PREDICTION OF FUTURE CURRENCY EXCHANGE RATES FROM CURRENT CURRENCY FUTURES PRICES: THE CASE OF GM AND JY

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INTRODUCTION

The collapse of the fixed exchange rate system in 1973 led to volatile currency exchange rates that are influenced by large financial transactions, higher mobility of capital, volatile interest rates, and speculation. This increase in volatility has created the need to find new instruments to manage risk through hedging and forecasting foreign exchange rates.

Among the instruments available, currency futures have been used to reduce the downside risk of adverse movements of exchange rates. They can be used also to provide estimates of future short term spot exchange rates as described below.

The most widely used models in pricing futures are the expectations hypothesis and the cost-of-carry model. The former implies that current futures contract prices summarize all relevant and available information concerning the future value of the spot exchange rate. In other words, the current price of a futures contract is equal to the market expectations

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of the spot price on the delivery date. If the expectations theory holds, there will be no expected gain nor loss from a position in the futures market. The cost-of-carry model links current currency futures prices to current currency spot prices and to the cost of carrying deliverable currency until the futures contract expires. According to this model, the futures price is the sum of the cash price and the carrying costs. If the difference between futures price and the cash price is greater than the carrying costs, arbitrageurs would buy spot and sell futures. As a result, the increasing demand for spot will drive the spot rates up and the increasing supply of futures will drive futures prices down. This will continue until all arbitrage profits disappear and convergence occurs. (If the difference between the futures price and the cash price is less than the carrying costs, arbitrageurs would follow an opposite strategy.)

In the foreign exchange markets, carrying costs are defined as the difference between the interest cost and the interest earned [Schwarz, Hill, and Schneeweis (1986)].

Mathematically:

$$F(t, n) = S(t) \qquad (1 + r - r^*)^n$$

where

$$\begin{aligned} r &= \text{domestic interest rate} \\ r^* &= \text{foreign interest rate} \\ F(t, n) &= \text{price of a futures with } n \text{ periods at time } t \\ S(t) &= \text{spot rate} \end{aligned}$$

Futures and spot rates are given per unit of foreign currency. For one period, the net carrying costs $= r - r^* = (F(t, 1) - St)/St$.

The results of the few empirical studies in the currency futures markets concerning the difference between the futures prices and the expected future spot rates are mixed. Thomas (1986) tested the expectations model for five currencies (British Pound, German Mark, French Franc, Swiss Franc, and Japanese Yen) for the period 1974–1983. The expectations model was rejected for the British Pound only. But, when seemingly unrelated regression was used, the expectations model was not rejected by the data.

Hill and Schneeweiss (1981) concluded that currency futures prices are, on average, unbiased forecasts of the future spot rates. Futures prices, however, exhibit lower degrees of forecast efficiency the longer the forecast horizon.

Panton and Joy (1978) argued that, in the absence of transaction costs and exchange accessibility restrictions, the interest rate parity must hold. They tested this relationship for six currencies. The results were mixed. In most cases, the mean deviations from the interest rate parity was not significantly different from zero; however, some futures prices deviated from the interest rate parity by more than what can be explained with transaction costs.

Although the empirical results are mixed, there is a tendency to believe that there is a difference between current currency futures prices and expected spot currency rates. A portion of the difference may represent a risk premium; or imply that markets are inefficient or models are misspecified; or a combination of those. The differences could be explained also by the variety of the data sources, especially in geographic terms which include inter alia, different timing, and business environments. Another reason could be the use of yields that do not correspond to the expiration date of the futures contract. Moreover, the use of closing prices, which are not necessarily trading prices, could explain some of this mixture in the results.

In this article, there is an attempt to solve some of those problems by using transaction prices with the yields that correspond to the expiration date of the futures contract.

FUTURES MODEL WITH CONTINUOUS COMPOUNDING OF INTEREST RATES

In this section, a cost-of-carry model with continuous compounding will be shown to be the same as the covered interest rate arbitrage with continuous compounding of interest rates.

