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10 Interest Differential and Covered Arbitrage

José Saúl Lizondo

10.1 Introduction

This paper deals with interest rate differentials between U.S. dollar denominated assets and Mexican peso denominated assets. In particular, the paper examines to what extent transaction costs can account for deviations from interest rate parity.

In section 10.2, I compare two propositions concerning the relationships between interest rate differentials and other economic variables. One of them is the Fisher hypothesis that relates the differential with the expected rate of change in the spot exchange rate. The other is the interest parity theorem that relates the differential with the forward premium or discount on foreign exchange. The connection between these propositions and the problems in testing the Fisher hypothesis for the Mexican peso are also discussed. In section 10.3, I restate the condition for covered interest arbitrage in the presence of transaction costs. I also discuss the availability of data and the procedure followed to estimate the transaction costs in the foreign exchange market. In section 10.4, I analyze the empirical evidence on covered interest arbitrage between U.S. dollar and Mexican peso denominated assets for the period from July 1979 to December 1980. The results show that only a small percentage of the deviations from parity can be accounted for by the transaction costs as previously measured. Then I examine two possible explanations. One of them is associated with additional costs and obstacles found in carrying out forward transactions. The other one is associated with the exchange gains tax treatment. Some concluding remarks are contained in section 10.5.

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10.2 The Fisher Hypothesis and Covered Interest Arbitrage

The Fisher hypothesis states that nominal interest rate differentials between assets that are identical in all respects except for the currency of denomination can be explained by the expected change in the spot exchange rate between those currencies over the holding period (Fisher 1930). Let S_t be the spot exchange rate at time t, defined as the domestic currency price of foreign currency; let i_t and i_t^* be one-period nominal interest rates at time t on domestic and foreign currency denominated assets, respectively; and let $E_t(X)$ denote the expected value of the variable X, conditional on all the information available at time t. The Fisher hypothesis may then be formally written as:

$$(1) \qquad \frac{(1+i_t)}{(1+i_t^*)} = \frac{E_t(S_{t+1})}{S_t}.$$

The interest parity theorem states that short-term capital movements will ensure that the returns on assets that are identical in all respects except for the currency of denomination will be equal when expressed in terms of the same currency after covering the exchange risk in the forward exchange market. This establishes a relationship between nominal interest rate differentials and the forward premium (or discount) on foreign exchange. Let F_t be the one-period forward exchange rate at time t. The condition for interest parity may then be formally written as:

$$(2) \qquad \frac{(1+i_t)}{(1+i_t^*)} = \frac{F_t}{S_t}.$$

From equations (1) and (2), it is clear that the Fisher hypothesis and the interest parity theorem are not equivalent unless the forward exchange rate at time t is equal to the expected value at time t of the spot exchange rate that will prevail at time $t+1$. That is, both propositions are equivalent only if

$$(3) \qquad F_t = E_t(S_{t+1}).$$

There are theoretical reasons that lead us to believe that equation (3) does not necessarily hold. Several models (Grauer, Litzenberger, and Stehle 1976; Stockman 1978; Frankel 1979; Fama and Farber 1979; Roll and Solnik 1979) imply that, under uncertainty, the forward rate is in general different from the expected value of the future spot rate. That difference may be the result of the existence of a risk premium. This premium depends on people's attitudes toward risk and some characteristics of the probability distributions of the variables included in the model. Moreover, even under risk neutrality, the forward rate may be different from the expected value of the future spot rate. This is because of the presence of a convexity term that arises from Jensen's inequality and the probability distribution of some of the variables included in the model. Jensen's inequality establishes that the expected value of a convex function of a random variable is larger than the value of the function evaluated at the expected value of the random variable. This implies that if the forward rate is equal to the expected value of the future spot rate from the domestic point of view, then they are not equal from the foreign point of view. This implication is known as the Siegel paradox, but it is thought to be of no empirical significance (Siegel 1972; McCulloch 1975).

Even when the implication of several models is that in general the forward rate is different from the expected value of the future spot rate, there are some conditions under which the same models imply that they are equal. Therefore, the validity of equation (3) is an empirical matter. Given that $E_t(S_{t+1})$ is not an observable variable, empirical work on this subject has tested the validity of equation (3) jointly with the hypothesis of market efficiency (Geweke and Feige 1979; Hansen and Hodrick 1980). If equation (3) holds and the market is efficient, the forward exchange rate should be the best forecast of the future spot rate. The tests are concerned both with whether the forward rate is an unbiased forecast of the future spot rate and with whether there is any other information that can be used to generate better predictions of the future spot rate. The information set generally includes past values of the forecast error for the same exchange rate and forecast errors from other currencies. Sometimes the hypothesis that the forward rate is the best forecast of the future spot rate is considered independently of its implications for market efficiency (Bilson 1980), but the results of the tests are nevertheless relevant for that issue.

The results of the tests tend to reject the joint hypothesis of market efficiency and the condition expressed in equation (3). If equation (3) does not hold, the Fisher hypothesis is different from the condition for interest parity. Therefore, there are reasons to test the empirical validity of each of them separately.

To test the Fisher hypothesis is to test whether equation (1) holds. Here, the same problem that was found in testing the validity of equation (3) is present: $E_t(S_{t+1})$ is not an observable variable. This problem is circumvented by testing the Fisher hypothesis jointly with the hypothesis of market efficiency (Cumby and Obstfeld 1980). If equation (1) holds and the market is efficient,

$$[(1 + i_t)/(1 + i_t^*)]S_t$$

should be the best forecast of the future spot rate. In particular, the forecast error should have zero mean and should be uncorrelated at all lags. The results of empirical work on this subject suggest that the Fisher hypothesis does not hold under the assumption of market efficiency.

