Covered Arbitrage in Foreign Exchange Markets with Forward Forward Contracts in Interest Rates

DILIP K. GHOSH*

I. INTRODUCTION

Interest-rate parity and discussions on arbitrage in foreign exchange markets have appeared in the literature for a long time. Ever since the classic treatment of the issue by Keynes (1923), several attempts have been made to reexamine and reinterpret this subject. Existing works revolve around the covered interest-rate parity involving spot and forward contracts in currency exchange rates, and domestic and foreign interest rates matching the maturity of the chosen forward contract. It has been pointed out that in the absence of interest-rate parity where transaction costs do not exist, an investor can make profits from appropriate currency market transactions without assuming any risk. Frenkel and Levich (1975, 1977), Deardorff (1979), and later a host of researchers [see, for instance, Blenman (1991) and Ghosh (1994, 1997, in press) and many others[1]] have discussed the feasibility of arbitrage profits or the absence thereof with and without transaction costs. This study attempts to open a new branch in which a new interest-rate parity can be derived; more importantly, it explains conditions where covered arbitrage can profitably arise in the market through the use of a forward forward contract on interest rate. In

*For correspondence, please use the following address: 206 Rabbit Run Drive, Cherry Hill, NJ 08003.
[1]See other studies cited in the Bibliography.

■ *Dilip K. Ghosh is a Professor of Finance at St. John's University, New York.*

The Journal of Futures Markets, Vol. 18, No. 1, pp. 115–127 (1998)

CCC 0270-7314/98/010115-13

Section II, the analytical structure that provides another version of interest-rate parity is introduced, and a strategy for covered arbitrage profits for an investor is explored. In Section III, transaction costs are considered and conditions for arbitrage profits are enunciated. In Section IV, the possibility of compounding profit levels is introduced. Finally, in Section V, some concluding remarks and suggestions for extending the work to other scenarios are made.

II. THE ANALYTICAL STRUCTURE: A NEW PARITY AND COVERED ARBITRAGE

In this section, a time line for an investor with a menu of available choices for the design of investment strategies is drawn. First, assume that the investor has quotations on the spot rate of exchange (S_0), the 3-month forward rate of exchange (F_{01}), the 3-month domestic and the foreign rates of interest (r_{01}, r^*_{01}), respectively. He has also 6-month quotations on all those rates; F_{02}, r_{02}, and r^*_{02}. In this situation, with the 3-month and 6-month data set, the investor must check if interest-rate parity exists for both maturity levels (that is, for 3 and 6 months). If interest-rate parity exists for, say, the 3-month situation, not for the 6-month period, or *vice versa,* the investor will engage in covered arbitrage in the situation that deviates from parity. If, however, both 3-month and 6-month quotations provide an arbitrage opportunity, the investor should get involved with the case that yields the higher rate of return. The case is simple so far. But in today's financial markets new instruments exist in the form of forward forward contracts and forward rate agreements (FRAs) on interest rates that allow more sophisticated investment strategies.

Consider forward forward contracts on interest rates, and examine their impact on interest-rate parity and absence thereof in an effort to measure arbitrage profits, and profit multipliers. A forward forward contract is one that fixes an interest rate now for a deposit or loan starting at a future date, say, 3 months from today, and expiring at a further future date, say, 6 months from today.[2] Therefore, a 3-to-6-month forward forward contract on interest rate is entered into today by an investor and a bank, and the terms of the contract are binding on both parties. Because these contracts are available currently in financial markets, one may encounter the scenarios defined by the time line in Figure 1. Here, the left

[2]The existing literature on this new instrument is almost nonexistent. Forward forward contracts on interest rates are a variant of forward rate agreements (FRAs) on interest rates, which appear to have better vintage. This instrument is still only in the arsenal of practitioners in banking institutions. However, one may review Sercu and Uppal (1995, pp. 190–194).

