THE JOURNAL OF FINANCE • VOL. XLIII, NO. 1 • MARCH 1988

Implied Spot Rates as Predictors of Currency Returns: A Note

DAVID R. PETERSON and ALAN L. TUCKER*

ABSTRACT

Currency call option transactions data and the Black-Scholes option pricing model, as modified by Merton for continuous dividends and as adapted to currency options by Biger and Hull and by Garman and Kohlhagen, are used to imply spot foreign exchange rates. The proportional deviation between implied and simultaneously observed spot rates is found to be a direct and statistically significant determinant of subsequent returns on foreign currency holdings after controlling for interest rate differentials. Further, an ex ante trading rule reveals that the additional information contained in implied rates often is sufficient to generate significant economic profits.

MANASTER AND RENDLEMAN [18], IN a recent study of the informational efficiency of the U.S. stock market, investigate the ability of call option prices to predict, through implied stock prices, the equilibrium values of their underlying common stocks. In an ex post test, Manaster and Rendleman find that closing option prices contain information beyond that reflected in closing stock prices. Due to data synchronization problems, however, these authors are unable to distinguish whether these results reflect superior or, simply, more recent information. In an ex ante test, Manaster and Rendleman are unable to reject the null hypothesis of no additional information content in implied stock prices. Bhattacharya [1], employing synchronized transactions data, finds that option prices possess information not contained in contemporaneous stock prices, although it is not clear whether the value of this information exceeds associated trading costs. Jennings and Starks [15] provide evidence supporting the stock options market's role in determining equilibrium stock prices. Specifically, Jennings and Starks examine stock price adjustments to quarterly earnings announcements using samples of firms with and without listed options and find that nonoption firms require substantially more time to adjust.

Similar to stock options, the possibility exists that foreign currency options contain information beyond that represented in their underlying market spot exchange rates. This study extends the Manaster and Rendleman methodology to call options on foreign exchange to investigate empirically this possibility. Specifically, this is accomplished by testing whether daily exchange rates that are implied from currency option prices and a version of the Black and Scholes [3] option pricing model (OPM) contain information that may be employed to signal profitable trading strategies in foreign exchange. Currency option transactions data are supplied by the Philadelphia Stock Exchange (PHLX). Results

* Florida State University and University of Tennessee, respectively. We thank Steven Manaster (a referee) and an anonymous referee for helpful comments.

generally indicate a direct and statistically significant relationship between subsequent returns on foreign currency holdings and information impounded in out-of-the-money call currency option prices.

This study is developed in the following sections. Section I provides a brief discussion of the new market in organized currency options trading and of why exchange rates implied from currency option prices may reflect information beyond that impounded in contemporaneously observed exchange rates. Section II discusses the extension of the OPM for the valuation of currency call options and how this model is used to impute spot exchange rates. Section III describes the data set. Trading strategies and empirical results are reported in Section IV, along with an assessment of the informational content of implied rates. Section V concludes the study.

I. Currency Options

The PHLX is the first organized market trading currency options in the U.S. The PHLX began trading in December 1982 with the British pound and currently trades options on six foreign currencies: the pound, Canadian dollar, deutsche mark, French franc, Japanese yen, and Swiss franc. The PHLX recently began options trading on the European Currency Unit and soon will trade options on the Australian dollar. Other organized markets trading currency options are located in Amsterdam, Chicago, Montreal, and Vancouver.

Whereas forward and futures contracts facilitate hedging against unanticipated depreciation in currencies for contractual international trade agreements, the financial manager of a multinational corporation may employ currency options to hedge the contingent transactions prevalent in international trade, such as the bidding for foreign contracts in the local currency. The currency options market provides a vehicle to hedge these contingencies against exchange rate risk with minimal cash outlay, thereby alleviating any investment opportunity costs.[1] The rapid growth of the market demonstrates the important role of these securities in helping multinational corporations better manage their currency portfolios.[2]

Currency options are derivative securities; that is, currency option prices are a function of their underlying exchange rates. Given the appropriate functional form, it is possible to impute exchange rates from currency option prices. Implied and simultaneously observed exchange rates may differ if information is contained in the currency options market that is not contained in the foreign exchange market. This is plausible because of the appealing features of the currency options market's microstructure, most notably its leverage aspect. Informed traders may choose to trade in this highly levered arena in order to optimize the returns to information. The additional leverage offered by out-of-the-money options makes these options the most attractive for informed traders;

[1] For a more thorough discussion of the role of currency options, see Feiger and Jacquillat [11], Gendreau [13], and Giddy [14]. See Bodurtha and Courtadon [4], Shastri and Tandon [21, 22], and Tucker [26] for recent empirical tests of currency options market efficiency.