The procedures used to test equations (1) and (3) are not adequate when studying currencies under fixed exchange rates when there is a positive and small probability of a large change in the exchange rate, either by devaluation or revaluation. The consequences of the existence of a positive and small probability of a drastic event has already been studied (Krasker 1980; Lizondo 1980). Also, when discussing the possible explanations for the rejection of the efficiency hypothesis in their works, Hansen and Hodrick (1980) say:

> Even though economic agents may process information optimally, the correct stochastic specification of government actions may not be consistent with the statistical model underlying our test. For instance, if economic agents correctly perceive that governmental actions will be roughly constant over relatively long periods and yet may change dramatically either at uncertain points in time or by an uncertain magnitude, we conjecture that it is possible that the statistical procedure we employ might yield sample autocorrelations in forecast errors that are large relative to their estimated standard errors even if the simple efficiency hypothesis is true. The cause of this could be a combination of incorrect assumptions we have made in determining the asymptotic covariance matrix for our estimators, a small sample size relative to the movements in government policy variables, and the inappropriateness of an ergodicity assumption in an environment where agents may assign positive a priori probabilities to events that may ultimately never occur.

These warnings are especially important when analyzing the validity of equation (3) under fixed exchange rates. For instance, assume that the level of the spot rate is equal to S_0. Also assume that, at time t, there is a positive and small probability P_t of a devaluation, between t and $t+1$, that will set the exchange rate at a new level $S_0(1+\alpha)$ with $\alpha > 0$. Assume that investors are risk neutral, that they know P_t and α, and that the market is efficient. Under those conditions, equation (3) holds and

$$F_t = S_0(1 + \alpha P_t).$$

As long as the devaluation does not take place, the forecast error,

$$e_t = F_{t-1} - S_t = S_0 \alpha P_{t-1},$$

is positive. In other words, the forward rate consistently overestimates the future spot rate and there seems to be a positive bias. Moreover, there is reason to believe that P_t is a variable with positive autocorrelation. The reason is that, in general, the variables that determine P_t, such as the level of international reserves and political stability, are themselves positively autocorrelated. Then, if yesterday's probability of a devaluation was relatively high but it did not take place, today's probability of a devaluation will tend to be relatively high too. In that case, the forecast error will show positive autocorrelation. Therefore, as long as the devaluation does not take place, the results of the usual tests will reject the joint hypothesis of market efficiency and equation (3), even when it is true.

It is also interesting to note that if the devaluation takes place between $t+k-1$ and $t+k$, the forecast error,

$$e_{t+k} = F_{t+k-1} - S_{t+k} = S_0 \alpha (P_{t+k-1} - 1),$$

will be negative, unless $P_{t+k-1} = 1$, which is very unlikely. In other words, for that period the forward rate will seem to have underestimated the future spot rate. These implications are consistent with the experience of the Mexican peso during the period prior to the devaluation of August 1976.

Even though Mexico has not formally had a fixed parity since September 1976, the exchange rate has been relatively constant since March 1977 and the peso has always been quoted at a discount on the forward market. This suggests that the problems of the bias and the autocorrelation mentioned above may have been always present.

Table 10.1 presents some information about the series of forecast errors $e_t = F_{t-1} - S_t$. The series consists of forty-three nonoverlapping monthly observations for the period from May 1977 to December 1980 using bid rates. The series has a positive mean, and only two of the observations are negative. It also shows positive autocorrelations at the first lags. A first order autoregressive model was estimated for the series.

The results show a significant positive constant and a significant first order autoregressive parameter. The specific model estimated for the series is less important than the general conclusions that the forward rate seems to have consistently overestimated the future spot rate and that the forecast error shows significant positive autocorrelations.

These types of results are generally used to reject the joint hypothesis of market efficiency and the validity of equation (3). As was mentioned above, under fixed exchange rates and positive probability of devaluation

Table 10.1

	Series $e_t = F_{t-1} - S_t$									
Mean	.196									
Standard deviation	.155									
Lags	1	2	3	4	5	6	7	8	9	10
Autocorrelations	.73	.51	.36	.25	.10	.06	.02	−.04	−.05	−.02
Estimated model	$e_t = .053 + .733\, e_{t-1} + u_t$									
	(.016) (.106)									
Number of observations	43									

Note: Figures in parentheses are standard deviations. Monthly nonoverlapping observations for the period May 1977 to December 1980. The S_t and F_t are bid rates. Spot rates are 9 AM New York time quotations, and forward rates are 12 AM New York time quotations. The source of data of exchange rates is the Federal Reserve Bank of New York.

these results should not be interpreted in that way because they are also consistent with market efficiency and equation (3). In other words, these results do not help us test equation (3) for the Mexican peso.

The same reasoning applies to equation (1). Under fixed exchange rates and positive probability of a devaluation, if the market is efficient and equation (1) holds, the domestic interest rate will reflect the expected devaluation. As long as the devaluation does not take place,

$$[(1 + i_t)/(1 + i_t^*)]S_t$$

will overestimate the future spot rate, and the forecast error is likely to show positive autocorrelation. Nevertheless, this reasoning assumes that domestic interest rates are free to adjust, reflecting the expected devaluation. This is not the case in Mexico. Interest rates on peso-denominated time deposits are officially determined, and returns on Mexican treasury bills are regulated through open market operations. In this case, we do not even have a strong presumption about the characteristics of the series of forecast errors

$$e_t = [(1 + i_{t-1})/(1 + i_{t-1}^*)]S_{t-1} - S_t.$$

Table 10.2 presents information on that series. The series consists of forty-three nonoverlapping monthly observations for the period from May 1977 to December 1980. Exchange rates are bid rates, and interest rates are after-tax rates on time deposits. The series has a positive mean, and nine of the observations are negative. It also shows a small positive autocorrelation at the first lag. A first order autoregressive model was estimated for the series.