Covered Interest Rate Arbitrage

In equilibrium, investors are indifferent between the following two alternatives. One is keeping one unit of currency A for n periods at r^*, and converting $\exp(n\, r^*)$ into currency B at the end of nth period. The other alternative is converting one unit of currency A to S units of currency B now, and lending them for n periods at r, the interest rate on B. Otherwise, arbitrage will take place to force equilibrium. Mathematically:

$$F(t, n) \cdot \exp(n \cdot r^*) = S(t) \cdot \exp(n \cdot r) \qquad (1)$$

or

$$F(t,n) = S(t) \cdot \exp(n \cdot r - n \cdot r^*) \tag{2}$$

If $n = 1$, then:

$$F(t,n) = S(t) \cdot \exp(r - r^*) \tag{3}$$

Cost-Of-Carry Model

In the commodity markets: $F(t,n) = S(t) +$ carrying costs where carrying costs include storage, insurance, etc. No margin requirements, no taxes, and no trading costs are assumed. In the foreign exchange markets, the carrying costs per period are: $\exp(r - r^*)$ per unit. The rationale behind this is that investors are indifferent between going long in futures, and buying the foreign currency earning $\exp(r^*)$ per unit while losing $\exp(r)$ per unit. The net cost will be $\exp(r - r^*)$ per unit for one period.

Mathematically:

$$F(t,n) = S(t) \cdot \exp(r - r^*) \tag{4}$$

This equation is the same as eq. (3) above.

If continuous compounding is not included in the analysis, the cost-of-carry and the interest rate parity models do not generate the same equation unless $r = r^*$, or accepting the approximation:

$$(F - S)/S = r - r^*$$

(forward discount or premium = interest rate differential).

DATA AND METHODOLOGY

The data include currency futures trading prices, the simultaneous currency spot rates, the date and time of the trade, the delivery dates of the futures contracts, and the interest rates for each currency involved in this research (the German Mark, the Japanese Yen, and the U.S. dollar).

The currency futures prices are from the Chicago Mercantile Exchange. The Euro-currency rates for 1 month, 3 months, 6 months, and 12 months are from the Financial Times. These rates are used because other rates (such as Treasury bills) are not published daily for all the maturities listed above.

The Eurocurrency deposit rates that correspond to the expiration dates are used. If the observed rates do not correspond to the maturity of the futures, linear interpolations or extrapolations are used to determine the appropriate domestic and foreign interest rates for the maturity of the futures contract. The major research question of this study is: How accurately can future spot exchange rates be predicted from current currency futures prices?

To answer this major research question, the following sub-questions will be addressed.

1. Do current futures prices convey some information about future spot exchange rates not captured by current spot exchange rates?
2. How well can the current implied spot exchange rates derived from current currency futures prices predict future spot rates?
3. How sensitive is the result to the time to maturity of futures contracts?

For empirical purposes, eq. (4) will be tested in the following form:

$$\text{Log } F(t, n) = (r - r^*) + \text{Log}(S(t)) \tag{5}$$

The rationale behind this is that spot exchange rates are assumed to be lognormally distributed. This assumption excludes the possibility of negative spot or futures prices.

The initial test is:

> H1: Current currency futures prices do not convey any information about anticipated future spot currency exchange rates not captured by current spot exchange market prices.

This hypothesis implies that model currency futures prices and market currency futures prices are the same. Otherwise, H1 will be rejected in favor of the alternate hypothesis H1a which would imply that markets are inefficient, and/or the model is misspecified.

> H1a: Current currency futures prices convey information about anticipated future spot currency exchange rates not captured by current spot exchange market prices.

To see whether H1 holds, the current implied spot rate $SF^*(t)$—calculated from the model—is compared to the observed current spot rate $S(t)$. If $SF^*(t) = S(t)$, then H1 holds. Otherwise, H1 will be rejected.

To compare SF^* with S, the following model is used:

$$\text{Log}(S(t)) = a1 + b1 * \text{Log}(SF^*(t)) + \text{error} \tag{6}$$

If $a1 = 0$ and $b1 = 1$, then H1 holds. If H1 does not hold, then markets are inefficient, or the model is misspecified, or both.