[2] In late 1983 average daily trading volume at the PHLX was about 5,000 currency option contracts. On one recent record-setting day, the exchange reported over 42,500 contracts traded. (See *Foreign Currency Options*, Philadelphia Stock Exchange, vol. 2, no. 20.)

indeed, Manaster and Rendleman envision information dissemination foremost through out-of-the-money options trading.

Other plausible explanations as to why the currency options market may reflect information not contained in underlying exchange rates center on differential trading costs, margin requirements, and limited losses associated with option purchases. The existence of a budget constraint may preclude the informed trader from simultaneously placing orders in both markets. In the analysis that follows, only the possibility of such informational divergence is required to investigate the ability of implied spot rates to predict subsequent currency returns.

II. The Currency OPM and the Imputation of Exchange Rates

The currency option pricing model used to impute exchange rates, provided by Biger and Hull [2] and Garman and Kohlhagen [12], is[3]

$$c = e^{-r^*T}S \times N(d_1) - e^{-rT}X \times N(d_1 - \sigma\sqrt{T}), \tag{1}$$

where

$d_1 = \{[\ln(S/X) + (r - r^* + (\sigma^2/2))T]/\sigma\sqrt{T}\}$,
c = the price of a currency call option,
S = the underlying spot exchange rate,
X = the exercise price,
r = the domestic riskless rate of interest,
r^* = the foreign riskless rate of interest,
σ^2 = the instantaneous variance of the return on a holding of foreign currency,
T = the time to option maturity expressed as a fraction of a year,
$N(\cdot)$ = the standard normal cumulative distribution function.

Equation (1) is an adaptation of the OPM of Black and Scholes [3], as extended by Merton [19] for continuous dividends. Since the interest gained on holding a foreign security is equivalent to a continuously paid dividend on a stock share, the Merton version of the OPM holds completely. The major transformation in the adaptation of the OPM to value currency options is the substitution of exchange rates for stock prices. As a consequence, the percentage change of exchange rates is assumed to follow a diffusion process with a constant mean and a standard deviation that varies with the square root of time. Other assumptions underlying the OPM and pertaining to equation (1) are continuously operating markets, constant risk-free interest rates, and zero transaction costs and taxes.

Bodurtha and Courtadon [5] conduct the most extensive test of the predictive ability of equation (1). They compute percentage model pricing errors using 3,326 PHLX-traded call options for the period from February 28, 1983 to September 21, 1983. The reported average percentage pricing error for all sample call options is −6.90 percent. The reported average percentage pricing error for the 1,014 out-of-the-money sample call options is −2.28 percent and is statistically insignificant. These pricing errors are smaller than corresponding errors reported for the

[3] See Biger and Hull [2], equation (3), and Garman and Kohlhagen [12], equation (7).

dividend-adjusted Black-Scholes stock OPM (cf. MacBeth and Merville [17]). Hence, equation (1) generally yields more predictive accuracy than the counterpart stock OPM employed by Manaster and Rendleman [18] to impute underlying security prices.

Given all other parameters, equation (1) can be used to impute the spot exchange rate S. The only unobservable parameter in (1) is the instantaneous variance σ^2. However, using pairs of option quotations on the same currency that exhibit the same expiration date but different exercise prices, it is possible to simultaneously impute both S and σ^2. Specifically, following a procedure similar to that of Manaster and Rendleman [18], for every foreign currency j for day t, the implied spot exchange rate, S^*_{jt}, and the implied standard deviation, σ^*_{jt}, are determined as the solution to

$$\min Q_{S_{jt},\sigma_{jt}} = \sum_{i=1}^{2} (c^i - c^i(S_{jt}, \sigma_{jt}))^2, \tag{2}$$

where c^i is the market price of the call currency option and $c^i(S_{jt}, \sigma_{jt})$ is the model-determined price from equation (1).[4]