The results show a significant positive constant and a first order autore-

Table 10.2

	Series $e_t = \left[\frac{1+i_{t-1}}{1+i_{t-1}^*}\right] S_{t-1} - S_t$									
Mean	.027									
Standard deviation	.073									
Lags	1	2	3	4	5	6	7	8	9	10
Autocorrelations	.21	.10	.06	−.03	−.06	.02	.08	−.03	−.02	−.06
Estimated model	$e_t = .022 + .216\, e_{t-1} + u_t$									
	(.011) (.154)									
Number of observations	43									

Note: Figures in parentheses are standard deviations. Monthly nonoverlapping observations for the period May 1977 to December 1980. The S_t are bid rates. The i_t and i_t^* are after-tax rates on Mexican peso and dollar time deposits, respectively, for Mexican depositors. The source of exchange rate data is described in table 10.1. Interest rates on dollar deposits are Eurodollar opening rates in London collected from Reuters news service. Interest rates on Mexican peso deposits were taken from "Indicatores Económicos," Banco de México, S.A.

gressive term that is not significant at the 5 percent level. The positive constant indicates that

$$[(1 + i_{t-1})/(1 + i^*_{t-1})] S_{t-1}$$

overestimated the future spot rate for the period considered.

Nevertheless, the extent of the overestimation is considerably smaller than the one found when using the forward rate to predict the future spot rate. Given that interest rates are regulated, these results do not imply that interest rates reflect the expected devaluation better than forward exchange rates do. On the other hand, those who believe that equation (3) holds may interpret the results as evidence that interest rates on Mexican peso deposits were not allowed to adjust by the full amount of the expected depreciation.

Therefore, not only are there technical obstacles in testing the Fisher hypothesis, there is also the issue of interpretation of the results when interest rates are regulated. In view of these problems, I will focus on testing the interest parity condition.

10.3 Covered Interest Arbitrage

The interest parity theory maintains that the returns on assets that are identical in all respects except for the currency of denomination will be equal when expressed in terms of the same currency after covering the exchange risk in the forward exchange market. Otherwise, capital flows would take place from the asset with the lower return to the asset with the higher return, until changes in interest rates or changes in exchange rates insure that equation (2) holds.

The observed deviations from the parity condition have been rationalized in terms of nonmonetary yields (Tsiang 1959), political risk (Aliber 1973; Doodley and Isard 1980), transaction costs (Branson 1969; Prachowny 1970; Frenkel and Levich 1975, 1977), capital controls (Doodley and Isard 1980), differential tax treatment (Levi 1977), and difference between short-run and long-run relationships (Pedersson and Tower 1979). Some of these and other explanations, like default risk and premature repatriation, are analyzed in a survey article by Officer and Willett (1970).

My purpose here is to analyze the deviations from interest parity between dollar-denominated assets and peso-denominated assets. I examine to what extent transaction costs can account for those deviations, and I also consider the effects of other factors, such as regulations on forward market operations and exchange gains tax treatment.

The framework used is based on Frenkel and Levich (1975). It consists of the derivation of a neutral band around the interest parity line. For points within the band, transaction costs exceed arbitrage profits. Therefore, those points do not violate in a meaningful sense the condition of equilibrium expressed in equation (2).

Frenkel and Levich consider four distinct transaction costs for a covered outflow (inflow) of capital: sale of domestic (foreign) securities, purchase of foreign (domestic) currency spot, purchase of foreign (domestic) securities, and sale of foreign (domestic) currency forward. Let the costs in the foreign and domestic security markets and in the spot and forward exchange markets be denoted by c^*, c, c_s, and c_f, respectively, as percentages of the total transaction. The condition for profitable capital outflows is

$$(4) \qquad (1+i) < \frac{F}{S}(1+i^*)\Omega',$$

and the condition for profitable capital inflows is

$$(5) \qquad \Omega'(1+i) > \frac{F}{S}(1+i^*),$$

where $\Omega' = (1-c)(1-c_s)(1-c^*)(1-c_f)$. This assumes that the initial position of the arbitragers is in securities. If the initial position of arbitragers is in cash Ω' should be replaced by $[\Omega'/(1-c)^2]$ in equation (4), and by $[\Omega'/(1-c^*)^2]$ in equation (5).

Due to unavailability of data, I assume that arbitragers begin their position with cash and that $c = c^*$. Under those conditions, I replace Ω' in equations (4) and (5) by $\Omega = (1-c_s)(1-c_f)$.

From equation (4), the lower limit on $p[p = (F-S)/S]$ for which outflows of capital are profitable is:

$$(6) \qquad \underline{p} = \frac{(1+i) - \Omega(1+i^*)}{\Omega(1+i^*)}.$$

From equation (5), the upper limit on p for which inflows of capital are profitable is:

$$(7) \qquad \bar{p} = \frac{\Omega(1+i) - (1+i^*)}{(1+i^*)}.$$

The neutral band is defined by equations (6) and (7). As long as $\bar{p} < p < \underline{p}$, arbitrage flows are not profitable. For $p < \bar{p}$ inflows are profitable, and for $p > \underline{p}$ outflows are profitable.

The empirical implementation of this problem requires the estimation of transaction costs in the spot and forward foreign exchange markets. Frenkel and Levich estimated those costs by studying the behavior of triangular arbitrage. They assume that deviations from triangular arbitrage are due to transaction costs, and their estimates of c_s and c_f are the percentages that bound 95 percent of those deviations.

The estimation of c_s and c_f by this procedure assumes that the various exchange rates reflect a direct exchange of one currency for another. Unfortunately, all the quotations of the Mexican peso with currencies different from the U.S. dollar are obtained through the Mexican peso/U.S. dollar exchange rate. Therefore, this procedure should not be applied in the present case.

In the empirical applications, S and F represent midpoint rates. Therefore, the transaction costs should be at least equal to one-half of the bid-ask spread in the respective market. In addition to that, c_s and c_f should include other costs, such as brokerage fees. This suggests that it is possible to estimate the transaction costs using data on bid-ask spreads.