To find whether the implied spot rates (SF^*) can predict future short-term spot exchange rates, an ordinary least square regression is used to estimate the coefficients $a1'$ and $b1'$ of the following model:

$$\text{Log}(S(t+1)) = a1' + b1' \,\text{Log}(SF^*(t)) + \text{error} \tag{7}$$

where

$S(t+1)$ = First trading price on day $t+1$

$SF^*(t)$ = Implied current spot rate derived from the last trading futures price on day t

To see how well the derived futures market model predicts future spot rates, it is applied to an out-of-sample period. The predicted rates from this model will be compared with the observed spot rates. The performance of this model is based on the value of the relative, the absolute, and the squared error, the error being the difference between the model price and the market price.

There are some limitations for this methodology. At the theoretical level, the informational efficiency of currency futures markets, and the validity of the models used are tested jointly. For instance, if the current implied spot rates are significantly different from the current observed spot rates, the market is inefficient, or the model is misspecified, or both. To overcome this problem two of the most liquid and heavily traded currencies are used. Under such conditions, it is reasonable to assume that markets are efficient. Then, the validity of the model can be tested.

The interest rates used here are the Euro-currency deposit rates. The futures prices, however, are U.S. market prices. This geographic difference might introduce some bias in the results. The fact is that different geographic areas are subject to different economic conditions, different political situations and regimes, and different trading hours.

RESULTS

The Relationship between Spot Rates and Derived Spot Rates

The results, reported in Tables I and II, show that current futures prices convey little information not captured by current spot exchange market prices. For instance, the intercept is significantly different from zero in one case (out of 6) for the German Mark futures with at least 60 days to maturity; the intercept is 0.03 with a t-statistic of 2.0.

TABLE I
Relationship Between Current Spot Rates and Implied Current Spot Rates Derived From Futures Prices For The Japanese Yen

*Model: Log S(t) = a + b * Log(SF*(t)) + Error*

Period	*# OBS*	*a*	*t-Stat for a*	*b*	*t-Stat for b*	*RSQ %*	*F-Test*	*DW*
09/85–02/87	307	0.02	2.3	0.996	530	99.89	281130	1.9
09/85–06/86	153	0.02	1.2	0.995	228	99.71	51830	1.9
06/86–02/87	154	0.02	1.0	0.994	190	99.58	35965	1.9
$G = 1$	53	0.00	0.30	0.999	473	99.98	223691	2.3
$G = 2$	85	0.00	0.23	0.999	422	99.95	178080	1.6
$G = 3$	170	0.03	2.3	0.993	320	99.83	102121	1.9

where:
$S(t)$ = Current spot rate at time t
$SF^*(t)$ = Implied spot rate derived from futures price at time t
RSQ = R-squared
$G = 1$: Futures with less than 30 days to maturity
$G = 2$: Futures with 30 or less than 60 days to maturity
$G = 3$: Futures with at least 60 days to maturity

The slope ranges from 0.992 with a standard error of 0.004 (which implies that the slope is significantly different from one in this case) to 1.00 with a standard error of 0.003.

For the Japanese Yen, the intercept is significantly different from zero in two cases (out of 6) for the whole period (the intercept being 0.02

TABLE II
Relationship Between Current Spot Rates and Implied Current Spot Rates Derived From Futures Prices For The German Mark

*Model: Log S(t) = a + b * Log(SF*(t)) + Error*

Period	*# OBS*	*a*	*t-Stat for a*	*b*	*t-Stat for b*	*RSQ %*	*F-Test*	*DW*
09/85–02/87	308	0.01	1.6	0.996	450	99.85	202176	2.0
09/85–06/86	153	0.03	1.2	0.992	151	99.34	22822	2.1
06/86–02/87	155	0.02	1.4	0.995	262	99.78	68811	1.7
$G = 1$	53	−0.00	−0.1	1.00	301	99.94	90396	2.1
$G = 2$	89	−0.00	−0.5	1.00	549	99.97	300948	2.1
$G = 3$	165	0.03	2.0	0.992	242	99.72	58572	2.1

where:
$S(t)$ = Current spot rate at time t
$SF^*(t)$ = Implied spot rate derived from futures price at time t
RSQ = R-squared
$G = 1$: Futures with less than 30 days to maturity
$G = 2$: Futures with 30 or less than 60 days to maturity
$G = 3$: Futures with at least 60 days to maturity

with a t-statistic of 2.3) and for futures with at least 60 days to maturity (the intercept being 0.03 with a t-statistic of 3.3). For the whole period, the slope is 0.996 with a standard error of 0.002 (which implies that the slope is significantly different from one); for futures with at least 60 days to maturity, the slope is also significantly different from one. The slope is 0.993 (the lowest in these cases) with a standard error of 0.003. The highest slope is 0.999 with a standard error of 0.002.

