$$

$R_{adj}^2 = 0.9674$; F-ratio = 556; SE = 0.0958; D.W. = 1.98;
whole period used.

Equally the construction of a backwardation dummy by using the known spot rate at $t-1$ leads to the same result as in equation (10). Because both forward and spot exchange markets are efficient, the asset market approach of the exchange rate determination can not offer a solution to the problem of identifying a market figure which reduces the bias of the forward rate as, for example, the backwardation variable BW_1 in equation (8).

An alternative way to solve the problem mentioned could be found in the more broadly defined monetary approach to the balance of payments (where the asset market approach might be a major part of any explanation). If, for example, the interest rate abroad is much higher than the domestic interest rate, short-run capital movements would be directed from the home to the foreign country. This capital outflow will, in general, produce

a depreciation of the home currency. Therefore, expected interest rate differentials could be used as predictors for future exchange rate movements. What is needed, however, is the interest rate differential for period t which is unknown or at least uncertain. A regression equation (11) using the known ratio of the domestic interest rate factor to the foreign interest rate factor, both at time $t-1$, results in an insignificant parameter for this variable, similar to the one of BW_2 in equation (10) above.

$$(11) \quad SR_t = \begin{matrix} 0.19098 \\ (0.22) \end{matrix} + \begin{matrix} 0.97920 \\ (28.96) \end{matrix} FR_{t-1} - \begin{matrix} 0.16455 \\ (0.18) \end{matrix} \left(\frac{1+i}{1+i^*} \right)_{t-1}$$

$$R_{adj}^2 = 0.9671; \text{ F-ratio} = 531; \text{ SE} = 0.0963; \text{ D.W.} = 1.89;$$

, whole period used, where i is the domestic (German) three month money market interest rate and i^* is the Euro-dollar interest rate for three month contracts.

In summary then, the outcome of this section indicates that knowledge of the presence of risk aversion in the forward exchange market, together with knowledge of the general direction (up or down) of the future unknown spot rate, improves the forecast ability of the known forward rate and reduces or eliminates the tendency of the latter to underpredict (overpredict) the future spot rate in cases of depreciation (appreciation). This additional information, however, is not contained in any market figures known at $t-1$.

V

This paper provides evidence for the ability of the forward rate to be an efficient but biased predictor of the future unknown (expected) spot rate (W-Germany, I.1970 to IV.1978, DM/\$ exchange rate). The time series used consist of average quarterly data. The use of average exchange rates, which are important for other, but related, empirical studies (e.g., Frenkel (1979)), precludes problems of overlapping timing and contract periods. This fact and the acceptance of the zero-hypothesis of no autocorrelation in the residuals of all empirical test equations presented, makes it unnecessary to take possible recontracting explicitly into account (as, for example, Stockman (1978) does). The bias of the forward rate in forecasting the future spot rate can be explained in terms of risk aversion on part of the participants in the futures exchange market. The associated risk in the currency market is interpreted in terms of the unknown purchasing power of future money supplies in different countries. Empirically a dummy variable is constructed to account for the existence of risk aversion. This variable is highly significant and, moreover, reduces (or absorbs) the bias of the forward rate as a forecasting variable. Unfortunately this risk-variable uses information not

available at time $t-1$, therefore it cannot be used for forecasting procedures. This variable, however, is able to show that over- and underpredictions of the forward rate are caused by special risk behavior in the currency market.

Appendix

DATA USED

TIME PERIOD	SPOT EXCHANGE RATE DM/\$	FORWARD EXCHANGE RATE DM/\$, 3-MONTH CONTRACT
1969 III	3.9844	3.9308
IV	3.7018	3.6870
1970 I	3.6830	3.6820
II	3.6359	3.6421
III	3.6313	3.6317
IV	3.6358	3.6359
1971 I	3.6332	3.6401
II	3.5652	3.5501
III	3.4200	3.3724
IV	3.3093	3.2933
1972 I	3.1960	3.1742
II	3.1761	3.1563
III	3.1794	3.1566
IV	3.2029	3.1870
1973 I	3.0114	2.9001
II	2.7360	2.6356
III	2.3940	2.3893
IV	2.5489	2.5892
1974 I	2.7152	2.6658
II	2.5025	2.4943
III	2.6104	2.6102
IV	2.5227	2.4786
1975 I	2.3369	2.3167
II	2.3546	2.3488
III	2.5527	2.5827
IV	2.5969	2.5847
1976 I	2.5742	2.5531
II	2.5578	2.5532
III	2.5313	2.4942
IV	2.4085	2.3870
1977 I	2.3953	2.3976
II	2.3618	2.3411
III	2.3076	2.2909
IV	2.2239	2.1756
1978 I	2.0760	2.0351
II	2.0768	2.0564
III	2.0069	1.9618
IV	1.8747	1.7928

SOURCES: Beihefte zu den Monatsberichten der Deutschen Bundesbank, Reihe 5, different volumes.
The spot and forward rates are quarterly average values.

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