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TRANSACTION COSTS AND INTEREST ARBITRAGE: TRANQUIL VERSUS TURBULENT PERIODS*

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This paper deals with transaction costs and the efficiency of short term capital movements. Our prime purpose is to examine whether, and to what extent, the efficiency of short term capital movements have been affected by different economic environments generated by the varying exchange rate regimes.

In a previous paper (Frenkel and Levich 1975), we suggested a method for estimating the cost of transactions that are associated with covered interest arbitrage. The period studied was January 1962-November 1967--a period which was relatively homogeneous in terms of the extent of volatility in the foreign exchange markets. We refer to that period as the "tranquil pegged exchange rate period." The British devaluation in November, 1967 terminated the "tranquil period" and set the stage for extremely turbulent times in the foreign exchange markets during 1968-1969, a period that may be referred to as "the turbulent pegged exchange rate period." Following a transitional phase, the system evolved into its present state referred to as the managed (or dirty) float.

In the present paper we apply the method of estimation to the above mentioned three phases of the exchange rate system, and concentrate on comparing the results obtained for these three periods. One of the conclusions emerging from such a comparison is reflected in the title of this paper and relates to the classification of periods; it suggests that for the study of covered interest arbitrage, it might be preferred to classify periods by the extent of turbulence rather than by the legal and institutional arrangements of the exchange rate regime (e.g., pegged or flexible exchange rate systems). In Section I we outline some of the theoretical aspects associated with incorporating the cost of transactions into the standard formulae of covered interest arbitrage. Section II contains a description of the methodology and the estimates of the cost of transactions. In Section III we use the estimated cost of transactions to assess their significance in accounting for the observed deviations from the parity condition during the three periods under examination. In Section IV we discuss the concept of "unexploited profit opportunities" and examine the implications of following a simple trading rule. In Section V we proceed in comparing some of the characteristics of the three periods by examining the time-series properties of the various exchange rates. Some concluding remarks are contained in Section VI.

I. Interest Arbitrage and Transaction Costs: Theoretical Aspects

The interest parity theory states that the equilibrium forward premium on foreign exchange is:

$$(1) \qquad \frac{F - S}{S} = \frac{i - i^*}{i + i^*}$$

where F and S are, respectively, the forward and spot exchange rates, and where i and i* are the domestic and the foreign rates of interest on securities that are identical in all respects except for the currency of denomination.

The formulation in equation (1) ignores any transaction costs in the security and the foreign exchange markets. In Frenkel and Levich (1975) we have shown that when costs are present (and are proportional to the value of transactions), the lower limit on the forward premium $p \equiv (F-S)/S$ for which covered outflow is profitable is

$$(2) \qquad \underline{p} = \frac{(1+i) - \Omega(1+i^*)}{\Omega(1+i^*)}$$

where

$$\Omega = (1-t)(1-t_s)(1-t^*)(1-t_f)$$

and where t, t^*, t_s and t_f denote, respectively, the percentage cost of transactions in domestic and foreign securities and in spot and forward exchange rates.[1] In (2), Ω summarizes the various costs of transactions. As long as there are any transaction cost $\Omega < 1$ and $\underline{p}$ exceeds the value that is indicated by equation (1). In other words the presence of costs implies that in order to induce marginal outflow, the forward premium on foreign exchange must be higher than otherwise so as to compensate for the costs.

By similar reasoning it can be shown that the upper limit on the forward premium for which covered inflow is profitable is:

$$(3) \qquad \bar{p} = \frac{\Omega(1+i) - (1+i^*)}{1+i^*}$$

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[1]To illustrate, consider the costs of covered outflow. If arbitragers do not hold cash, then covered outflow requires the execution of four transactions: (a) sale of domestic securities with transaction costs of t percent, (b) spot purchase of foreign currency with transaction costs of t_s percent, (c) purchase of foreign security with transaction costs of t^* percent, and (d) forward sale of foreign currency with transaction costs of t_f percent.

which is smaller than the value indicated from equation (1).

Equations (2) and (3) set the limits for a neutral band within which covered interest arbitrage is not profitable. Whenever the forward premium falls within the neutral band such that

$$(4) \qquad \frac{\Omega(1-i) - (1+i^*)}{1+i^*} \leq p \leq \frac{(1+i) - \Omega(1+i^*)}{\Omega(1+i^*)} ,$$

there will be no incentive for covered interest arbitrage.[2] Thus, points that are bounded within the neutral band may be viewed as equilibrium points even though the condition of equation (1) is not satisfied. The width of the neutral band increases with the cost of transactions; therefore, the higher the costs, the more likely it is that situations that seem to entail profit opportunities are in fact equilibrium positions that are bounded within the band.[3] To enable such an analysis it is necessary, therefore, to estimate these costs.