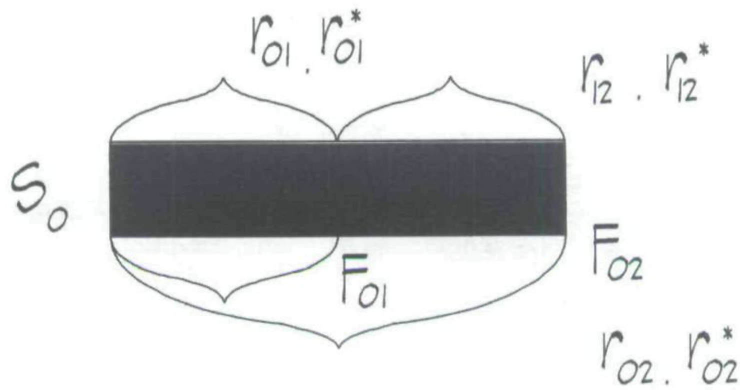

FIGURE 1
Investor's time line.

end is now (today), the mid-point is 3 months from today, and the right end is 6 months from today. S_0 is the currently quoted spot rate of exchange of, say, £1 in terms of U.S. dollars (that is, $S_0 = \$/£1$), F_{01}, and F_{02} are forward rates of exchange for 3-month and 6-month maturities; r_{01} and r_{02} are 3-month and 6-month interest rates in the domestic market. Similarly, r^*_{01} and r^*_{02} are foreign market interest rates for 3 and 6 months, respectively. Now, let r_{12}, and r^*_{12} be 3-to-6-month domestic and foreign forward forward interest rates, which an investor can lock in now. The whole spectrum of quotations available right now for the investor in question is then exhibited as follows:

S_0 = he spot rate of exchange of one British pound in terms of U.S. dollars

F_{01} = 3-month forward rate of exchange of one British pound in terms of U.S. dollars

F_{02} = 6-month forward rate of exchange of one British pound in terms of U.S. dollars

r_{01} = 3-month interest rate in domestic (U.S.) money market

r^*_{01} = 3-month interest rate in foreign money market

r_{02} = 6-month interest rate in domestic money market

r^*_{02} = 6-month interest rate in foreign money market

r_{12} = 3-month forward forward interest rate in domestic money market, effective 3 months from today, but the contract can be made right now

$r_{12}^* =$ 3-month forward forward interest rate in foreign (British) money market, effective 3 months from today, but the contract can be made right now

Under the given menu of market data, the question is: can the investor make arbitrage profits? This study answers this question and then the conclusion is generalized by giving conditions where risk-free profit opportunities exist and where those opportunities vanish.

Given the market situations with all these quotations, the investor has a number of opportunities to consider. Because all the possible scenarios cannot be depicted within a reasonable space, and because all possible scenarios are not economically meaningful, only a few alternatives are considered. Other scenarios can be worked out easily. Consider an investor who has all the information on his or her computer screen—real time, on line. He can borrow, say, $\$M$ from his bank at r_{01} for 3 months, or at r_{02} for 6 months. He may then exchange $\$M$ at the spot rate for British pounds, and invest the pound amount either at r_{01}^* or at r_{02}^*, and sell the amount, $M/S_0\,(1 + r_{01}^*)$, at the 3-month forward rate, or sell the amount, $M/S_0(1 + r_{02}^*)$, at the 6-month forward rate, and get the dollar amount, $M/S_0\,(1 + r_{01}^*)\cdot F_{01}$ or $M/S_0\,(1 + r_{02}^*)\cdot F_{02}$, depending upon the initial choice of maturity. The arbitrage profit levels from 3-month and 6-month maturities must then be as follows, respectively:

$$\pi_{01} = M\left[\frac{F_{01}}{S_0}(1 + r_{01}^*) - (1 + r_{01})\right] \tag{1}$$

$$\pi_{02} = M\left[\frac{F_{02}}{S_0}(1 + r_{02}^*) - (1 + r_{02})\right] \tag{2}$$

