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Forward and Futures Prices: Evidence from the Foreign Exchange Markets

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ABSTRACT

Empirical studies of the Treasury Bill markets have revealed substantial differences between the futures price and the implied forward price. These differences have been attributed to taxes, transaction costs, and the settling up procedure employed in the futures market. This paper examines the forward and futures prices in foreign exchange in an attempt to distinguish between the competing explanations.

EMPIRICAL STUDIES OF THE Treasury bill market have revealed differences between the futures price (or rate) and the implicit forward price derived from the term structure of interest rates.[1] These differences have generally been attributed to market "imperfections" such as taxes and transaction costs. (See, for example, Arak [1], Capozza and Cornell [2], and Rendelman and Carabini [6]). Recently, however, Cox, Ingersoll, and Ross [3], henceforth CIR, derived a model in which forward and futures prices need not be equal, even in perfect markets without taxes, as long as interest rates are stochastic.

The significance of the CIR effect may be hard to investigate using only data from the bill market, because of the potentially complicating effects of taxes and transaction costs unique to this market. By using data from the foreign exchange market, we are able to eliminate the tax effect and reduce the impact of transaction costs. The question we address is whether the discrepancies observed in the Treasury Bill market are also observed in the foreign exchange market. If they are, then we have evidence that the differences are due to a combination of the CIR effect and the transaction costs common to both markets. If they are not, then either the magnitude of the CIR effect is much less in the foreign exchange market, or the Treasury Bill results are due to the unique tax treatment and transaction costs of that market.

This paper is organized as follows. In Section I the trading mechanics of the forward and futures markets in foreign exchange are discussed. Section II reviews the explanations for the discrepancies between the forward and futures prices for Treasury Bills. The institutional differences between the foreign exchange and bill markets are also summarized to show which of these explanations cannot apply to the foreign exchange market. In Section III, the data are decribed and the empirical results are presented. The conclusions are summarized in the final section.

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[1] The papers include Capozza and Cornell [2], Lang and Rosche [5], Rendleman and Carbini [6], and Vignola and Dale [7].

I. Forward and Futures Trading in Foreign Exchange

The forward market in foreign exchange is handled almost exclusively by banks at the retail level. An agent who wants to take a forward position contacts a bank to request a quote. If the agent accepts a bank's quote, a forward contract is established. The contract specifies the amount of foreign exchange to be delivered, the date of delivery, and the price. If the agent decides to close out his position prior to the delivery date, a covering transaction with the bank must be arranged.

For example, suppose the agent decides to purchase one million Swiss Francs, six months forward. He contacts Citibank which gives him a quote of .6201/.6205. He accepts the quote and contracts to buy one million Swiss Francs in six months at $.6205. Three months later the agent decides to cover his position. He contacts Citibank, which gives him a quote of .6250/.6255 for *three* forward francs. If he accepts the price of .6250, Citibank nets out his position on their books and pays him (.6250-.6205) 1,000,000 = $4,500.

If the agent is a good customer of Citibank, no margin need be posted to make the forward contract. In addition, no money changes hands until either the position is covered or delivery occurs. Most contracts in the forward market are settled by delivery.

Unlike the forward market, the futures market deals in standardized contracts. Both contract size and the delivery date are specified in advance by the exchange. Trading in these standardized contracts is conducted by open auction on the floor of the exchange. Rather than matching individual buyers and sellers, however, the clearing house of the exchange takes the opposite side of each position. The clearing house, therefore, is the seller for every buyer and the buyer for every seller. An agent who places an order to buy Swiss Francs in the futures market has a contract to buy from the clearing house. If he later decides to cover the position, he places an order to sell Swiss Francs for the same delivery date. When that order is executed, the clearing house nets out his position on its books. Over 95% of the positions in the foreign exchange futures market are covered prior to delivery.

For the clearing house to perform its function, all profits and losses must be settled on a daily basis. This procedure, called "marking to the market," requires that funds change hands each day, even if the positions are not covered. In addition to marking to the market, traders are also required to post a performance bond, called margin, when a position is opened. The margin requirement, however, may be satisfied by pledging Treasury Bills so the opportunity cost is zero. For this reason, we shall ignore the margin requirement for the remainder of the paper.[2]

A simple example illustrates how the market works. The standardized Swiss Franc contract calls for delivery of 125,000 francs. Contracts trade for delivery in March, June, September, and December up to two years in the future. If today's date were 3 June and our agent wanted to buy one million Swiss Francs six months hence, the best he could do would be to trade the December contract that calls for delivery on the third Wednesday in December (16 December in

[2] Traders who qualify as hedgers may have the margin requirement waived.