III. Data

Transactions currency call option quotations from the PHLX are employed for the period from January 1984 through August 1984. These quotations, numbering over 20,000, contain the time of trade (to the minute) as well as call price, exercise price, maturity, and volume data. The PHLX records the underlying interbank spot exchange rate at the exact clock time of every currency option trade. Hence, the data exhibit complete synchronization of option prices and underlying exchange rates.[5] The interest rate parameters are the weekly three-month and six-month U.S. and foreign Treasury bill rates reported in the *Federal Reserve Bulletin*. When foreign bills are unavailable, interbank loan rates are employed.[6]

For every trading day and currency, a pair of out-of-the-money ($S/X < 1$) option quotations is obtained where the exercise price differs, the expiration date is the same, the clock time between option transactions is minimized, and all trades occur before 3:00 P.M. Eastern time. Only out-of-the-money option quotations are examined initially because it is these highly levered options that are, in theory, most attractive to informed traders attempting to optimize the returns to information. In order for a particular trading day to be included in the sample,

[4] A Newton-Raphson optimization technique may be used to solve equation (2). The DFP algorithm in the program GQOPT (Princeton University) is used here.

[5] This insulates the results reported here from the interpretation that more recent information, rather than truly additional information, is contained in implied exchange rates.

[6] These rates are averages of daily data for the week preceding each trade. For example, if a trade occurs on a Tuesday, the interest rate parameters used are the average daily rates for the preceding Monday through Friday. Since additional interest rate information is available to investors that is not impounded in these weekly rates, tests conducted here potentially are biased toward acceptance of the null of insignificance. To investigate the robustness of the results with respect to the interest rate parameters used, Eurocurrency rates from the *London Financial Times* are employed in the tests reported in the next section, with no material change in results. Eurocurrency rates are available for maturities of seven days and one, two, three, six, and twelve months and, therefore, afford somewhat better alignment of option and interest rate maturities.

option trades meeting the above criteria must occur for the British pound, deutsche mark, Japanese yen, and Swiss franc.[7] Further, closing interbank spot exchange rates must appear in *The Wall Street Journal* (*WSJ*) for all four foreign currencies for the current and subsequent trading day. In addition, all options must have at least thirty days until maturity; this criterion is imposed to avoid potential mispricing biases associated with near-maturity options similar to those found for common stock options.[8] Finally, all options must not violate the lower boundary condition where

$$c \geq S - Xe^{-r^*T}. \tag{3}$$

Options consistent with inequality (3) are unlikely to be exercised prematurely.[9]

The above requirements yield a sample of 388 pairs of out-of-the-money options—ninety-seven daily quotations for each of the four currencies. Table I presents a description of the number of minutes of clock time between pairs of option transactions in the sample, defined as D. Of the 388 pairs, 129 (thirty-three percent) trade less than one minute apart and 222 (fifty-seven percent) trade less than two minutes apart. Only forty-six pairs (twelve percent) trade more than thirty minutes apart. The close time proximity of option transactions should lead to greater precision in estimation of implied variances and rates.[10]

Consistent with Manaster and Rendleman's analysis of stock options, define the proportional deviation between implied and observed market spot exchange rates for currency j and day t, Δ_{jt}, as[11]

$$\Delta_{jt} = (S_{jt}^* - S_{jt})/S_{jt}. \tag{4}$$

Table II presents a frequency distribution of the proportional deviations. Almost thirty-seven percent of the implied rates are within 0.5 percent of their corresponding market rates, while over sixty-two percent are within a one percent range. The distribution of the proportional deviations exhibits the same negative

[7] The Canadian dollar is excluded due to infrequent trading. Bodurtha and Courtadon [4] report that options trading on the Canadian dollar represents less than five percent of all currency options trading volume at the PHLX. Options trading on the French franc did not begin until September 1984.

[8] See Patell and Wolfson [20] and Emanuel and MacBeth [8].