From eq. (1) one obtains that if

$$\frac{F_{01}}{S_0}(1 + r_{01}^*) - (1 + r_{01}) = 0$$

interest-rate parity exists for 3-month maturity, yielding

$$r_{01} - r_{01}^* = \left(\frac{F_{01} - S_0}{S_0}\right)(1 + r_{01}^*) \tag{3}$$

Similarly, from eq. (2), in the situation of interest-rate parity, one can get

$$r_{02} - r_{02}^* = \left(\frac{F_{02} - S_0}{S_0}\right)(1 + r_{02}^*) \tag{4}$$

These are the expressions of interest-rate parity long known in the existing literature. In the event of inequality between the left-hand and the right-hand sides in (3) and/or (4), the investor has an opportunity for a risk-free profit *via* what is popularly called covered arbitrage. If the left-hand side in (3) or in (4) is greater than the right-hand side, the investor should borrow in the home market and invest in the foreign market. In the opposite situation, the opposite strategy—that is, borrowing in the foreign market and investing in the home market—will yield positive profits to the investor, risk-free. To make these statements more comprehensible, take, for instance, eq. (3) and assume that $r_{01} = 10\%$, $r^*_{01} = 9.5\%$, $S_0 = 2$, and $F_{01} = 2.15$. In this case, note the following situation, where

$$(r_{01} - r^*_{01}) < \left(\frac{F_{01} - S_0}{S_0}\right)(1 + r^*_{01})$$

With these data, one can find that $(0.10 - 0.095) < [(2.15 - 2.00)/2.00]\,(1 + 0.095)$. If the investor borrows \$1,000,000 at 10% from a domestic bank, and exchanges his borrowed \$1,000,000 at the spot rate, \$2.00 = £1, he gets £500,000, which, invested in the British market at 9.5%, yields £500,000 × 1.095 = £547,500. This amount of pound sterling is sold forward at 2.15 to bring the U.S. dollar amount to \$1,177,125, from which the investor must subtract the borrowed amount and the total interest accrued on it (\$1,000,000 × 1.1 = \$1,100,000). Note now that the investor ends with a net amount of \$77,125.

Next, consider the following alternatives: (a) the investor exchanges his $\$M$ in the spot market, invests the converted amount in the foreign market for 6 months in this instance, sells the newly created amount in the forward market and subtracts therefrom the original principal and the accrued interest; (b) he first borrows $\$M$ for 3 months (not 6 months), and at the same time enters into a 3-to-6-month forward forward contract with a bank to put his amount, $M/S_0(1 + r^*_{01})$ (3 months from now) in deposit at r^*_{12} for the next 3 months, which at the end of 6 months from today becomes $M/S_0(1 + r^*_{01})\,(1 + r^*_{12}) \cdot F_{02}$ upon the forward sale of the foreign currency amount. The profit level in this instance then would be

$$\pi_{0.1,2} = M\left[\frac{F_{02}}{S_0}(1 + r^*_{01})\,(1 + r^*_{12}) - (1 + r_{01})\,(1 + r_{12})\right] \quad (5)$$

Compare (2) and (5). In the event $\pi_{02} = \pi_{0.1,2}$ one obtains a new interest-rate parity, which can be expressed as follows:

$$[(1 + r_{01})(1 + r_{12}) - (1 + r^*_{01})(1 + r_{12}) - (r_{02} - r^*_{02})]$$
$$= \left(\frac{F_{02} - S_0}{S_0}\right)[(1 + r^*_{01})(1 + r^*_{12}) - (1 + r^*_{02})] \quad (6)$$

This is a new interest-rate parity. If there is no rollover with forward forward contracts on interest rates, the original interest-rate parity, which is defined by

$$(r_{02} - r^*_{02}) = \left(\frac{F_{02} - S_0}{S_0}\right)(1 + r^*_{02}) \quad (7)$$

is once again smoothly rehabilitated.[3] It should be noted that under pure expectations hypothesis on the term structure on interest rates (which holds in equilibrium) one can observe the following relations:

$(1 + r_{01})(1 + r_{12}) = (1 + r_{02})$, and $(1 + r^*_{01})(1 + r^*_{12}) = (1 + r^*_{02})$,

and in that case then parity holds, and arbitrage profits do not arise. But, in reality, the market has a centripetal move toward equilibrium at any point of time, but it is not in equilibrium *necessarily* at every point in time,

[3]Take eq. (1*):

$$[(1 + r_{01})(1 + r_{12}) - (1 + r^*_{01})(1 + r^*_{12}) - (r_{02} - r^*_{02})]$$
$$= \left(\frac{F_{02} - S_0}{S_0}\right)[(1 + r^*_{01})(1 + r^*_{12}) - (1 + r^*_{02})]$$

and decompose it as follows:

$$\frac{r_{02} - r^*_{02}}{1 + r^*_{02}} = \left(\frac{F_{02} - S_0}{S_0}\right)\left[1 - \frac{(1 + r^*_{01})(1 + r^*_{12})}{(1 + r^*_{02})}\right] + \frac{(1 + r_{01})(1 + r_{12}) - (1 + r^*_{01})(1 + r^*_{12})}{(1 + r^*_{02})}$$

whence:

$$\frac{r_{02} - r^*_{02}}{1 + r^*_{02}} = \left(\frac{F_{02} - S_0}{S_0}\right) - \left(\frac{F_{02} - S_0}{S_0}\right)\left[\frac{(1 + r^*_{01})(1 + r^*_{12})}{(1 + r^*_{02})}\right] + \frac{(1 + r_{01})(1 + r_{12}) - (1 + r^*_{01})(1 + r^*_{12})}{(1 + r^*_{02})}$$

If pure expectations theory holds in both home and domestic economies, that is, $(1 + r_{01})(1 + r_{12}) = (1 + r_{02})$, and $(1 + r^*_{01})(1 + r^*_{12}) = (1 + r^*_{02})$, then (6) reduces to the following:

$$\frac{r_{02} - r^*_{02}}{1 + r^*_{02}} = \left(\frac{F_{02} - S_0}{S_0}\right) - \left(\frac{F_{02} - S_0}{S_0}\right) + \frac{(1 + r_{01})(1 + r_{12}) - (1 + r^*_{01})(1 + r^*_{12})}{(1 + r^*_{02})}.$$

The whole expression then reduces to interest-rate parity minus deviation from interest-rate parity. Because deviation from interest-rate parity is zero in this case, interest-rate parity theory holds.

and hence parity does not take place, and thus (8) becomes meaningful at many times. Grabbe (1991, p. 266) correctly notes, "It is tempting to equate the implied forward rate $f(t + n, T - n)$ [*in this study's example,* r_{12}] with the expected short-term interest rate that will prevail at time $t + n$ [*in this case, for 3-to-6 months from now*]. The expectations theory should be considered a purely empirical proposition in the same way that the speculative efficiency hypothesis is a purely empirical proposition."[4] If liquidity preference or market segmentation theory can precisely bring out the relations $(1 + r_{01})(1 + r_{12}) = (1 + r_{02})$, and $(1 + r^*_{01})(1 + r^*_{12}) = (1 + r^*_{02})$, then (6) holds, and arbitrage profits become nonexistent. In that situation it is useless to discuss (8) further [as (6) and (8) cannot hold simultaneously]. Because theoretically one cannot establish that (6) holds always [again, see Grabbe (1991)] and empirical evidence for the absence of parity does often exists, (8) is a significant situation to work on, and profit possibilities should be explored.

Now consider the following scenario:

$$[(1 + r_{01})(1 + r_{12}) - (1 + r^*_{01})(1 + r^*_{12}) - (r_{02} - r^*_{02})]$$
$$\neq \left(\frac{F_{02} - S_0}{S_0}\right)[(1 + r^*_{01})(1 + r^*_{12}) - (1 + r^*_{02})] \tag{8}$$

If the left-hand side of (8) is greater than the right-hand side, then it is evident that the investor should borrow in the domestic market at r_{01} and invest in the foreign market at r^*_{01} for the first 3 months, and then roll over for the next 3 months with currently available 3–6-month forward forward contracts on interest rates instead of taking a straight 6-month position right now. If the left-hand side is less than the right-hand side, he or she should start at foreign borrowing and investing in the domestic economy, and take the opposite position in terms of the choice of investment horizon.