1981). To contract to buy one million Swiss Francs, he would place an order to go long eight December futures contracts. For illustration, suppose his order was filled at $.6200. If the futures price fell to .6190 the next day, the agent would have incurred a loss of $1,000 (.001 × 125.000 × 8 = $1,000). This would have to be paid to the clearing house before the following day's opening. Since all profits and losses are settled daily, nothing special happens when a contract is covered. The profit or loss for the final day is cleared, and the position is netted out on the books of the clearing house.

II. Explanations for a Discrepancy between Forward and Futures Prices

A. The settling up problem and the Cox-Ingersoll-Ross model

From the preceding section, it is clear that an agent who took a long position in the futures market and a short position of the same size in the forward market would not necessarily have a riskless position, because the futures position must be settled daily. If the daily interest rate at which inflows can be invested (or the outflows can be financed) is stochastic, the forward-futures hedge is risky.

Cox, Ingersoll, and Ross [3] derive an expression for the difference between the forward and futures price caused by the settling up procedure. Their model is based on the insight that a forward contract can be duplicated by a combination of a futures contracts and daily borrowing or lending. Because two assets with identical cash flows must have the same price in equilibrium, relative valuation equations for forward and futures contracts can be derived.

To express the CIR solution, we use their notation:

t = current time
s = maturity date for forward and futures contracts
$H(t)$ = futures price at time t
$G(t)$ = forward price at time t
$P(t)$ = price at time t of a discount bond paying one dollar at time s.

$$\operatorname{cov}(H(u), P(u)) = \lim_{\Delta u \to 0} \operatorname{cov}\left[\frac{H(u+\Delta u)}{H(u)}, \frac{P(u+\Delta u)}{P(u)}\right] \Big/ \Delta u$$

In terms of the preceding notation, CIR show that the difference between the forward and futures price, $H(t) - G(t)$, is equal to the current *value* of the payment flow given by:

$$\textstyle\sum_{j=t}^{s-1} [H(j+1) - H(j)]\left[\frac{P(j)}{P(j+1) - 1}\right] \tag{1a}$$

For a continuous-time, continuous-state economy, this reduces to

$$-\int_{s}^{t} H(u)[\operatorname{cov}[H(u), P(u)]]\, du \tag{1b}$$

It is important to note that Expressions (1a) and (1b) are stochastic and that the difference between the forward and futures price is not equal to the payment flow, but equal to its present value. To obtain an explicit solution, therefore, a complete valuation model is required.

B. Differential Tax Treatment

The Treasury Bill futures market provides the individual investor with a unique tax option. Suppose the investor takes long position in a contract with over six months to maturity. If he has a gain at maturity, he closes out his futures position and reports the profit as long-term *capital* gain. If he has a loss, he takes delivery of the bills and sells them in the cash market, thereby generating an *ordinary* loss. The same potential does not exist on a short position, because all profits on short positions are taxed as short-term capital gains irrespective of the holding period.[3] Commerical dealers in bills, on the other hand, are taxed at ordinary income rates on all gains and losses.

The tax option creates an added demand for long positions in futures contracts with a maturity of over six months. This increased demand may tend to drive the futures price above the implied forward price. Any differential between the forward and futures price, however, presents commerical dealers with an arbitrage opportunity. The equilibrium differential between the forward and futures price, therefore, is indeterminate. Demand side analysis implies the differential must equal the value of the tax option, while supply side analysis implies the differential should be zero. In the "real world," any differences between these two extremes could be observed although a priori one might expect the difference to be closer to the side of the market with the smaller transaction costs.

Even in markets such as foreign exchange, where taking delivery will not produce ordinary loss, individuals will still have a preference for the long side of the market, because positions held for more than six months are taxed as long-term capital gains. The investor takes a long position in a contract with over six months to maturity and closes it out just prior to the six-month deadline if he has a loss (reporting a short-term loss) or holds it just past the six-month deadline if he has a gain (reporting a long-term gain). Whether or not this preference for the long side leads to a bias in the futures price for foreign exchange again depends on the behavior of commercial dealers.