McCormick (1979) estimated the costs of transactions in the spot foreign exchange market using triangular arbitrage between U.S. dollars, British pounds, and Canadian dollars. The period of estimation was April 26, 1976 to October 22, 1976. When using exchange rate quotations with no time difference among them, his estimate of c_s was .090 percent, considerably smaller than the estimates of Frenkel and Levich that used quotations with some time difference among them.

Table 10.3 presents information on the bid-ask spreads of the British pound/U.S. dollar and the Canadian dollar/U.S. dollar exchange rates for the same period as McCormick's estimation. The average spreads in the spot markets were .060 percent for the British pound/U.S. dollar exchange rate and .022 percent for the Canadian dollar/U.S. dollar

Table 10.3 Percentage Bid-Ask Spreads (April 26, 1976–October 22, 1976)

	Maximum	Minimum	Average	Standard Deviation
	British Pound/U.S. Dollar			
Spot	.610 (.150)	.011	.060	.055
Forward 3 months	.646 (.212)	.038	.100	.057
	Deutsche Mark/U.S. Dollar			
Spot	.103 (.103)	.025	.058	.014
Forward 3 months	.366 (.154)	.025	.111	.029
	Canadian Dollar/U.S. Dollar			
Spot	.117 (.078)	.019	.022	.011
Forward 3 months	.158 (.147)	.039	.047	.018
Number of observations: 126				

Note: Figures in parentheses indicate the maximum value of the spread when the largest observation is deleted. The source of the data is the *International Monetary Market Yearbook, 1976–1977.*

exchange rate. In view of McCormick's estimate of c_s and the information of table 10.3, I considered it a reasonable procedure to estimate the transaction costs for the Mexican peso/U.S. dollar spot exchange as one-half the bid-ask spread plus .06 percent.

Another question to discuss is the stability of transaction costs. The triangular arbitrage procedure produces one estimate for the whole period and therefore assumes that costs were stable during the period of estimation. Nevertheless, looking at table 10.3 it is possible to see that bid-ask spreads have large fluctuations. If other components of the costs do not vary inversely with the spread, and I do not see any reason why they would, one should have one estimate of the cost for each of the observations. Therefore, for the Mexican peso I use one-half of the bid-ask spread plus .06 percent for each of the observations. I am aware that this is a compromise because I am still using McCormick's estimate to justify the .06 percent above the half bid-ask spread.

For the estimation of transaction costs in the three months forward market, McCormick assumes $c_f = .96941\ c_s$ for arbitrage between U.S. dollars, British pounds, and Deutsche marks, and $c_f = 1.00913\ c_s$ for arbitrage between U.S. dollars, British pounds, and Canadian dollars. These are relationships found by Frenkel and Levich for the 1973–1975 period using the procedure of triangular arbitrage. On table 10.3, it is possible to see that the spread in the three months forward market is about twice the spread in the spot market. If the other components of the cost are not lower in the forward market, and I do not see any reason why they would be, c_f should be larger than c_s at least in one-half of the differences between the bid-ask spreads of both markets. Therefore, McCormick's procedure seems to me to be inadequate. Therefore, for the estimation of the costs of transactions in the forward market I also use one-half of the bid-ask spread plus .06 percent for each of the observations.

Table 10.4 presents information on spreads in Mexican peso exchange rates for the period for which bid and ask rates are available. It also presents, indirectly, information about the estimates of c_s and c_f. The

Table 10.4 **Percentage Bid-Ask Spreads in Mexican Peso Exchange Rates (July 1979–December 1980)**

	Maximum	Minimum	Average	Standard Deviation
Spot	.35 (.31)	.02	.10	.05
Forward 1 month	2.77 (2.48)	.08	.52	.37
Forward 3 months	4.98 (4.97)	.13	1.18	.70
Number of observations:	354			

Note: Figures in parentheses indicate the maximum value of the spread when the largest observation is deleted. The source of the data is described in table 10.1.

spread in the spot and the forward markets are considerably larger than for other currencies. This may be a consequence of banks assigning a larger risk to take positions in Mexican pesos than in other currencies and widening the spread accordingly. The effects of uncertainty on bid-ask spreads is theoretically considered in Allen (1977). Some empirical evidence on that relationship is provided by Fieleke (1975), Aliber (1975), and McKinnon (1976). Another interesting point to observe in table 10.4 is that the average spread in the forward market is considerably larger, with respect to the spread in the spot market, than for the other currencies. This may be a consequence of the Bank of Mexico intervening actively in the spot market and presumably not intervening in the forward market.

After determining the procedure to use to estimate transaction costs in the foreign exchange market, it is necessary to consider the assets whose returns are to be compared. Ideally, the assets should be identical in all respects except for the currency of denomination. One important factor to take into account is the political risk (Aliber 1973). When comparing the returns on assets denominated in currencies of two countries, the assets should be issued in the same financial center, that is, the same legal jurisdiction, located in a third country. Under those conditions, it is expected that the probability of future capital controls will affect the returns on both assets to the same extent. The empirical evidence shows that assets differing essentially only in their currency of denomination, such as Eurocurrency deposits, conform with the interest parity condition after considering the transaction costs. For the comparison of returns on treasury bills, the transaction costs explain a considerably smaller percentage of the deviations from interest arbitrage (Aliber 1973; Frenkel and Levich 1977, 1979; McCormick 1979).

For the Mexican peso we should use interest rates on deposits in foreign banks placed in foreign countries that are not subject to Mexican official regulations on interest rates. Unfortunately, data are not available on interest rates paid on those types of deposits. Therefore, I use time deposits and Mexican treasury bills as peso-denominated assets. For the dollar it does not matter whether we use Eurodollar deposits or dollar deposits created by the Mexican banking system. The interest rates paid on both types of deposits are the same for the period under consideration.

Finally, it is important to take into account the effect of taxes on the net returns to investors (Levi 1977). I use the after-tax returns on the different assets for Mexican individuals.