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[2] It should be noted that the above formulation assumed that potential arbitragers always hold securities; as a result, the initial transaction had to be a sale of securities for cash. Since, however, at each period some fraction of the existing stock of securities matures, some arbitragers may initially hold cash for a short while. When profit opportunities arise, the cost of arbitrage for the cash holders will be lower and the neutral band will be narrower. Allowing for this possibility in the above formulae results in a more conservative measure of the cost of transactions where in equation (2) we replace Ω by $\Omega_1 = \Omega/(1-t)^2$ and in equation (3) we replace Ω by $\Omega_2 = \Omega/(1-t^*)^2$ with the corresponding modification of condition (4).

[3] Observed deviations from the arbitrage condition induced various attempts to reconcile the theoretical expectations with the empirical facts. In addition to covered interest arbitrage, the modern theory of forward exchange considers also the activities of hedging and speculation as factors determining the forward rate (e.g., Tsiang (1959), Kenen (1965), and Grubel (1966). Other attempts to account for the persisting deviations emphasized the role of transaction costs (Branson 1969), Frenkel and Levich (1975)), political risk (Aliber (1973)), the role of the elasticities of demand and supply in the capital markets (Prachowny (1970), and Frenkel (1973)) as well as differential tax treatments (Levi 1977). For a survey see Officer and Willet (1970).

II. The Cost of Transactions: Methodology and Estimates

There are no direct estimates of the cost of transactions in either the market for foreign exchange or the security market. If deviations from the interest parity condition were due only to the cost of arbitrage, then the existing deviations would provide a measure of the cost. This approach to the measurement of the cost of transactions is clearly unsatisfactory since the assumption being made is that all profit opportunities are exploited. Thus the answer to the basic question under consideration is being assumed without verification. An estimate of the cost should be deduced from data other than the existing deviations from covered interest parity.

In an earlier paper (Frenkel and Levich 1975), we proposed a procedure for the estimation of the cost of transactions in the market for foreign exchange by using data on triangular arbitrage. Briefly, the essence of triangular arbitrage is to ensure consistency of cross exchange rates.[4] As an example, consider the exchange rates between the U.S. dollar and the U.K. pound, the U.S. dollar and the German mark, and between the German mark and the U.K. pound. In the absence of transaction costs arbitrage among currencies ensures that equation (5) holds

$$(\$/£)_\tau = (\$/DM)_\tau \; (DM/£)_\tau \qquad (5)$$

where the terms in parentheses indicate the corresponding exchange rates, and the subscript τ indicates that these prices are for foreign exchange delivered at the same maturity τ. If transactions in the foreign exchange market are costly, the two sides of equation (5) could differ, and the

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4 For an analysis and measurement of triangular arbitrage see Grubel (1966).

maximum discrepancy would correspond to the differential costs involved in executing the two types of exchange. Furthermore, if the cost of transacting is approximately equal across leading currencies, then one would expect the maximum discrepancy between the two sides of equation (5) to correspond to the cost of one transaction. Accordingly, this is the way that we estimate the cost of transactions in the market for foreign exchange. This estimate should be interpreted to encompass the total cost associated with a transaction. Thus it includes elements like brokerage fees, time cost, subscription costs and all other components that comprise the cost of being informed.[5]

Taking the cost of transactions in the market for foreign exchange as the upper limit of the discrepancy from triangular arbitrage, is based on the assumption that the structure of the cost remains stable throughout the period under examination. It is only under this assumption that we can interpret smaller deviations from triangular arbitrage as being within

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[5]This suggested procedure could be criticized on the grounds that it presumes that arbitrage in currencies is efficient and therefore that the upper limit of the deviations from the equality implied by triangular arbitrage measures the cost of transaction. It seems, however, that if there is a market for which this presumption is justified, it is the market for foreign exchange. This was also the market used by Walras in developing the concept of arbitrage as well as in developing the notion that discrepancies from parity in that market correspond to the cost of transactions:

> "Whenever this state of general equilibrium is disturbed, it will be restored by arbitrage operations in bills of exchange exactly like arbitrage operations in commodities . . . Bills of exchange are <u>par excellence</u> the most suitable commodity for arbitrage operations. At every commercial center there are special bankers, called <u>cambists,</u> whose business it is to keep continual watch on the rates of exchange and to restore general equilibrium in foreign exchange by taking advantage of the possibility of any profit to be made by making indirect rather than direct purchases . . . There is a limit of the loss and premium on exchange; and this limit is the total cost . . . If the limit were exceeded, the debtor would prefer to send species. Hence the limit cannot be exceeded." (Walras, 1870, Lesson 34.)