[9] The pricing formula described in equation (1) is for European options, whereas the empirical sample consists of American options. However, since the cash flow analogous to a dividend payment is continuous interest on the holding of a foreign security, premature exercise, similar to that associated with discontinuous dividend payments on common stocks, should not be an important pricing factor. Premature exercise is optimal only when currency call options are deep in the money and the foreign riskless interest rate is greater than the domestic rate. (See Merton [19], footnote 62.) Options used here are out of the money, and, during the period examined, only United Kingdom interest rates are greater than U.S. rates. Further, Shastri and Tandon [23] employ simulation analysis to demonstrate that the application of an American evaluation formula does not systematically alter currency options valuation. Bodurtha and Courtadon [5] report similar results using PHLX-traded call options. Finally, just four currency call option contracts traded at the PHLX were exercised prematurely over the period January 1984 through June 1984, as reported by the Options Clearing Corporation.

[10] However, the tests reported in the next section also were performed excluding option transactions more than thirty minutes apart, with no material change in results.

[11] The market spot exchange rates correspond chronologically with the last traded option in the pairs.

Table I

Number of Minutes in Clock Time between Pairs of Option Transactions (D)

Value of D	Number of Observations	Percentage of Observations
$D < 1$	129	33.2
$1 \leq D < 2$	93	24.0
$2 \leq D < 3$	25	6.4
$3 \leq D < 4$	15	3.9
$4 \leq D < 10$	45	11.6
$10 \leq D < 30$	35	9.0
$30 \leq D < 60$	19	4.9
$D \geq 60$	27	6.9
	388	100.0[a]

[a] Total less than 100% due to rounding.

Table II

Frequency Distribution of the Percentage Proportional Deviation between Implied and Market Spot Exchange Rates, $\Delta_{jt} \times 100$

Value of $\delta_{jt} = (\Delta_{jt} \times 100)$	Number of Observations	Percentage of Observations
$\delta_{jt} < -5$	8[a]	2.1
$-5 < \delta_{jt} < -4$	8	2.1
$-4 < \delta_{jt} < -3$	13	3.4
$-3 < \delta_{jt} < -2$	12	3.1
$-2 < \delta_{jt} < -1$	40	10.3
$-1 < \delta_{jt} < -0.5$	46	11.9
$-0.5 < \delta_{jt} < 0$	52	13.4
$0 < \delta_{jt} < 0.5$	90	23.2
$0.5 < \delta_{jt} < 1$	53	13.6
$1 < \delta_{jt} < 2$	60	15.5
$2 < \delta_{jt} < 3$	4	1.0
$\delta_{jt} > 3$	2[b]	0.5
	388	100.0[c]
Mean:	0.003%	
Standard deviation:	1.748	

[a] The smallest deviation is −9.22%.
[b] The largest deviation is 4.11%.
[c] Total greater than 100% due to rounding.

skewness found by Manaster and Rendleman. However, the distribution is much tighter around zero. The mean of the distribution is 0.003 percent, and the standard deviation is 1.748 percent. The likely causes of this tighter distribution are closer chronological alignment of option and underlying security prices, model superiority attributable to the continuous nature of dividends, and greater daily trading volume in underlying currencies.[12]

[12] Although the magnitudes of the proportional deviations are small, they should be quite insensitive to bid-ask spreads. Unfortunately, option bid-ask spreads are unavailable for the period. The option trade price must be used. Building on Smith [24], $dS/dc = 1/N(d_1)$. Bid-ask spreads vary at the PHLX depending on the underlying currency and option price. (See Tucker [26].) For reasonable