10.4 Empirical Results

The period of observation is July 1979 to December 1980, for which there is information on bid and ask exchange rates. During that period, Mexican treasury bills were issued each week. For those days I obtained a series of net returns for a three-month holding period. Data on rates of interest on three-month deposits in pesos and three-month deposits in dollars were collected for the same dates. After deleting some observations for days on which data in some of the variables were not available, there were seventy-five observations left. Based on the prices of the treasury bills one month prior to their expiration, I generated a series of net returns for a one-month holding period. Data on rates of interest on one-month deposits in pesos and one-month deposits in dollars were collected for the same dates. After deleting some days, there were seventy observations left.

Using that data, I computed $\underline{p}$ and $\bar{p}$ from equations (6) and (7) for arbitrage between Mexican peso time deposits and U.S. dollar time deposits, and for arbitrage between Mexican treasury bills and U.S. dollar time deposits. The results are presented in table 10.5.

The first column indicates the percentage of observations that lay within the neutral band, that is, observations for which $\bar{p} \leq p \leq \underline{p}$. It is possible to see that only a small proportion of the observations fall in that category. For all the observations outside the band $p > \underline{p}$. This indicates that for those observations there seems to be an opportunity for profitable capital outflows. The proportions of observations within the band is larger for Mexican treasury bills than for Mexican peso time deposits. This is the result of an official policy of keeping interest rates on time deposits below the rates on treasury bills. This policy also gave rise to a complaint from the commercial banks of "unfair competition" by the government in the attraction of funds. The proportion of observations

Table 10.5 **Deviations from Interest Parity Computed from Equations (6) and (7)**

	%ONB[a]	Average $\underline{p} - \bar{p}$[c]	Average $\underline{p} - p^*$[c]	NOBS[b]
One month:				
Time deposits	10.00	.88	.44	70
Treasury bills	25.71	.88	.44	70
Three months:				
Time deposits	4.00	1.50	.75	75
Treasury bills	18.67	1.51	.76	75

Note: Three-month returns on Mexican treasury bills were taken from "Anuario Financiero y Bursátil" 1979 and 1980, Bolsa Mexicana de Valores, S.A. de C.V. One-month returns were calculated from a sample of prices provided by six brokerage firms. For the sources of the other data used on this table see tables 10.1 and 10.2.

[a]%ONB = Percentage of observations within the neutral band.

[b]NOBS = Number of observations.

[c] $$\underline{p} = \frac{(1+i) - \Omega(1+i^*)}{\Omega(1+i^*)};\ \bar{p} = \frac{(1+i)\Omega - (1+i^*)}{(1+i^*)};\ p^* = \frac{i-i^*}{(1+i^*)}.$$

within the band is also larger for one-month assets than for three-month assets. This may arise because in general the discount on the peso increases substantially with the time length of the contract, and this is not completely reflected in the time structure of interest rates on peso-denominated assets. The second column indicates the average size of the band, $\underline{p} - \bar{p}$. The band is wider for three-month assets than for one-month assets, reflecting the larger spread in the three-month forward market than in the one-month forward market. Given that for all the observations outside the band there are incentives for capital outflows, $p > \underline{p}$, I computed the maximum positive deviation of p from "complete" parity consistent with equilibrium. Let $p^* = (i - i^*)/(1 + i^*)$, then "complete" parity means $p = p^*$. Therefore, the maximum positive deviation of p from complete parity consistent with equilibrium is $\underline{p} - p^*$. The third column of table 10.5 provides information on that variable. Those numbers say, for example, that on average the one-month forward discount on the peso needs to increase more than .44 percent above the parity line to present opportunities for profitable capital outflows.

The results of table 10.5 indicate the presence of persistent deviations from interest parity that provide incentives for capital outflows. This leads us to think about the reasons why prices did not adjust to reach equilibrium. Given that domestic interest rates and the spot exchange rate are controlled, and that the Eurodollar rate can be considered exogenous, the only price left to perform the adjustment is the forward exchange rate. One explanation of the results may be the presence of corner solutions in which we observe interest rate quotations for peso-denominated assets that seem to be out of equilibrium, but the quantity of those assets demanded at those prices is zero, that is, nobody is holding peso-denominated time deposits and nobody but the central bank is holding Mexican treasury bills. But this is not the case. Another possibility is to emphasize the difference in time for the different quotations. Spot exchange rates are recorded at 9:00 AM New York time, forward rates are recorded at 12:00 AM New York time, Eurodollar rates are London opening rates, peso time deposit rates are valid for the whole day, and Mexican treasury bill rates are daily averages. Even when there is time difference among the quotations, it seems to me that they do not provide a plausible explanation of the results. In particular, if time differences were the cause of the deviations, we would expect to observe deviations of p above and below the band, but we only observe deviations of p above the band. Therefore, we have to look for other explanations of the results. I examine two possible explanations below; one is associated with additional costs and obstacles found in carrying out forward transactions, and the other is associated with the exchange gains tax treatment.

Mexican investors with an initial position in pesos can make arbitrage operations selling pesos, investing in dollar deposits and selling dollars forward. It seems that Mexican investors were actually doing all those operations through foreign banks. Those banks were in fact creating peso-denominated deposits located in various foreign countries, among them were Panama and the United States. Even when there are not records about the interest rates paid on those deposits, some sources affirm that they were calculated as the Eurodollar deposit rate plus the discount on the peso. Under those circumstances, we expect the parity condition to be very robust, as it happens with Eurocurrency deposits on other currencies. This arbitrage activity may have prompted the Bank of Mexico in April 1980 to ask the foreign banks to abstain from performing those operations. At the same time Mexican brokerage firms were forbidden to intervene directly or indirectly in those type of operations. Only the Mexican commercial banks are allowed to perform those operations. But there is a special regulation for forward transactions. When a commercial bank sells dollars forward, the buyer must deposit in Mexican pesos 25 percent of the value on the contract, without interest, during the life of the contract. Given that commercial banks act as intermediaries, they have to sell dollars in both cases, inflow of arbitrage capital and outflow of arbitrage capital. The foregone interest on the 25 percent deposit is an additional cost that must be borne by the arbitrager. Under those conditions, there are incentives for capital outflows if:

$$(1 + i) < \frac{F}{S}(1 + i^*)\Omega(1 - .25i). \tag{8}$$

There are incentives for capital inflows if:

$$\frac{\Omega(1 + i)}{(1 + .25i)} > \frac{F}{S}(1 + i^*). \tag{9}$$

From equations (8) and (9),

$$\underline{p} = \frac{(1 + i) - \Omega(1 + i^*)(1 - .25i)}{\Omega(1 + i^*)(1 - .25i)}, \tag{10}$$

$$\bar{p} = \frac{\Omega(1 + i) - (1 + i^*)(1 + .25i)}{(1 + i^*)(1 + .25i)}. \tag{11}$$