Similar concepts of the operation of the foreign exchange market can be found in Ricardo (1811, pp. 9-10) and Cournot (1838, chap. iii).

a neutral band such that the cost of transaction exceeds arbitrage profits. Therefore, it is necessary to identify periods during which market conditions were approximately homogenous. In identifying such periods we follow the suggestion of Leamer and Stern (1972) and inspect the ratio of the forward to the spot exchange rates for various currencies. A forward rate lying outside the support limits may indicate (under a regime of pegged exchange rates) pressures reflecting lack of confidence in the government's ability to maintain the peg. When the exchange rate is flexible, there is no obligation to maintain a specific rate; in this case periods may be classified according to the degree of volatility of the ratio of the forward to the spot exchange rate.

In Figure 1 we plot the ratio of the 90-day forward to the spot exchange rates for two pairs of currencies: the mark-dollar and the pound-dollar rates. As is evident, several periods emerge: (i) 1962-1967--which we identify as the tranquil peg, (ii) 1968-1969--which we identify as the turbulent peg, and (iii) 1973-1975--the managed float. We chose not to analyze the period 1970-1972 which marks the breakdown of the pegged rate system and the transition towards the current regime. As can be seen from Figure 1 the various peaks and troughs correspond to the major crises in the international financial markets.[6] To further explore the relative homogeneity of the three periods, we have examined the deviations from triangular arbitrage; while these deviations differ markedly among periods, their structure is relatively stable within each period. Accordingly, we have concluded that there are three distinct periods for which we need to estimate the cost of transactions in the market for foreign exchange.

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[6] A more comprehensive Crisis Index which provides for a similar classification is developed by Stokes (1972).