IV. Empirical Results

For every day t ($t = 1, \cdots, 97$), the parameters Δ_{jt} are ranked in ascending order for the four currencies ($j = 1, 2, 3, 4$). If implied spot exchange rates contain no information beyond that already present in market rates, then there should be no relationship between the Δ_{jt} and future rates of return on foreign currency holdings. However, time-varying differentials between domestic and foreign nominal interest rates may be useful in predicting rates of return of exchange rates.[13] Thus, the explanatory power of the Δ_{jt} needs to be examined after controlling for interest rate differentials. To investigate this hypothesis, the daily returns on a holding of foreign currency, R_{jt}, are regressed on lagged proportional deviations, $\Delta_{j,t-1}$, and lagged interest rate differentials, $r_{t-1} - r^*_{j,t-1}$.[14] The domestic and foreign interest rates are the same measures specified in the OPM given by equation (1). Foreign currency positions are assumed to be undertaken at the 3:00 P.M. Eastern time interbank spot exchange rates on the same day as the proportional deviations are determined and closed out the next trading day at the same time. Thus, the tests to be performed are similar to Manaster and Rendleman's ex ante tests in that information obtained from the options market is available before the currencies are purchased. These tests potentially are biased against finding additional information in implied exchange rates since time has elapsed between when implied rates are determined and the currency positions are taken. Although market exchange rates are available at the time of every currency option trade, the Δ_{jt} must be known for all four currencies before they can be ranked. The most immediate simultaneous market quotation for all four currencies is at the 3:00 P.M. Eastern time rates reported in the *WSJ*.[15]

The linear regression equation relating currency returns and lagged proportional deviations is

$$\tilde{R}_{jt} = \hat{\alpha}_j + \hat{\beta}_{1j}\Delta_{j,t-1} + \hat{\beta}_{2j}(r_{t-1} - r^*_{j,t-1}) + \tilde{\varepsilon}_{jt}, \tag{5}$$

where $\hat{\alpha}_j$, $\hat{\beta}_{1j}$, and $\hat{\beta}_{2j}$ are coefficients to be estimated and $\tilde{\varepsilon}_{jt}$ is an error term.

Returns on holdings of different foreign currencies are not likely to be independent since factors causing general changes in the value of the U.S. dollar should affect all exchange rates similarly. Thus, the seemingly unrelated regres-

---

values of X, T, r, r^*, and σ, however, implied rates will change only about 0.1 percent for spreads exhibited at the PHLX. Further, bid-ask spreads should not affect systematically implied values and, hence, proportional deviations for the sample of out-of-the-money options used here. Although the OPM appears to represent the data well, the possibility remains that misspecification of the model is related to the empirical results reported in the next section.

[13] See Sweeney [25], for example, for analysis and discussion of this and related issues. He finds, though, that inclusion of the interest rate differential has negligible impact on the validity of his filter rules to earn profits in the foreign exchange market.

[14] Returns are calculated using log-relatives, or $R_{jt} = \ln(S_{jt}/S_{j,t-1})$. Returns from foreign currency positions on Friday to Monday or when holidays occur are treated as one-day returns.

[15] In addition to this strategy, an alternative option-matching technique was employed. This alternative selected the two qualifying option transactions immediately preceding 3:00 P.M. This strategy yields option quotations closer to the time at which spot rate positions are assumed to be undertaken but renders less precision in the estimates of implied values due to greater elapsed time between option transactions. However, empirical results from this alternative strategy (not reported) are similar to those results to be presented.

sion (SUR) methodology developed by Zellner [28] is applied to the estimation of equation (5). The SUR approach allows for possible cross-equation contemporaneous correlation in the error terms. If such correlation exists, then the SUR methodology provides more efficient estimators relative to ordinary least-squares estimators.

The SUR estimation is performed based on currency ranking by $\Delta_{j,t-1}$, yielding four equations, one for each rank, aligned in calendar time. In other words, the first equation consists of a time series of observations on the currency with the lowest ranked $\Delta_{j,t-1}$ on a given day, while the fourth equation consists of observations on the currency with the highest ranked $\Delta_{j,t-1}$ on a given day. Thus, there is one equation for every rank and all currencies appear in every equation at some point in time.

Panel A of Table III presents results from the estimation of equation (5) by the SUR methodology for the sample of out-of-the-money options, while Panel B presents similar results for a sample consisting of all qualifying options, regardless of their S/X ratio. That is, this second sample relaxes the requirement that options exhibit an S/X ratio less than one, thereby affording closer alignment of qualifying option pairs. In three of the four regressions in Panel A, the estimated coefficient on the lagged proportional deviation ($\hat{\beta}_{1j}$) is positive and statistically significant at the five percent level. Further, the F-statistic rejects, at the five percent significance level, the null hypothesis that all four $\hat{\beta}_{1j}$ coefficients are equal to zero.[16] None of the coefficients on lagged interest rate differentials ($\hat{\beta}_{2j}$) is individually significantly different from zero. Also, the F-statistic cannot reject the null hypothesis that all four $\hat{\beta}_{2j}$ coefficients equal zero. This evidence suggests that out-of-the-money currency call option prices contain information useful in predicting subsequent currency returns after controlling for (insignificant) interest rate differentials. None of the eight slope coefficients in Panel B is statistically significant, although all four $\hat{\beta}_{1j}$ are positive. Further, the F-statistics fail to reject the null hypotheses that all four $\hat{\beta}_{1j}$ coefficients and all four $\hat{\beta}_{2j}$ coefficients are equal to zero for the second sample. This evidence corroborates the observation that highly levered out-of-the-money options are