Unfortunately, our data do not allow us to test for the existence of the tax effect in the foreign exchange futures markets. The only forward and futures contracts which have an identical maturity of six months or more are the one-year contracts. Trading in the International Monetary Market futures contracts with a maturity of one year is very sporadic. It is common for contracts of that maturity to go several days, or even weeks, without trading. Thus, we confine our selves to contracts of one, two, three, and six months maturity. For such contracts, all profits and losses from futures trading are short term. Under these circum-

[3] It should be noted that the IRS did not formally decide to tax Treasury Bill futures in this fashion until 1978. Prior to that time confusion existed as to whether Treasury Bill futures would be considered capital assets, like other futures contract, or whether they would be taxed like cash Treasury Bills.

stances, individual traders are taxed symmetrically on short and long positions, so that there is no reason for the futures and forward price to diverge because of tax effects.[4]

C. Special Costs of Short-Selling Bills

There is no explicit forward market in Treasury Bills. To establish a forward position, the investor must short a cash bill. Because the short seller cannot match the guarantee provided by the U.S. government, he must pay a premium. Evidence cited by Capozza and Cornell [2] indicates that this premium is approximately 50 basis points per year.

The arbitrager does not face this problem in the foreign exchange market. The existence of an explicit forward market obviates the need for cash transactions completely. Eliminating the cost of shorting cash bills significantly narrows the boundaries on the forward-futures price differential set by the no arbitrage condition.

D. Transaction Costs and Differential Default Risk

Transaction costs produce a band around the equilibrium forward-futures differential within which arbitrage is not profitable. Even within the band, however, there are forces which should drive the differential toward its equilibrium level. Assume, for example, that the equilibrium differential is zero, but that the futures price is currently above the forward price. Agents who had already decided to take a short position would be attracted to the futures market, while those desiring a long position would gravitate toward the forward market. Such behavior on the part of investors would push the differential toward equilibrium.

Comparative default risk is difficult to assess. The clearing house stands behind all futures contracts, while forward contracts are guaranteed by the contracting parties. The contracting parties, however, are generally major banks, corporations, and governmental bodies. In both cases, therefore, the probability of default is small.

E. Predictions of the Theories

The main distinctions between the bill market and the foreign exchange market are the tax treatment and the existence of forward trading. If either the tax effect or the cost of shorting cash bills is responsible for the discrepancy between forward and futures prices, then the discrepancy should not be observed in our foreign exchange sample. On the other hand, if the discrepancy is due to the CIR effect, then it should be observable in the foreign exchange market, unless the value of the payment flow given by (1a) or (1b) is much less for foreign exchange than for Treasury Bills. Finally, we have argued that neither transaction costs nor differential default risk should produce a substantial difference between forward and futures prices in the foreign exchange market.

[4] Actually, the tax treatment on long and short positions under six months may not be symmetric. If delivery on a long position is accepted, then taxes could be postponed and converted to long term if the underlying asset is held long enough.

III. Data and Empirical Tests

All our data were provided by the International Monetary Market of the Chicago Mercantile Exchange, henceforth referred to as the IMM. Until 1978 the IMM was the only futures market for foreign exchange in the United States. Recently other exchanges, such as the Commodity Exchange of New York, have begun trading foreign exchange futures, but the volume on these competing exchanges is insignificant over our sample period.

Our sample begins with the June 1974 futures contract. Foreign exchange futures trading on the IMM began on 16 May 1972, but trading was very thin until mid-1974. For this reason we chose the later starting date. The sample runs through the June 1979 futures contract.

The currencies studied are the British Pound, Canadian Dollar, German Mark, Japanese Yen, and Swiss Franc. These were the only currencies actively traded on the IMM over the entire sample period. There was also an active forward market in each of these five currencies. The futures prices we use are the daily closing prices. Closing times on the IMM range from 1:15 P.M., Chicago time, for the Swiss Franc to 1:25 P.M. for the Japanese Yen. The forward prices the IMM provided us were given to the exchange by Continental Illinois Bank. The forward quotes are for 1:00 P.M., Chicago time. Since the forward and futures prices are not recorded at the same instant, some random variation between the two prices will be observed. This random error, though, will not bias the results. (Only a trend in prices would produce bias, but any trends which might exist are far too small to be significant over an interval of half an hour or less.)