Prediction of Future Spot Exchange Rates

To find whether implied current spot rates derived from current futures prices have some relationship with future spot rates, eq. (7) is used. The results are reported in Tables III and IV. The intercepts are, in general, insignificantly different from zero. For the German Mark futures with 30 or less than 60 days to maturity the intercept is 0.06 with a t-statistic of 2.5 (the slope is 0.984 with a standard error of 0.006). For the Japanese Yen futures, the intercept is 0.04 (for the whole period) with a t-statistic of 2.4 (the slope is 0.991).

The slopes are insignificantly different from one in all cases except for futures with 30 or less than 60 days to maturity for both currencies. For German Marks futures, the slope is 0.984 with a standard error of 0.006. For the Japanese Yen, the slope is 0.986 with a standard error of 0.007.

TABLE III

Regression Results of $S(t+1)$ Against $SF^*(t)$ For The Japanese Yen

Model: $Log(S(t+1)) = a + b * Log(SF^*(t)) + Error$

Period	*# OBS*	*a*	*Stat for a*	*b*	*t-Stat for b*	*RSQ %*	*F-Test*	*DW*
09/85–02/87	307	0.04	2.4	0.991	274	99.60	75157	2.0
09/85–06/86	153	0.03	1.0	0.993	138	99.22	19105	2.0
06/86–02/87	154	0.12	1.8	0.971	56	95.86	3545	1.9
$G = 1$	53	0.02	0.6	0.995	110	99.58	12127	2.2
$G = 2$	85	0.06	1.9	0.986	138	99.56	18938	2.3
$G = 3$	169	0.03	1.5	0.993	209	99.61	43506	2.1

where:
$S(t+1)$ = Current spot rate at time $t+1$
$SF^*(t)$ = Implied spot rate derived from futures price at time t
RSQ = R-squared
$G = 1$: Futures with less than 30 days to maturity
$G = 2$: Futures with 30 or less than 60 days to maturity
$G = 3$: Futures with at least 60 days to maturity

TABLE IV

Regression Results of $S(t + 1)$ Against $SF^*(t)$ For The German Mark

Model: $Log(S(t + 1)) = a + b * Log(SF^*(t)) + Error$

Period	*# OBS*	*a*	*t-Stat for a*	*b*	*t-Stat for b*	*RSQ %*	*F-Test*	*DW*
09/85–02/87	307	0.03	1.7	0.993	243	99.49	54499	2.1
09/85–06/86	152	0.07	1.8	0.983	98	98.47	9702	2.1
06/86–02/87	155	0.04	1.0	0.990	96	98.35	9160	2.0
$G = 1$	53	0.03	0.8	0.992	106	99.54	11219	1.5
$G = 2$	89	0.06	2.5	0.984	152	99.62	23051	2.1
$G = 3$	165	0.00	0.2	0.999	161	99.37	25780	1.8

where:
$S(t + 1)$ = Current spot rate at time $t + 1$
$SF^*(t)$ = Implied spot rate derived from futures price at time t
RSQ = R-squared
$G = 1$: Futures with less than 30 days to maturity
$G = 2$: Futures with 30 or less than 60 days to maturity
$G = 3$: Futures with at least 60 days to maturity

Now, to predict future spot rates, eq. (7) is applied to the first 200 observations of the data for each currency. The estimated models are:

For the German Mark:

$$\underset{}{\mathrm{Log}(S(t + 1))} = \underset{(1.3)}{0.03} + \underset{(144)}{0.991} * \mathrm{Log}(SF^*(t)) + \text{error}$$

For the Japanese Yen:

$$\mathrm{Log}(S(t + 1)) = \underset{(1.5)}{0.03} + \underset{(205)}{0.993} * \mathrm{Log}(SF^*(t)) + \text{error}$$

(the numbers in parenthesis are t-statistics).