[16] The possible presence of heteroscedasticity is examined in three ways. The first test, developed by White [27], derives from the fact that heteroscedasticity leads to an inconsistent least-squares covariance matrix estimator, and is a general test for misspecification. In a SUR model, Duncan [7] suggests applying White's test equation by equation and rejecting homoscedasticity if significance is found in any one of the equations. White's test is applied to each of the four equations, and, in this application, the test statistic is distributed χ^2 with five degrees of freedom under the null hypothesis of homoscedasticity. In all four cases, the null hypothesis is not rejected at the five percent significance level. The second test, developed by Breusch and Pagan [6] and Koenker [16], examines whether residual variance is a linear function of a nonstochastic vector of explanatory variables. In the present context, the set of explanatory factors is three binary variables (plus a constant) representing the four currencies. The test statistic is computed for each of the four equations and is distributed χ^2 with three degrees of freedom under the null hypothesis of homoscedasticity. All four test statistics fail to reject the null hypothesis at the five percent significance level. The third test, developed by Engle [9], investigates the presence of first-order autoregressive conditional heteroscedasticity. Under the null hypothesis of homoscedasticity, the test statistic is distributed χ^2 with one degree of freedom. The test is applied to each of the four equations, and, again, in each case it is not possible to reject the null hypothesis. Thus, heteroscedasticity does not appear to be a significant problem in the model.

Table III

Slope Coefficient Estimates and t-Statistics from Seemingly Unrelated Regression Estimation of Exchange Returns on Lagged Proportional Deviations and Interest Rate Differentials

$$\tilde{R}_{jt} = \hat{\alpha}_j + \hat{\beta}_{1j}\,\Delta_{j,t-1} + \hat{\beta}_{2j}\,(r_{t-1} - r^*_{j,t-1}) + \tilde{\varepsilon}_{jt}$$

A. Out-of-the-Money Options

Rank	$\hat{\beta}_{1j}$	$t(\hat{\beta}_{1j})$	$\hat{\beta}_{2j}$	$t(\hat{\beta}_{2j})$
1	0.011	1.91*	−0.044	−1.26
2	0.036	1.08	−0.028	−0.80
3	0.151	2.03*	0.067	1.35
4	0.167	1.83*	−0.035	−0.91

H_0: All $\hat{\beta}_{1j} = 0$; $F = 2.79$*
H_0: All $\hat{\beta}_{2j} = 0$; $F = 1.01$

B. All Options

Rank	$\hat{\beta}_{1j}$	$t(\hat{\beta}_{1j})$	$\hat{\beta}_{2j}$	$t(\hat{\beta}_{2j})$
1	0.085	0.92	−0.009	−0.62
2	0.004	0.08	−0.031	−1.52
3	0.051	1.31	−0.019	−0.50
4	0.124	1.37	−0.061	−1.47

H_0: All $\hat{\beta}_{1j} = 0$; $F = 0.96$
H_0: All $\hat{\beta}_{2j} = 0$; $F = 0.91$

* Significant at the five percent level (one-tailed test for t-statistics).

more attractive to informed traders seeking to optimize the returns to information.

To test for the economic value of the added information impounded in out-of-the-money currency call option prices, and given the insignificance of interest rate differentials, an ex ante trading rule similar to that designed by Manaster and Rendleman [18] is examined. If the currency options market contains additional information beyond that found in the spot market, then higher ranked currencies may be expected to offer greater rates of return on currency holdings. Based on out-of-the-money options, Panel A of Table IV reports the mean return and standard deviation for every currency rank. The average returns are unidirectional; currencies ranked 1 tend to have the smallest returns, while those ranked 4 tend to exhibit the greatest returns, suggesting that relative return rankings are related to implied spot exchange rates.