Another potential problem is the daily price limit imposed by the exchange. Suppose, for example, that the Swiss Franc closed the previous day at $.6200. Currently, daily price changes in the futures market are limited to $.0100. If the price in the forward market, which has no limit, rises to $.6350 the next day, the futures price would rise to $.6300 and trading would stop. Traders would not be willing to sell until the price hit $.6350, but the limit rule prevents the price from rising to that level. The result is a spurious divergence of the forward and futures price. Fortunately, limit moves have been very rare in the foreign exchange futures market, and our sample contains only two such occurrences, both for the Swiss Franc. When computing our statistics, these two observations are eliminated.

Finally, we have the problem that bid and ask quotes are not both available throughout the entire sample period in the forward market. The problem is not that data for specific days are missing, but rather that the IMM did not report the ask quotes for months at a time. While we do have a complete series of bid prices, about one-third of the ask prices are missing. If only bid prices are used, however, the difference between the futures price and the forward price will be overstated by approximately one-half the bid-ask spread. To adjust for this bias, we first computed all statistics, including standard errors, using the bid prices. Next, we computed the mean bid-ask spread from observations when both prices were available. Lastly, we adjusted the mean difference between the futures and forward price by one-half of the mean bid-ask spread. The standard errors were not adjusted.

The results are reported in Table I. The most striking fact is the small mean discrepancy between the futures and forward price. Only two of the mean differences are significantly different from zero: the three-month maturity for the British Pound and the one-month maturity for the Canadian Dollar. (Note that if we had attempted to adjust the standard errors to take account of variance in the bid-ask spread, the standard errors would be higher and the t-statistics would be smaller.) Both the Canadian and British results, however, are affected by the existence of several large negative observations in 1974 and 1975, when futures trading was very thin. Deleting just two observations, for example, switches the sign of the mean difference in both cases.

The results are economically, as well as statistically, insignificant. With the same two exceptions, the adjusted mean difference between the futures price and the forward price is less than the bid-ask spread in the forward market. Even in these two cases, the mean difference is less than twice the bid-ask spread, which is still too small for arbitragers to exploit on average.

Arbitrage profits can be made when the mean difference is zero, if there are instances when the differences between the forward and futures prices exceeds the cost of transacting. (Obviously such discrepancies would have to be both

Table I

Future vs. Forward Prices
Statistics for Price Differentials

Currency	Maturity	(1) Mean (Fut-For)[c]	(2) t-statistic	(3) Mean (Ask-Bid)	(4) N
British Pound[a]	1	−3.26	0.39	15.65	21
	2	−13.91	−1.48	15.24	21
	3	−32.16**	−4.05	19.83	21
	6	−17.89	−1.54	20.16	21
Canadian Dollar[a]	1	−4.73*	−2.59	4.18	21
	2	1.16	0.74	4.06	21
	3	0.51	0.57	4.72	21
	6	−1.37	−0.37	5.01	21
German Mark[a]	1	0.26	0.27	4.82	21
	2	1.31	1.15	5.00	21
	3	2.01	1.55	4.56	21
	6	0.34	0.19	5.42	21
Japanese Yen[b]	1	3.06	1.54	5.29	20
	2	−1.91	−1.24	6.79	17
	3	−1.71	−0.70	7.22	20
	6	−4.17	−0.95	10.79	17
Swiss Franc[a]	1	3.99	1.15	6.53	20
	2	−0.47	−0.23	6.35	21
	3	0.71	0.26	5.83	21
	6	2.16	1.04	7.89	20

[a] Each unit is $.0001
[b] Each unit is $.000001
[c] Forward price is equal to the observed bid price plus one-half the mean bid-ask spread.
* Significant at 5% level
** Significant at 1% level