In both cases, no significant first order autcorrelation is found. Now, to evaluate the predictive power of these models, they are applied to an out-of sample period beyond the first 200 observations used to estimate the parameters.

There are 107 observations. The evaluation of the model is based on the mean of the pricing error, the relative pricing error, the absolute pricing error, and the relative absolute pricing error. The results are reported in Tables V and VI, and summarized in Table VII. For the German Mark, the model is slightly underpricing, on average, the future spot exchange rates. The error is \$3 per 10,000 Marks; the relative error is zero, the absolute error is \$26 per 10,000 Marks, and the relative

TABLE V
Forecasting of Japanese Yen Exchange Rates From Implied Current Spot Rates Derived From Futures Prices

A. Model: $Log(S(t + 1)) = 0.03 + 0.993\ Log(SF^*(t))$
$(1.5) \quad (205)$

The numbers in parenthesis are t-statistics.
RSQ = 99.4% and F-test value = 27652, DW = 2.0.
Estimates based on the first 200 observations.

B. Predictive Power of the Model for an Out-of-Sample Period

(107 Observations)		*Mean*	*Standard Deviation*	*Minimum Value*	*Maximum Value*
ER	cent per 100	0.03	0.35	−1.21	1.34
RER		0.00	0.01	−0.02	0.02
ABS	cent per 100	0.26	0.24	0.00	1.34
RABS		0.00	0.00	0.00	0.02
ERSQ		0.13	0.25	0.00	1.81

where:
ER = Estimated current spot rate minus observed current spot rate
RER = ER/(observed current spot rate)
ABS = Absolute value of ER
RABS = Relative absolute value
ERSQ = ER squared

absolute error is zero. The standard deviation of the error is 0.36 per unit which implies that the mean is insignificantly different from zero.

For the Japanese Yen, the model is overpricing, on average, future spot rates. The error is $3 per 1,000,000 Yen. The relative error is zero, the absolute error is $26 per 1,000,000 Yen, and the relative absolute error is zero. The standard deviation of the error is 0.35 per 100 units which implies that the mean is insignificantly different from zero. Since the errors are insignificantly different from zero, both models can well predict future spot rates.

CONCLUSIONS

The results of this research show that current currency futures prices convey little information not captured by spot market rates. The continuous compounding cost-of-carry model appears to hold strongly for contracts with less than 60 days to maturity. For longer maturities, a liquidity premium might exist.

TABLE VI
Forecasting of German Mark Exchange Rates From Implied Current Spot Rates Derived From Futures Prices

A. Model: $Log(S(t + 1)) = 0.03 + 0.991 * Log(SF^*(t))$
$(1.3) \quad (144)$

The numbers in parenthesis are t-statistics.
RSQ = 99.1% and F-test value = 20865, DW = 2.1.
Estimates based on the first 200 observations.

B. Predictive Power of the Model for an Out-of-Sample Period

(107 Observations)		*Mean*	*Standard Deviation*	*Minimum Value*	*Maximum Value*
ER	cent	−0.03	0.36	−1.26	1.31
RER		−0.00	0.01	−0.02	0.02
ABS	cent	0.26	0.26	0.00	1.31
RABS		0.00	0.00	0.00	0.02
ERSQ		0.13	0.28	0.00	1.71

where:
ER = Estimated current spot rate minus observed current spot rate
RER = ER/(observed current spot rate)
ABS = Absolute value of ER
RABS = Relative absolute value
ERSQ = ER squared

In addition, the implied spot rates derived from currency futures are good predictors of short term future spot rates. The implied spot rates, derived from futures prices model, slightly underprice the German Mark, and slightly overprice the Japanese Yen. However, the pricing errors are insignificantly different from zero.

TABLE VII
Predictive Power of Implied Spot Rates

	German Mark			Japanese Yen		
107 Observations		*Mean*	*Standard Deviation*		*Mean 100th*	*Standard Deviation*
Error	cent	−0.03	0.36	cent	0.03	0.35
Relative		−0.00	0.01		0.00	0.01
Absolute		0.26	0.26		0.26	0.24
Relative absolute		0.00	0.00		0.00	0.00

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