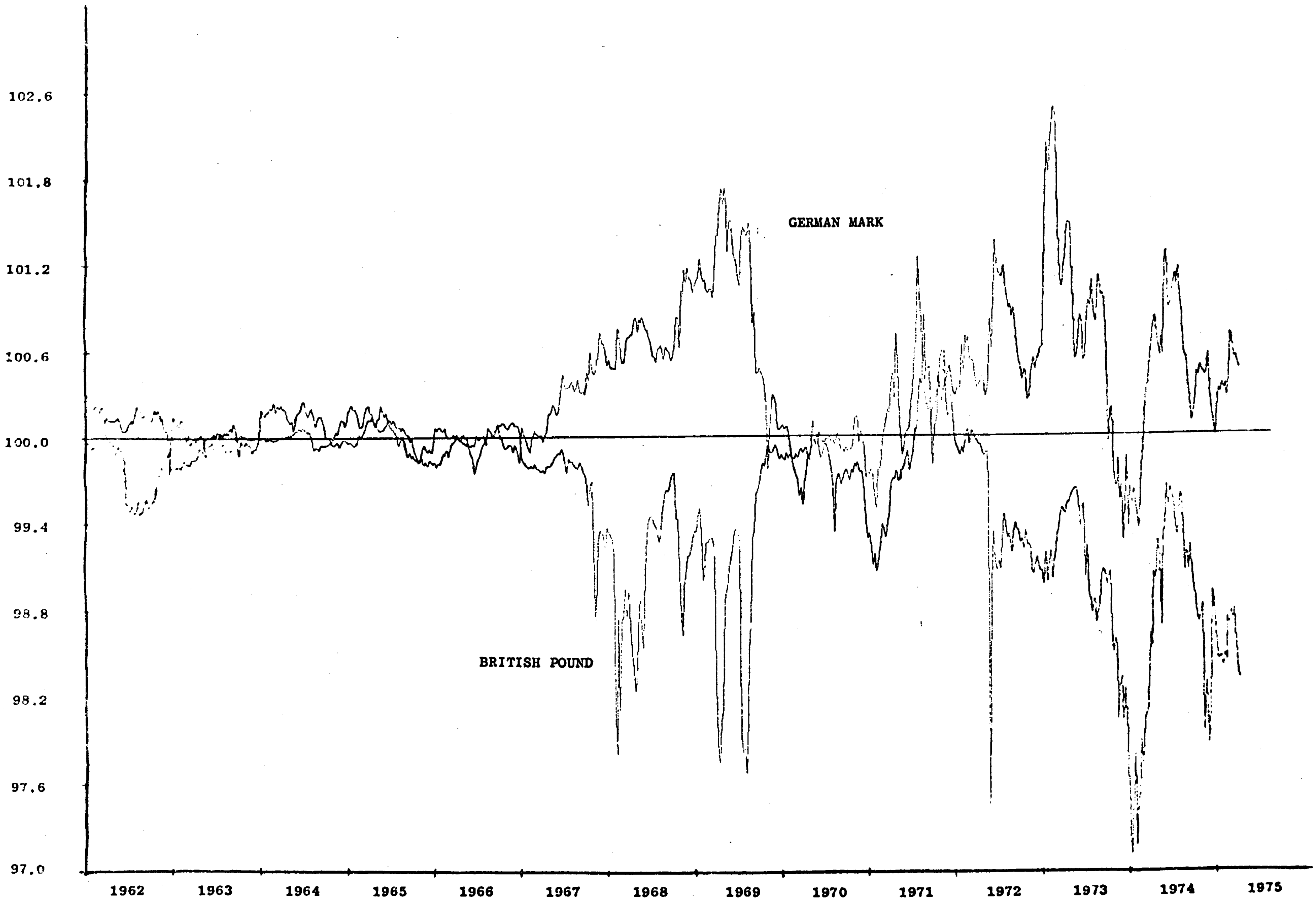

Fig. 1--Weekly Observations of the Ratio of 90-Day Forward to Spot Exchange Rates.

To estimate the cost of transactions we have analyzed the series of weekly observations of the spot and the 90-day forward exchange rates.[7] Using these observations we have computed for each period two series of weekly percentage deviations from the triangular arbitrage of equation (5) for the spot and the forward rates. The upper limits of these series of deviations correspond to t_s and t_f, respectively--the cost of transactions in the spot and the forward markets. To allow for errors in measurement and other data inaccuracies, we have taken a more conservative measure: our estimates of t_s and t_f for the various periods are the percentage deviation which bounds 95 percent of the weekly deviations from triangular arbitrage.

The indirect exchange between the U.S. dollar and the U.K. pound in equation (5) was assumed to occur through the German mark. In principle, other currencies could be used as intermediaries. It is expected that competition will assure that the cost of transacting will tend to be equalized among leading vehicle currencies. To allow, however, for possible differences in transaction costs as a function of the intermediate currency, we have also computed the cost for the case in which the Canadian dollar (\$C) replaces the German mark as the vehicle of arbitrage as in equation (5')[8]:

$$(5') \qquad (\$/£)_\tau = (\$/\$C)_\tau (\$C/£)_\tau$$

The various estimates of the cost of transactions in the market for foreign exchange are summarized in Table 1. As can be seen these estimates differ significantly among the different periods under consideration while

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[7] All data sources used in this paper are outlined in the appendix.

[8] For a related discussion on the role of the cost of transactions in the determination of vehicle currencies see Swoboda (1969).

within each period the estimates show much less variation with respect to the choice of the intermediate currency.

The changes in the cost of transactions are also related to the pattern that is depicted in Figure 1. The British devaluation in November 1967 signified the start of the turbulent period which manifested itself in lack of confidence and increased uncertainty. In the face of these developments dealers require a larger compensation for carrying inventory of various currencies and for standing ready to take immediate positions. In addition, the period following the British devaluation witnessed a lower degree of communications and harmonization among Central Banks resulting in wider bands, and larger uncertainty.