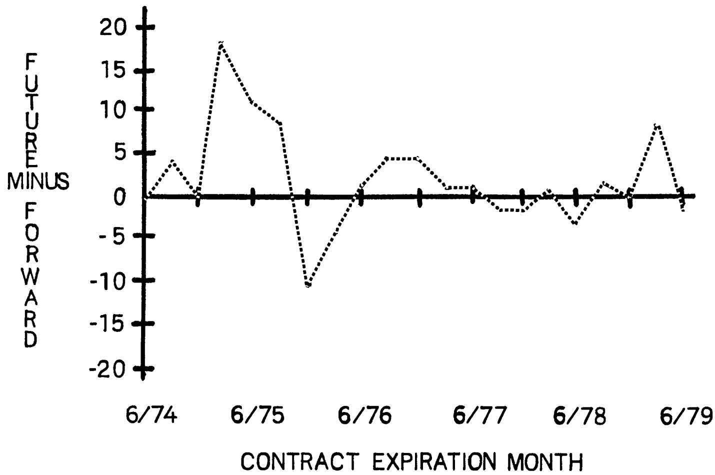

Figure 1. German Mark Spread: Three-Month Maturity

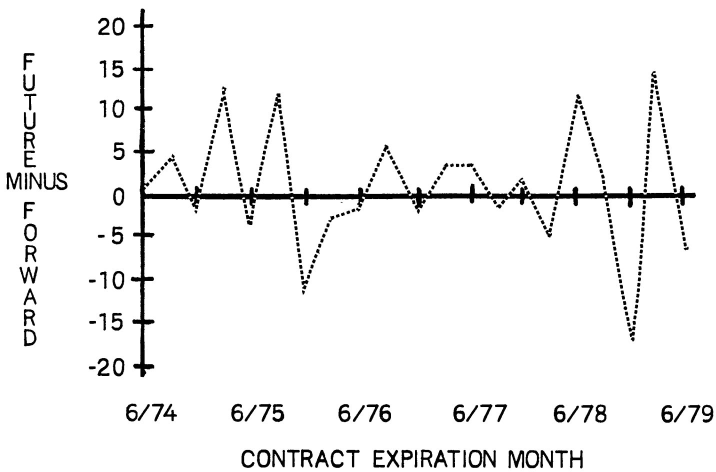

Figure 2. Swiss Franc Spread: Three-Month Maturity

positive and negative for the mean to be zero.) This possibility is investigated in Figures 1 and 2. The three month maturity for the Geman Mark and Swiss Franc is used in the figures because futures trading is more active for these contracts, particularly in the earlier years. The figures show the difference between the futures price and the adjusted forward price oscillating in a narrow range around zero. The *maximum* discrepancy of 17 points is only about three times the bid-ask spread in the forward market and only 0.40 percent of the average forward price. Since potential arbitragers must undertake two trades in both the futures and forward market, even the maximum discrepancy is not of economic significance.

These results are in sharp contrast to those in the Treasury Bill market, where average differences between forward and futures prices were five percent of the

Table II
Convariance Estimates

Maturity Date	Treasury Bills	German Mark	Swiss Franc
March 1979	-3.98×10^{-9}	3.36×10^{-8}	-1.08×10^{-8}
	(−0.68)[a]	(−0.15)	(−0.04)
June 1978	1.25×10^{-8}	-2.63×10^{-7}	-3.38×10^{-7}
	(3.12)	(−1.73)	(−1.73)
September 1977	3.58×10^{-9}	1.62×10^{-7}	1.47×10^{-7}
	(1.28)	(1.61)	(1.48)

[a] t-statistic from regression of percentage change in price of discount bond on percentage change in futures price.

futures price or as high as ten times the bid-ask spread in the cash market were observed for three month contracts.[5] No discrepancies of that magnitude are found in the foreign exchange market.

It is possible that the conflicting results for the two markets are consistent with the CIR effect, because the value of the cash flow represented by (1a) or (1b) may be quite different for different futures contracts. To investigate this possibility, we computed the covariance between percentage changes in the futures price and percentage changes in the discount bond price for Treasury Bill futures and for several foreign exchange futures contracts. We used a limited number of contracts, because all the data had to be collected and entered by hand.

The maturity dates for the chosen futures contracts were September 1977, June 1978, and March 1979. These contracts were selected because the maturity of the Treasury Bill and foreign exchange contracts differed only by one day.[6] (For other contracts the difference was eight, or even fifteen, days.) For the discount bond price, we used the bid price of the cash Treasury Bill which matured on the same day as the Treasury Bill futures contract. Both cash and futures prices for bills were stated in terms of a maturity value of 100, so a typical price would be 96.751. (In the case of the futures market, the prices were computed from the IMM index, but the index itself was not employed). Foreign exchange futures prices were stated in terms of the dollar price of foreign exchange as quoted on the IMM.

A sample of forty trading days was used to estimate the covariance. In each case the sample begins 60 days, or about three months, before the maturity of the futures contract. The estimation results are reported in Table II. In addition to the covariances, the t-statistics from regressions of the percentage change in the discount bond price on the percentage change in the futures price are also reported.