The additional costs in foregone interest on the 25 percent deposit widen the neutral band. This can be checked by comparing equations (10) and (11) with equations (6) and (7). With a wider band, the percentage of observations within the band should rise.

Table 10.6 presents the results of the computations when using equations (10) and (11) for $\underline{p}$ and $\bar{p}$, respectively. As expected, the costs of arbitrage activity rise substantially. This is reflected in the second and third columns. For example, under the new conditions, on average, the one-month forward discount on the peso needs to increase more than .81

Table 10.6 **Deviations from Interest Parity Computed from Equations (10) and (11)**

	%ONB[a]	Average $\underline{p} - \bar{p}$[c]	Average $\underline{p} - p^*$[c]	NOBS[b]
One month:				
Time deposits	52.86	1.61	.81	70
Treasury bills	80.00	1.69	.85	70
Three months:				
Time deposits	38.67	3.82	1.94	75
Treasury bills	58.67	4.08	2.07	75

Note: For the sources of data see table 10.5.

[a]%ONB = Percentage of observations within the neutral band.

[b]NOBS = Number of observations.

[c] $\underline{p} = \dfrac{(1+i) - \Omega(1+i^*)(1-.25i)}{\Omega(1+i^*)(1-.25i)}$; $\bar{p} = \dfrac{\Omega(1+i) - (1+i^*)(1+.25i)}{(1+i^*)(1+.25i)}$; $p^* = \dfrac{i - i^*}{(1+i^*)}$.

percent above the parity line to present opportunities for profitable capital outflows through Mexican commercial banks. Also as expected, the percentage of observations inside the neutral band rises considerably. As in the previous case, and for the same reasons, the percentage of observations inside the band is larger for Mexican treasury bills than for peso time deposits, and they are also larger for one-month assets than for three-month assets.

It is unclear if arbitragers actually incur the additional costs of the 25 percent deposit. Sources in Mexican commercial banks affirm that the previous deposit regulation left them out of the market, because individuals prefer to operate through foreign commercial banks located in foreign countries to avoid the regulation. Nevertheless, the results of table 10.6 give us an idea of the costs that arbitragers will be willing to bear before resorting to Mexican commercial banks, that is, the costs they will be willing to bear to circumvent the regulation.

Another factor that may partially explain the results of table 10.5 is the exchange gains tax treatment. If there is a depreciation of the exchange rate, holders of dollar deposits must pay taxes on the increase of the peso value of the deposit. Therefore, holders of dollar deposits must take into account the possible change in the exchange rate. Given that the future value of the spot exchange rate is unknown at the time of creating a deposit, there is uncertainty; hence, it is not formally correct to call the operations we are considering arbitrage. Nevertheless, I will continue using that term. Let t denote the marginal rate of taxation, and let S_1 denote the value of the spot exchange rate at the time when the deposit matures. Assume that investors are risk neutral; they are interested only in the expected returns of their operation. Under those assumptions there are incentives for capital outflows if:

$$(12) \qquad (1+i) < \frac{F}{S}(1+i^*)\Omega - E\left(\frac{S_1 - S}{S}\right)t.$$

There are incentives for capital inflows if:

$$(13) \qquad (1+i)\Omega > \frac{F}{S}(1+i^*) - \frac{F}{S}E\left(\frac{S_1 - S}{S_1}\right)t.$$

For the construction of a neutral band based on these conditions, we need to know $E[(S_1 - S)/S]$ and $E[(S_I - S)/S_1]$. Assuming that $F = E(S_1)$ and ignoring Jensen's inequality, we can replace those expressions by $(F - S)/S$ and $(F - S)/F$, respectively. Under those assumptions and using equations (12) and (13), we can derive

$$(14) \qquad \underline{p} = \frac{(1+i) - (1+i^*)\Omega}{(1+i^*)\Omega - t},$$

$$(15) \qquad \bar{p} = \frac{(1+i)\Omega - (1+i^*)}{(1+i^*) - t}.$$

There is a substantial difference between the effects of the tax on exchange gains and the effects of the 25 percent deposit. The deposit increases the costs for both capital inflows and capital outflows. Therefore, $\underline{p}$ rises and $\bar{p}$ decreases, widening the band around the parity line. This can be checked by comparing equations (10) and (11) with equations (6) and (7). On the other hand, the tax on exchange gains increases the costs for capital outflows while giving incentives to capital inflows. Therefore, besides affecting the width of the band, the tax displaces the band upward. As the comparison of equations (14) and (15) with equations (6) and (7) indicates, $\underline{p}$ and $\bar{p}$ both increase.

Table 10.7 presents the results when equations (14) and (15) are used to compute $\underline{p}$ and $\bar{p}$. The value assumed for t is .55, which is the highest marginal tax rate for individuals. The percentage of observations within the band is larger than in table 10.5 for each of the categories, and the band size is also larger. In this case, the observations outside the band are distributed above and below it. That is, sometimes there seem to be opportunities for profitable capital outflows and sometimes there seem to be opportunities for profitable capital inflows. The opportunities for capital outflows are present in the first part of the period, in which domestic interest rates were relatively low. The opportunities for capital inflows are present in the second part of the period, in which domestic interest rates have risen considerably. Considering capital outflows, on average, the one-month discount of the peso has to rise more than 1.34 percent above the parity line for them to be profitable.