In the most recent managed float period, the cost of transactions in foreign exchange have risen to unprecedented heights. Depending on the currency and on the maturity of the contract, the cost of transactions during the period is between six to ten times higher than the corresponding cost during the tranquil peg. In the face of increased uncertainty concerning the evolution of the system and the financial collapse of some institutions, many banks are reluctant to take positions even for a short period which results in larger deviations from triangular arbitrage.[9]

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[9]The financial collapse of some institutions due to losses from foreign exchange operations encouraged governments to tighten controls over such operations, and thereby to further increase the cost of transactions. An instructive example to this effect is provided by the market and governmental reactions to the failure of the German Herstatt bank. This reaction is described in the Weekly Review of the Harris Bank (of June 28, 1974):

> "The Bundesbank's closing of a large German bank due to foreign exchange losses was received with nervous uncertainty in all exchange markets . . . Starting next month, all German banks will be required to report their foreign currency positions up to the month's end in one month, three months, and over three months categories . . . By weekend, most exchanges settled back to a thin but restrained trading with unusually wide trade margins."

TABLE 1

ESTIMATES OF THE PERCENTAGE COST OF TRANSACTIONS
IN THE MARKET FOR FOREIGN EXCHANGE
(Spot and 90-Day Forward)

Period	Arbitrage between Securities Denominated in	Intermediate Currency	t_s	t_f	$t_s + t_f$
Jan. 1962–Nov. 1967	$U.S. and £	DM	0.051	0.076	0.127
	$U.S. and £	$C	0.058	0.068	0.126
Jan. 1968–Dec. 1969	$U.S. and £	DM	0.102	0.160	0.262
	$U.S. and £	$C	0.085	0.112	0.197
July 1973–May 1975	$U.S. and £	DM	0.523	0.507	1.030
	$U.S. and £	$C	0.438	0.442	0.920

It should be emphasized, however, that these developments need not be interpreted as a necessary characteristic of the flexible exchange rate regime. They may have been just coincidental to the timing of the system's evolution into the current regime or they may have reflected the friction associated with the transition towards and the familiarization with a new exchange rate system. There is, however, a presumption that ask-bid spreads, which are components of the cost of transactions, are higher during periods of uncertainty. Volatility of price series may imply that price changes contain new information. Dealers, wishing to protect themselves against the superior information that may be possessed by several traders, will quote a wider ask-bid spread and thereby raise the cost of transactions. Indeed, evidence on the early float indicates the close link between the extent of uncertainty and the ask-bid spread.[10] In addition, if transaction costs include fixed components, the average cost of transaction is inversely related to the size of transactions. To the extent that the rise in uncertainty reduced the average size of transactions, it may have contributed to the higher cost.

The second class of transactions required for covered interest arbitrage involve the security markets. We adopt Demsetz's (1968) estimate

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[10] Using daily observations on the ask-bid spread for various currencies during the early float in 1971, Fieleke (1975) found a close link between the spread and some proxies for the extent of uncertainty. Our approach to the estimation of the cost of transactions in the market for foreign exchange differs in that we do not interpret the size of the daily deviation from triangular arbitrage as the daily cost. Rather we prefer to provide an estimate for a longer period that is more or less homogenous. We do observe, however, a close relationship between our estimates and the estimates derived from the ask-bid spread. Lack of data of the various currencies for the whole of the three periods prevented a complete comparison of the two approaches. Further evidence of the pattern displayed by the ask-bid spread are provided in Aliber (1975), McKinnon (1976) and McCormick (1976). An interesting theoretical analysis on the relationship between uncertainty and the ask-bid spread is contained in Allen (1975).

according to which total costs are about 2.5 times the ask-bid spread. Since the ask-bid spread corresponds to the cost of two transactions (a round trip), our estimate of the cost of a single transaction is 1.25 times the ask-bid spread.

In the next section we explore the role of transaction costs on the efficacy of covered interest arbitrage among various groups of securities. One group comprises traditional pairs of securities: the U.S.-U.K. treasury bills and the U.S.-Canadian treasury bills. The second group comprises external pairs of securities, e.g., securities that are issued in the Euro-market.[11] Since we did not have a uniform source of information on the spreads in the Euro-currency markets for the period as a whole, we report estimates only for the latter two sub-periods. The modal values of these costs for the various sub-periods are reported in Table 2. As can be seen from Table 2 the cost of transactions in the U.S. treasury bills increased over the period under examination while the cost in the Euro-dollar market remained stable as between the last two sub-periods. The cost in the thinnest market--the Euro-sterling market--exceeded the corresponding cost in the other markets and rose during the managed float period.

III. Interest Arbitrage and Transaction Costs: Empirical Aspects

In this section, we use the formulae developed in Section I together with the estimates of the cost of transactions to examine their quantitative impact on the operation of covered interest arbitrage. Of special interest is the comparison of the efficacy of covered interest

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[11]Aliber (1973) has argued that the traditional pair does not always satisfy the comparability criterion since treasury bills are issued in financial centers that may differ in political risks. In that respect the Euro-market securities are more comparable since both are issued in an external center.