Panel B of Table IV presents matched-pair t-statistics testing the equality of mean returns of one rank versus another. Three of the six t-statistics in Panel B indicate statistically significant differences in the mean returns across currency rankings. These differences are economically important, affording returns in excess of transaction costs. Thus, it appears that the additional information contained in implied rates often is sufficient to generate significant economic profits.

The insignificance between mean returns in half of the pairings reported in Panel B of Table IV cannot be construed as supporting the hypothesis that the

Table IV

Test of Ex Ante Trading Rule

A. Mean Returns and Standard Deviations of Four Currencies

Currency Rank	Mean Return	Standard Deviation
1	−0.00046	0.00529
2	−0.00039	0.00580
3	0.00051	0.00561
4	0.00149	0.00880

B. Matched-pair t-statistics on Difference in Mean Returns

Currency Rank	2	3	4
1	−0.21	−2.03*	−1.71*
2		−1.97*	−1.22
3			−0.59

* Significant at the five percent level (one-tailed test).

foreign exchange and currency options markets contemporaneously reflect common information because the trading strategy outlined above may have been unable to detect such opportunities for these pairings. To further investigate this issue, the frequency distribution of the predicted versus actual return rankings is presented in Table V. A nonparametric test is performed to determine whether there is a significant relationship between actual return rankings and return rankings predicted by the proportional deviations between implied and observed exchange rates. If there is no relationship, then the expected value of every cell is 24.25. The chi-square test statistic, used to determine whether the pattern of numbers in Table V is different from random, is 16.86 and significant at the six percent level. Thus, there is evidence in the frequency distribution of a relationship between predicted and actual returns. Results reported in Table V are consistent with those of Manaster and Rendleman for implied stock prices and suggest that foreign exchange option prices are useful in predicting subsequent currency returns.

V. Conclusion

This study extends the methodology developed by Manaster and Rendleman [18] to foreign currency options in order to investigate empirically whether such options may be profitably used in currency transactions. Using synchronized data supplied by the Philadelphia Stock Exchange and a version of the Black and Scholes [3] option pricing model, exchange rates are implied that, when compared with contemporaneously observed market rates, are used to signal trading strategies in foreign currency positions. At any point in time, information may be contained in the currency options market, and not in the currency market, because of the different microstructures of the two markets. That is, the speeds at which foreign exchange rates and currency option prices adjust to new information depends on the magnitude of friction in each market.

Each qualifying day four currencies are ranked on the percentage deviation of implied and market exchange rates. Analysis controlling for interest rate differentials and employing the seemingly unrelated regression methodology indicates

Table V

Frequency Distribution of the Return Ranks of the Four Foreign Currencies

	Predicted Rank			
Actual Rank	1	2	3	4
1	26	23	20	28
2	26	33	22	16
3	27	22	27	21
4	18	19	28	32

The null hypothesis of random selection states that the expected value of every cell is 24.25.

$\chi^2_{(9)} = 16.861$, significant at the six percent level.

a positive and statistically significant relationship between returns on foreign currency holdings and lagged proportional deviations using out-of-the-money currency call options, suggesting that such highly levered options are attractive to informed traders seeking to optimize the returns to information. Further, an ex ante trading rule indicates that returns are directly related to rank, and tests of equality of mean returns across ranks often are statistically and economically significant.

As discussed by Sweeney [25] and others, the finding of abnormal profits in foreign exchange markets, such as those reported here, may be attributable to market inefficiency or time-varying risk premia.[17] In the present context, a further possibility is that misspecification of the option pricing model may be related to the rates of return on foreign exchange. Although the resolution of this issue requires further research, there is a growing body of literature documenting profitable trading strategies. As Sweeney notes, in the absence of definitive evidence of time-varying risk premia, portfolio managers may find it difficult to ignore such profits.

[17] See Fama [10], for example, for evidence of risk premia that vary over time.