III. THE PARITY AND COVERED ARBITRAGE WITH TRANSACTION COSTS

The discussions in Section II do not include the transaction costs that an investor usually incurs in both foreign exchange markets and in money markets. In this section, transaction costs are considered. It has been

[4]This discussion focuses on the contextual relevance of the term structure of interest. It should be noted that if the relations $(1 + r_{01})(1 + r_{12}) = (1 + r_{02})$, and $(1 + r^*_{01})(1 + r^*_{12}) = (1 + r^*_{02})$ hold, scope for arbitrage profits does not exist. Empirically one often finds the following: $(1 + r_{01})(1 + r_{12}) \neq (1 + r_{02})$, and $(1 + r^*_{01})(1 + r^*_{12}) \neq (1 + r^*_{02})$. See Grabbe (1991) on this issue.

postulated by Frenkel and Levich (1977) and Deardorff (1979) in the original conceptual environment that transaction costs are proportional. Recently Rhee and Chang (1992), Ghosh (1991, 1994), Blenmann (1991, 1992, 1996), and Blenman and Thatcher (1995, 1997) introduced *ask* and *bid* quotations that essentially capture foreign exchange transaction costs, and *lending* and *borrowing* rates of interest that capture those costs in money market operations. The following notations are used:

S_0^A = spot *ask* rate of exchange of one British pound in terms of U.S. dollars

S_0^B = spot *bid* rate of exchange of one British pound in terms of U.S. dollars

F_{01}^A = 3-month forward *ask* rate of exchange of one British pound in terms of U.S. dollars

F_{01}^B = 3-month forward *bid* rate of exchange of one British pound in terms of U.S. dollars

F_{02}^B = 6-month forward *bid* rate of exchange of one British pound in terms of U.S. dollars

F_{02}^A = 6-month forward *ask* rate of exchange of one British pound in terms of U.S. dollars

$r_{0i(L)}$ = i-month *lending* rate of interest in domestic money market (i = 3, 6)

$r^*_{0i(L)}$ = i-month *lending* rate of interest in foreign money market (i = 3, 6)

$r_{0i(B)}$ = i-month *borrowing* rate of interest in domestic money market (i = 3, 6)

$r^*_{0i(B)}$ = i-month *borrowing* rate of interest in foreign money market (i = 3, 6)

$r_{12(V)}$ = 3–6-month forward forward interest rate in domestic money market, effective 3 months from today, but the contract can be made right now [V = *lending* (L) or *borrowing* (B)]

$r^*_{12(V)}$ = 3–6-month forward forward interest rate in foreign (British) money market, effective 3 months from today, but the contract can be made right now [V = *lending* (L) or *borrowing* (*B*)]

To capture transaction costs, π_{01} and π_{02}, and $\pi_{0.1,2}$, defined by eqs. (1), (2), and (4) are presented and modified as π^T_{01}, π^T_{02}, and $\pi^T_{0.1,2}$, respectively, as follows:

$$\pi^T_{01} = M\left[\frac{F^A_{01}}{S^B_0}(1 + r^*_{01(L)}) - (1 + r_{01(B)})\right] \qquad (0.1^T)$$

$$\pi_{02}^{T} = M\left[\frac{F_{02}^{A}}{S_0^B}(1 + r_{02(L)}^{*}) - (1 + r_{02(B)})\right] \qquad (0.2^T)$$

$$\pi_{0.1,2}^{T} = M\left[\frac{F_{02}^{A}}{S_0^B}(1 + r_{01(L)}^{*})(1 + r_{12(L)}^{*})\right.$$