Once again, it is not clear whether the exchange gains tax is actually paid by holders of dollar deposits. It seems that individuals are able to evade relatively easily the payment of the tax, but that firms are moni-

Table 10.7 **Deviations from Interest Parity Computed from Equations (14) and (15)**

	%ONB[a]	Average $\underline{p} - \bar{p}$[c]	Average $\underline{p} - p^*$[c]	NOBS[b]
One month:				
Time deposits	85.71	1.93	1.34	70
Treasury bills	74.28	1.93	1.52	70
Three months:				
Time deposits	40.00	3.24	2.98	75
Treasury bills	49.77	3.26	3.52	75

Note: For the sources of data see table 10.5.

[a]%ONB = Percentage of observations within the neutral band.

[b]NOBS = Number of observations.

[c] $\underline{p} = \dfrac{(1+i)-(1+i^*)\Omega}{(1+i^*)\Omega - t}$; $\bar{p} = \dfrac{(1+i)\Omega-(1+i^*)}{(1+i^*)-t}$; $p^* = \dfrac{i-i^*}{1+i^*}$.

tored more closely and are less able to evade it. The results of table 10.7 give us an idea of the costs that holders of dollar deposits will be willing to bear to evade paying those taxes.

As a final exercise, I consider the case in which both regulations—the 25 percent deposit and the tax on exchange gains—are present. Under those conditions there are incentives to capital outflows if:

$$(1+i) < \frac{F}{S}(1+i^*)\Omega(1-.25i) - E\left(\frac{S_1 - S}{S}\right)t. \tag{16}$$

There are incentives to capital inflows if:

$$\frac{\Omega(1+i)}{(1+.25i)} > \frac{F}{S}(1+i^*) - \frac{F}{S}E\left(\frac{S_1 - S}{S_1}\right)t. \tag{17}$$

From equations (16) and (17), and under the assumptions made previously,

$$\underline{p} = \frac{(1+i) - \Omega(1+i^*)(1-.25i)}{\Omega(1+i^*)(1-.25i) - t}, \tag{18}$$

$$\bar{p} = \frac{\Omega(1+i) - (1+i^*)(1+.25i)}{(1+.25i)(1+i^*-t)}. \tag{19}$$

Comparing equations (18) and (19) with equations (6) and (7), it is clear that $\underline{p}$ is larger than in the first case considered as a consequence of both regulations: the exchange gains tax reduces the denominator, and the 25 percent deposit increases the numerator and reduces the denominator. As previously mentioned, the effects of the two regulations work in opposite directions on $\bar{p}$. The 25 percent deposit reduces it and the exchange gains tax increase it.

Table 10.8 presents the results for the case in which both regulations are present. The band has widened substantially and, as a result, all the observations lie within it. Now, for example, on average it is necessary for the one-month discount on the peso to rise more than 2.16 percent above the parity line for capital outflows to be profitable.

10.5 Concluding Remarks

Domestic interest rates may be linked to foreign interest rates by the Fisher hypothesis through the expected change in the exchange rate, and by the interest parity condition through the forward exchange rate premium or discount. Under a system of fixed exchange rates it is difficult to test the equivalence between the two propositions, and it is also difficult to test the Fisher hypothesis itself. Even more, in the case in which interest rates are officially regulated, interest rate differentials do not reflect exchange rate expectations but official economic policy. Interest parity, on the other hand, may be expected to work even with controlled interest rates if there are no capital controls and if individuals have access to the forward foreign exchange market.

The empirical evidence presented in this paper for the period 1979–1980 suggests that transaction costs in the foreign exchange market account for a small percentage of the deviations from parity. There are several causes that may help to explain this result. Here, I examined two of them: One is the requirement of a previous noninterest-bearing deposit in forward exchange operations, and the other is a tax on exchange gains. The explicit consideration of those additional costs increases the required deviation of the forward discount on the peso from interest

Table 10.8 **Deviations from Interest Parity Computed from Equations (18) and (19)**

	%ONB[a]	Average $\underline{p} - \bar{p}$[c]	Average $\underline{p} - p^*$[c]	NOBS[b]
One month:				
Time deposits	100.00	3.55	2.16	70
Treasury bills	100.00	3.73	2.44	70
Three months:				
Time deposits	100.00	8.31	5.61	75
Treasury bills	100.00	8.90	6.47	75

Note: For the sources of data see table 10.5.

[a]%ONB = Percentage of observations within the neutral band.

[b]NOBS = Number of observations.

[c] $\underline{p} = \dfrac{(1+t) - \Omega(1+i^*)(1-.25i)}{\Omega(1+i^*)(1-.25i) - t}; \bar{p} = \dfrac{\Omega(1+i) - (1+i^*)(1+.25i)}{(1+.25i)(1+i^*-t)}; p^* = \dfrac{i-i^*}{(1+i^*)}.$

parity for capital outflows to be profitable. This helps us to understand the observed deviations. Even when it is not clear if individuals actually incur those additional costs, such costs certainly present obstacles to the free movement of funds.

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Comment Kenneth Rogoff

Lizondo's paper achieves a significant step toward explaining and quantifying the segmentation of Mexican financial markets from world financial markets. He shows explicitly how to take into account tax laws and forward contract regulations in analyzing covered interest arbitrage between dollar time deposits (in Mexican banks) and peso time deposits or treasury bills.