The covariances are all very small, on the order of 1.0×10^{-7} or less. It may seem surprising that the covariance for the foreign exchange futures exceeds that

[5] See Cornell and Capozza [21].

[6] For many commodities delivery can occur any time during the month of maturity. This makes the definition of maturity ambiguous. Fortunately, this problem does not occur in the case of Treasury Bills or foreign exchange, because delivery for both occurs on the day after trading ends.

for Treasury Bill futures, since cash bill prices and bill futures prices are more highly correlated than cash bill prices and foreign exchange futures prices. It turns out, however, that foreign exchange futures prices are much more variable than bill prices, and this effect swamps the impact of the correlation when computing the covariance.

The economic significance of our covariance estimates can be approximated by returning to (1b) and making the simplifying assumption that the covariance is equal to our estimated value during the life of the futures contract. For Treasury Bills, furthermore, we know that $H(u)$ will always be less than 100. Since the present value of a risky payment stream typically will be less than the size of the stream, it follows that

$$|H(t) - G(t)| = \left| \text{Val} \left[\int_s^t H(u) \left[\text{cov}(H(u), P(u)) \right] du \right] \right|$$

$$|H(t) - G(t)| = \left| \text{Val} \left[C \int_s^t H(u)\, du \right] \right|$$

$$|H(t) - G(t)| \leq \left| C \int_s^t 100\, du \right|$$

$$|H(t) - G(t)| \leq |C100(t - s)|$$

Substituting the maximum value of the estimated covariance for Treasury Bills, $C = 1.25 \times 10^{-8}$, and setting $t - s$ equal to sixty trading days, or ninety calendar days before maturity, yields

$$|H(t) - G(t)| \leq 1.25 \times 10^{-8} \times 100 \times 60$$

$$|H(t) - G(t)| \leq 7.5 \times 10^{-5}.$$

This means, for example, that if the forward price were 96.000, the futures price would be 96.00075; a very small difference in light of the fact that Treasury Bill prices are only stated to three decimal points. In terms of yield, the difference is less than *one-tenth* of a basis point.

Such a precise bound cannot be placed on the differential in the case of foreign exchange futures because there is not a known limit on $H(u)$. Suppose, nonetheless, that we pick a high upper bound for $H(u)$, such as \$1.00 for the mark and the franc. Even with this inflated figure and the maximum covariance, the absolute value of the differential is only

$$|H(t) - G(t)| = 3.38 \times 10^{-7} \times 1. \times 60\ 2.0 \times 10^{-5}$$

which is less than 1 percent of the bid-ask spread.

Rendleman and Carabini [6] and French [4] also estimated the equilibrium forward-futures differential. Rendleman and Carabini assumed that a simple valuation model held, so that a closed form solution to (1b) could be derived. Using that solution, they concluded that the differential should be approximately 3–4 basis points for contracts with 270 days to maturity, and less for contracts with shorter maturities. Though higher than our estimate, this is still an insignificant difference compared to the bid-ask spread in the cash market which is at least 10 basis points for 270 day contracts, and the observed differential which has exceeded 100 basis points. French, on the other hand, assumed that the nominal interest rate and the marginal utility of the commodity on which the futures contract is written are uncorrelated. This is not an appropriate assumption for financial futures, so his results are not directly comparable with ours. Nonetheless, French also found discrepancies of the same order of magnitude.

In light of these results, it is not surprising that forward and futures prices were found to be nearly identical in the foreign exchange market. With such small covariances, the CIR model predicts that the two prices should be indistinguishable. For this reason, another explanation must be sought for the differential observed in the Treasury Bill market.

IV. Summary and Conclusions

The large discrepancies between forward and futures prices found in the Treasury Bill market were not found in the foreign exchange market. The foreign exchange data reveal that mean differences between forward and futures prices are insignificantly different from zero, both in a statistical and economic sense. The mean discrepancy is less than the mean bid-ask spread in the forward market in 18 of the 20 cases, and barely exceeds it in the other two. Even when individual observations were analyzed, the maximum difference rarely exceeded two bid-ask spreads.

Such results are consistent with the Cox-Ingersoll-Ross model because the relevant covariance is so small that forward and futures prices should be indistinguishable in equilibrium. Unfortunately, this covariance term is even smaller in the case of Treasury Bill futures. Explanations for the Treasury Bill results, therefore, must rely on conditions unique to the market. Two obvious candidates are the tax treatment of bills and the cost of establishing forward positions, which requires shorting cash bills.

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