$$\left. - (1 + r_{01(B)})(1 + r_{12(B)})\right] \qquad (0.2,1^T)$$

From the equality of (0.2^T) and $(0.2,1^T)$ one can establish the following parity statement:

$$[(1 + r_{01(B)})(1 + r_{12(B)}) - (1 + r_{01(L)}^{*})(1 + r_{12(L)}^{*})$$

$$- (r_{02(B)} - r_{02(B)}^{*})] = \left(\frac{F_{02}^{A} - S_0^B}{S_0^B}\right)[(1 + r_{01(L)}^{*})$$

$$= (1 + r_{12(L)}^{*}) - (1 + r_{02(L)}^{*})]. \qquad (1^{T*})$$

In the event of the inequality between these two sides of (1^{T*}), the opportunity for arbitrage profit arises, and persistence of that profitable scenario exists. The next section explores this possibility.

IV. COMPOUNDING OF COVERED ARBITRAGE PROFITS

Section II and Section III delineate the conditions under which covered arbitrage profits can exist. It is now time to examine the possibility of compounding the original profits made in the arbitrage operation by exploiting the initial absence of parity. Consider the possibility that

$$\tau_{0.1,2}^{T} = M\left[\frac{F_{02}^{A}}{S_0^B}(1 + r_{01(L)}^{*})(1 + r_{12(L)}^{*})\right.$$

$$\left. - (1 + r_{01(B)})(1 + r_{12(B)})\right] > 0 \qquad (0.2,1^{T\prime})$$

That means the investor first borrows $\$M$ for 3 months (not 6 months) at $r_{01}^{(B)}$, and at the same time enters into a 3–6-month forward forward contract with that or any other bank for the rate $r_{12(B)}$ to put his amount $M/S_0^B(1 + r_{01(L)}^{*})$ in deposit at $r_{12(L)}^{*}$ 3 months from now for the next 3 months, which at the end of six months from today then becomes

$$\frac{M}{S_0^B}(1 + r_{01(L)}^{*})(1 + r_{12(L)}^{*})\,F_{02}^{A}$$

upon the forward sale of the foreign currency amount. The present value of this amount of profit is

$$\pi_{0.1,2(0)}^{T(1)} \equiv \frac{\pi_{0.1,2}^{T}}{(1 + r_{01(B)})\,(1 + r_{12(B)})}$$

Because this profit is made by the investor on the first opportunity, it is designated as the first round by assigning 1 as the superscript—that is, by modifying the notation to $\pi_{0.1,2(0)}^{T(1)}$. By plugging in this profit level along with the original amount, $M, that is, by putting in the $\$(M + \pi_{0.1,2(0)}^{T(1)})$ amount in the same way as the initial amount of $M, the investor can make the following amount in the second round:

$$\pi_{0.1,2(0)}^{T(2)} = M\alpha^T(\alpha^T + 2)^{2-1}$$

and from his nth round, after putting in all previous levels of profits, that is, by plugging in $M + \Sigma_{i=1}^{n-1} \pi_{0.1,2(0)}^{T(i)}$, he gets the following amount of profit:

$$\pi_{0.1,2(0)}^{T(0)} = M\alpha^T(\alpha^T + 2)^{n-1}$$

where

$$\alpha^T = \left[\frac{\left[\frac{F_{02}^{A}}{S_0^{B}}(1 + r_{01(L)}^{*})\,(1 + r_{12(L)}^{*}) - (1 + r_{01(B)})\,(1 + r_{12(B)})\right]}{(1 + r_{01(B)})\,(1 + r_{12(B)})}\right]$$

It is a matter of simple verification that on the very first round of arbitrage, an investor's level of profit can be shown to be equal to $\pi_{0.1,2(0)}^{T(1)} = M\alpha^T(\alpha^T + 2)^{1-1} = M\alpha^T$. It is evident now that $(\alpha^T + 2)^{i-1}$ is the multiplier of the initial covered arbitrage profit on the ith round ($i = 1, 2, 3, \ldots, n$). Next, the summation of $\pi_{0.1,2(0)}^{T(i)}$'s over first n iterations measures the cumulative profits on first n successive rounds in the market with the data frozen over the period of iterations. This cumulative profit is then defined as follows:

$$\pi_0^{T*} = M\alpha^T\left[\frac{1 - (\alpha^T + 2)^n}{1 - (\alpha^T + 2)}\right]$$

Similar results in other possible scenarios can be derived.