There is one confusing aspect of Lizondo's otherwise very clear analysis, and most of this comment will be directed toward clarifying it. Lizondo defines deviations from covered interest parity on the basis of net of tax interest rates, but gross of tax capital gains on exchange rate depreciation (see tables 10.2 and 10.5). The taxes on capital gains are introduced only in the latter part of the paper as one major factor which helps explain the author's definition of covered interest deviations.[1] Because these deviations only take into account the taxes on interest income, and because peso-denominated deposits yielded a higher interest rate during the sample period, the deviations are skewed in favor of dollar assets. The deviations would be less skewed if they were based on gross yields, or if they included capital gain taxes on dollar appreciation against the peso. Of these two consistent definitions of covered interest arbitrage, it would probably be better to look first at gross yields. Tax laws and forward contract regulations could then be used to explain deviations from zero, much as Lizondo does.[2] Some aspects of the relationship between gross of tax and net of tax covered interest parity are developed in the analysis below. This analysis also expands on Lizondo's observation that covered interest arbitrage can involve risk because of taxes.

Covered interest parity is defined in equation (1) on a gross of tax basis:

$$1 + i_t = F_t(1 + i_t^*)/S_t, \tag{1}$$

where i_t and i_t^* are the interest rates on peso-denominated Mexican bank time deposits and dollar-denominated Mexican bank time deposits. S_t is the spot rate at time t (peso/dollar), and F_t is the forward rate at time t.

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1. The size of the bounds in Lizondo's table 10.8 would be smaller if centered on a definition of covered interest deviations which included the tax on capital gains. Incidentally, the one- and three-month bounds in Lizondo's tables differ so much because the interest rate deviations are not annualized.
2. This is really only a suggestion of an alternative way to organize the paper, since it would lead to much the same conclusions as Lizondo's.

The forward rate and the interest rates in equation (1) are of the same maturity.

In equation (2), (covered) interest arbitrage is defined on a net of tax basis for a taxpaying Mexican investor:[3]

$$(2) \quad \begin{aligned}(1+i) - \tau_i i = \hat{S}_{t+1}(1+i^*)/S_t + \phi(F_t - \hat{S}_{t+1}) - \tau_i i^* \hat{S}_{t+1}/S_t \\ - \tau_s(\hat{S}_{t+1} - S_t)/S_t - \tau_f \phi(F_t - \hat{S}_{t+1}),\end{aligned}$$

where $\hat{S}_{t+1}$ is the expected value of S_{t+1} (which is not necessarily equal to the forward rate when there is a risk premium); τ_i is the marginal tax rate on interest income from peso-denominated deposits and also on the peso value of interest income from dollar-denominated deposits; τ_s is the marginal tax rate on capital gains from exchange rate depreciation; τ_f is the marginal tax rate on capital gains from forward contracts; and ϕ is the quantity of dollars the investor sells forward to cover his exchange rate risk. Because of taxes, he will not necessarily need to cover the principal plus gross interest exactly; we will solve for the appropriate ϕ^* below. The left-hand side of equation (2) represents the principal plus net interest income obtained by placing one peso in a one-period peso-denominated time deposit. The right-hand side of (2) represents the after-tax peso income obtained by converting one peso into dollars and placing it in a one-period dollar-denominated time deposit, while simultaneously selling ϕ dollars forward. The first term on the right-hand side represents the gross expected return from holding the dollar time deposit, and the second term represents the gross expected return on the forward contract. Even though the forward rate may equal the expected value of the future spot rate, it is important to retain this term because we want to analyze risk as well as expected return. The third term on the right-hand side of (2) represents the expected tax on the dollar interest income. This term is uncertain at time t due to the assumption that investors have to pay interest income taxes on the peso value of their dollar interest income. The fourth term represents the expected tax on the expected appreciation of the principal. The final term represents the expected tax on the expected capital gain or loss on the forward contract.

By choosing the size of the forward contract ϕ appropriately, the investor can insure himself of a riskless peso return on his dollar-denominated asset. The appropriate ϕ^* is found by summing the coefficients on the expected spot rate $\hat{S}_{t+1}$ in equation (2), and setting ϕ so that this sum is zero. Performing this calculation yields

$$(3) \quad \phi^* = [(1-\tau_s) + i^*(1-\tau_i)]/S_t(1-\tau_f).$$

3. Net of tax interest arbitrage may be relevant even for an analysis of tax-avoiding investors. Lizondo points out that the taxes may provide a measure of tax-avoidance costs.

The expression for net of tax covered interest arbitrage is obtained by using equation (3) to substitute for ϕ^* in equation (2). It is clear from equations (2) and (3) that covered interest arbitrage does not become risky when taxes are introduced as long as the investor adjusts the size of his forward contract to take the taxes into account. The covering forward contract becomes smaller as interest income taxes and exchange rate capital gain taxes rise, and falls as capital gain taxes on forward contracts rise. When all three tax rates are equal, the covering forward contract ϕ^* is $(1 + i^*)/S_t$, which is exactly the size of the covering forward contract in equation (1) for gross of tax interest arbitrage.

The case where the capital gain tax rates and income tax rates are all equal is important because when $\tau_i = \tau_s = \tau_f$, net of tax covered interest arbitrage, equations (2) and (3), implies gross of tax interest arbitrage, equation (1). Thus deviations from gross of tax covered interest arbitrage can only be attributed to taxes to the extent that marginal tax rates on interest income and capital gains differ. Again, this result holds whether or not the forward rate is equal to the expected value of the future spot rate.

In conclusion, I should note that Lizondo's paper contains a useful discussion of a number of methodological issues faced by an empirical researcher who is trying to extract information from exchange market data. The so-called "peso problem" is particularly relevant to the problem at hand. It is worth emphasizing that the "peso problem" refers to the slow convergence to normality of distributions which include the small probability of a major event. Even if the rare event (which in this case is a sudden devaluation of the Mexican peso) occurs in the sample, problems arise. The asymptotic, normal distribution on which most statistical tests are based may still provide only a poor approximation to the sample distribution unless the sample size is very large, perhaps large enough to include many devaluations. The problems posed by Jensen's inequality are also more likely to be significant when there is a small probability of a major intervention.