REFERENCES

1. M. Bhattacharya. "Price Changes of Related Securities: The Case of Call Options and Stock." *Journal of Financial and Quantitative Analysis* 22 (March 1987), 1–15.
2. N. Biger and J. Hull. "The Valuation of Currency Options." *Financial Management* 12 (Spring 1983), 24–28.
3. F. Black and M. Scholes. "The Pricing of Options and Corporate Liabilities." *Journal of Political Economy* 81 (May/June 1973), 637–69.
4. J. Bodurtha and G. Courtadon. "Efficiency Tests of the Foreign Currency Options Market." *Journal of Finance* 41 (March 1986), 151–62.
5. ———. "Tests of the American Option Pricing Model on the Foreign Currency Options Market." *Journal of Financial and Quantitative Analysis* 22 (June 1987), 153–67.
6. T. Breusch and A. Pagan. "A Single Test for Heteroscedasticity and Random Coefficient Variation." *Econometrica* 47 (September 1979), 1287–94.
7. G. Duncan. "Estimation and Inference for Heteroscedastic Systems of Equations." *International Economic Review* 24 (October 1983), 559–66.
8. D. Emanuel and J. MacBeth. "Further Results on the Constant Elasticity of Variance Call Option Pricing Model." *Journal of Financial and Quantitative Analysis* 17 (November 1982), 533–54.
9. R. Engle. "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflations." *Econometrica* 50 (July 1982), 987–1008.

10. E. Fama. "Forward and Spot Exchange Rates." *Journal of Monetary Economics* 14 (November 1984), 319–38.
11. G. Feiger and B. Jacquillat. "Currency Option Bonds, Puts and Calls on Spot Exchange and Hedging of Contingent Foreign Earnings." *Journal of Finance* 34 (December 1979), 1129–39.
12. M. Garman and S. Kohlhagen. "Foreign Currency Option Values." *Journal of International Money and Finance* 3 (December 1983), 231–37.
13. B. Gendreau. "New Markets in Foreign Currency Options." *Business Review*, Federal Reserve Bank of Philadelphia (July/August 1984), 3–12.
14. I. Giddy. "Foreign Exchange Options." *Journal of Futures Markets* 3 (Summer 1983), 143–66.
15. R. Jennings and L. Starks. "Earnings Announcements, Stock Price Adjustment, and the Existence of Option Markets." *Journal of Finance* 41 (March 1986), 107–25.
16. R. Koenker. "A Note on Studentizing a Test for Heteroscedasticity." *Journal of Econometrics* 17 (September 1981), 107–12.
17. J. MacBeth and R. Merville. "Tests of the Black-Scholes and Cox Call Option Valuation Models." *Journal of Finance* 35 (May 1980), 285–301.
18. S. Manaster and R. Rendleman. "Option Prices as Predictors of Equilibrium Stock Prices." *Journal of Finance* 37 (September 1982), 1043–57.
19. R. Merton. "Theory of Rational Option Pricing." *Bell Journal of Economics* 4 (Spring 1973), 141–83.
20. J. Patell and M. Wolfson. "The Ex-Ante and Ex-Post Price Effects of Quarterly Earnings Announcements Reflected in Option and Stock Prices." *Journal of Accounting Research* 19 (Autumn 1981), 431–58.
21. K. Shastri and K. Tandon. "Arbitrage Tests of the Efficiency of the Foreign Currency Options Market." *Journal of International Money and Finance* 4 (December 1985), 455–68.
22. ———. "Valuation of Foreign Currency Options: Some Empirical Tests." *Journal of Financial and Quantitative Analysis* 21 (June 1986), 145–60.
23. ———. "On the Use of European Models to Price American Options on Foreign Currency." *Journal of Futures Markets* 6 (Spring 1986), 93–108.
24. C. Smith. "Option Pricing: A Review." *Journal of Financial Economics* 3 (January/March 1976), 3–51.
25. R. Sweeney. "Beating the Foreign Exchange Market." *Journal of Finance* 41 (March 1986), 163–82.
26. A. Tucker. "Empirical Tests of the Efficiency of the Currency Option Market." *Journal of Financial Research* 7 (Winter 1985), 275–85.
27. H. White. "A Heteroscedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroscedasticity." *Econometrica* 48 (May 1980), 817–38.
28. A. Zellner. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *Journal of the American Statistical Association* 52 (June 1962), 340–68.