V. CONCLUDING REMARKS

Many interesting extensions of these results can be made by introducing others features to this trading strategy. This article concentrates on theoretical structure, but empirical studies could and should follow. Now some observations on microstatics and macrodynamics of the market in the context of this research follow.

It is a fundamental reality that if arbitrage opportunity exists in the marketplace, soon it will disappear by the dynamics of competition, and in that sense it may appear quite questionable if the second, and the third, and the *n*th round of arbitrage activities of an investor can ever take place. A careful reflection on this point is absolutely essential, and upon that reflection and comprehension of market forces one should realize a few points. First of all, if an investor finds that an arbitrage opportunity exists, he or she ascertains profits *instantly* for all the n rounds of arbitrage. The market data are are same for round 1 and round n within 20 seconds or 2 minutes in which quotes do not change from the investor's screen. The investor's first and his *n*th executions take place *almost* at the very same instant with programmed trading, these two rounds differing only by the amounts of arbitrage funds. In the first round, the amount is $\$M$, and in the *n*th round the amount will be $M + \sum_{i=1}^{n-1} \pi_{0.1,2(0)}^{T(i)}$, and the time involved in these n successive rounds may be less than 1 second with digitized signatures of approval by the bank(s). The moment the market data are factored in, and $\pi_{0.1,2}$ ($\neq 0$) is ascertained, one computes $\pi_{0.1,2(0)}^{1}$, $\pi_{0.1,2(0)}^{2}$, $\pi_{0.1,2(0)}^{3}$, . . . , $\pi_{0.1,2(0)}^{n}$, and so on. If the investor can exploit the market one time *via* arbitrage, he can exploit the same market several times, because the moment is *virtually* frozen, and the data for market exploitation remain the same. Note, the investor is a microagent operating in the market place in which even the speediest adjustment cannot deprive him of the opportunity to take advantage of the market misalignment. It is known that arbitrage exists in the market, and many players subsist on it.

Second, one should note that in the trillion-dollar market a million or even a few billions by a microagent may not throw the market into any state of concussion. However, if a large number of participants act in the same moment, there may be an execution jam, and nobody is likely to take any profits out of arbitrage. In this situation of multiple players the macrodynamics of the market set in and force arbitragers into zero-profit condition. One should realize also, that before any iteration is executed, some quotes may change. To guard against this possibility appropriate limit orders should be put in with each iteration of covered arbitrage; this should guarantee nonnegative profit conditions in the repeated arbitrage acts.

Market dynamics and market efficiency are of paramount significance. Clinton (1976), and Dornbusch (1976) highlight and examine some of these concerns quite efficiently. One should note that in the frozen (static) moment, no adjustment is possible, and microlevel arbitrage is certainly an exploitable opportunity.

At this point a few more issues should be addressed. One may wonder why an investor who sees an arbitrage opportunity will start with 1 million dollars instead of hundreds of millions or billions of dollars. The answer is simple. If the investor has 1 million dollars as the maximum amount available to him, he has to begin only with that much money. Of course, if he has more, he will initiate his moves with more funds. Second, the issue here is not what the optimal amount of initial investment funds for arbitrage should be; the issue is: if an initial amount—be it $\$M$ or $\$Z$—is available for arbitrage, what amount of money can potentially be generated out of that initial situation? Two other issues should be noted. One may argue that because profits out of the first round of arbitrage are obtained only at the end of 6 months from today, how is this investor getting funds for second, and third, and other rounds? Note here that π_1 is a sure amount of money made by the investor without taking any risk, and any bank should recognize this. It is equally recognizable that this investor has $\pi_{1(0)} \equiv \pi_1/1 + r)$ and it is his or her equity position that he or she can legitimately utilize. Note that although a given spot rate and a given forward rate are *usually* defined at a point in time and, corresponding to those defined quotes, a set of domestic and foreign interest rates will yield $\pi_{0.1,2} = 0$, one can find another set of interest rates from the available spectrum of interest rates that will yield $\pi_{0.1,2} \neq 0$. Additionally, one who watches real-time data recognizes that quotations on spot rates and forward rates by different banks and/or dealers are not always the same at the same instant, which creates an opportunity for arbitrage. Finally, if only one round of arbitrage is undertaken, it may appear that arbitrage profit is negligible, but the replication of the same strategy over and over can make arbitrage profits significant.

BIBLIOGRAPHY

Blenman, L. P. (1991): "A Model of Covered Interest Arbitrage under Market Segmentation," *Journal of Money, Credit, and Banking*, 23(4):706–717.

Blenman, L. P. (1992): "The Interest Rate Parity: Seven Expressions: A Reply," *Financial Management*, 21(3):10–11.

Blenman, L. P. (1996): "Contemporaneous, Non-Contemporaneous Currency Exchanges and Arbitrage Activity," *The International Journal of Finance*, 8(1):15–32.

Blenman, L. P. and Thatcher, J. S. (1995): "Arbitrage Opportunities in Currency and Credit Markets: New Evidence," *The International Journal of Finance*, 7(11):123–1145.

Blenman, L. P., and Thatcher, J. S. (1997): "Arbitrageur Heterogeneity, Investor Horizon and Arbitrage Opportunities: An Empirical Investigation," *Financial Review*.

Clinton, K. (1976): "Spot Rates, Forward Rates and Exchange Market Efficiency," *Journal of Financial Economics*, 5(1):55–65.

Deardorff, A. V. (1979): "One-Way Arbitrage and Its Implications for the Foreign Exchange Markets," *Journal of Political Economy*, 87(2):351–364.

Dornbusch, R. (1976): "Expectations and Exchange Rate Dynamics," *Journal of Political Economy*, 84(6):1161–1176.

Frenkel, J. A., and Levich, R. M. (1975): "Covered Interest Arbitrage: Unexploited Profits?," *Journal of Political Economy*, 83(4):325–338.

Frenkel, J. A., and Levich, R. M. (1977): "Transaction Costs and Interest Arbitrage: Tranquil Versus Turbulent Periods," *Journal of Political Economy*, 85(6):1209–1226.

Ghosh, D. K. (1991): "The Interest Rate Parity: Seven Expressions," *Financial Management*, 20(4):8–9.

Ghosh, D. K. (1994): "The Interest Rate Parity, Covered Interest Arbitrage and Speculation under Market Imperfection," in D. K. Ghosh, and E. Ortiz (Eds.), *Changing Environment of International Financial Markets: Issues and Analysis*, London: Macmillan, Chap. 6, pp. 69–79.

Ghosh, D. K. (1997): "Naked and Covered Speculation in the Foreign Exchange Market," D. K. Ghosh and E. Ortiz (Eds.), *The Global Structure of Financial Markets*, London: Routledge, Chap. 9, pp. 119–143.

Ghosh, D. K. (in press): "Risk-Free Profits with Forward Contracts in Exchange Rates and Interest Rates," *Journal of Multinational Financial Management*.

Grabbe, J. O. (1991): *International Financial Markets* (2nd ed.), New York: Elsevier Science Publishing Co.

Keynes, J. M. (1923): *A Tract on Monetary Reform*, London: Macmillan.

Rhee, S. G., and Chang, R. P. (1992): "Intra-Day Arbitrage Opportunities in Foreign Exchange and Eurocurrency Markets," *Journal of Finance*, 47(1): 363–379.

Sercu, P., and Uppal, R. (1995): *International Financial Markets and the Firm*, Cincinatti, OH: South-Western College Publishing and London: Chapman and Hall.