TABLE 2

ESTIMATES OF THE PERCENTAGE COST OF TRANSACTIONS
IN THE MARKETS FOR 90-DAY SECURITIES

Period	U.S. Treasury Bills--t	Euro $ rate t (external)	Euro £ rate t* (external)
Jan. 1962-Nov. 1967	0.0095	N.A.	N.A.
Jan. 1968-Dec. 1969	0.0132	0.0381	0.1172
July 1973-May 1975	0.0299	0.0381	0.1175

arbitrage--when allowance is made for the cost of transactions--in exploiting profit opportunities during the specified periods. Prior to that examination, a preliminary note on transformation of data in the presence of transaction costs is pertinent.

III.1. Transformation of Data and Transaction Costs

Virtually all studies of covered interest arbitrage that we are familiar with have examined arbitrage of short term securities--typically 90-day securities--but have expressed the rates of interest and the forward premium on foreign exchange on an annual basis. Similarly, published sources of data report their annualized values. The process of annualizing rates of return on 90-day contracts amounts basically to quadrupling the 90-day magnitudes. This procedure introduces noise to the data since there is no presumption that the premium on a one year forward contract for foreign exchange should be four times the premium on a 90-day forward contract. By the same token, the structure of the various yield curves may be such that interest rate differentials on one-year securities are not exactly equal to four times the corresponding differential on 90-day securities.

More fundamentally, in dealing with annualized data of instruments that are of 90-day maturity, the implicit assumption that is being made is that the proceeds of the 90-day loan are reinvested three more times at the same rate of return. In the presence of transaction costs this implies that one has to take account of four transactions rather than only one. It is clear that the method of annualizing the data increases all deviations four fold. Thereby, if the financial instruments are 90-day securities, this creates illusory profit margins. Similarly, if the data collector were to choose to decadize rather than annualize the 90-day data, the profit margins would have been multiplied by forty. Since our estimates of the costs are specific to the 90-day maturity contracts, it is important to associate them to contracts of this length only. Applying these estimates to the annualized data raises the important question of the relationship between the cost of transactions and the maturity of the arbitraged assets. Some preliminary evidence on the term structure of the cost of transactions suggest that the cost tends to rise with the length of the contract (while it tends to decline with the width of the market) but we have not yet analyzed the exact relationship between the cost and the term to maturity.

The basic model of the covered interest arbitrage is a one-period model; it is clear, therefore, that the introduction of annualized data for contracts of maturities differing from one year may, in the presence of transaction costs, introduce confusion and leave the impression of illusory profit opportunities.[12] Consequently, to conform to the 90-day, one-period model, we have transformed the annualized data back into their 90-day counterparts by dividing the published premia and interest rates by four. The following empirical analysis of covered interest arbitrage is based on the transformed data.

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[12] It is interesting to note that similar issues were dealt with (more than a century ago) by Viscount Goschen in The Theory of the Foreign Exchanges in his attempt to reconcile what seemed to be unexploited profit opportunities:

> "[I]t may well be inquired--How is it possible that . . . such a difference in the rates of interest can exist between two countries . . . This is a mystery which has puzzled many during periods . . . It is a question, however, which can be solved with the greatest ease . . . It must not be forgotten that--the interest being taken at a percentage calculated per annum, and the probable profit having, when an operation in three-month bills is contemplated, to be divided by four, whereas, the percentage of expense has to be wholly borne by the one transaction --a very slight expense becomes a great impediment. If the cost is only 1/2 percent, there must be a profit of 2 percent per annum in the rate of interest, or 1/2 percent on three months, before any advantage commences" (Goschen 1864, pp. 139-43).

III.2. Deviations from Parity: Tranquil versus Turbulent Periods

We turn now to examine, for the various periods, the role of the cost of transactions in accounting for deviations from the interest parity condition. The traditional pairs are analyzed by examining weekly data on arbitrage of 90-day U.S. and U.K. treasury bills as well as between the 90-day U.S. and Canadian bills. The external pair is analyzed by examining weekly data on arbitrage between 90-day Euro-dollar and Euro-sterling securities.

The neutral band around the interest parity line was computed by using the various estimates of the cost of transactions in foreign exchange --t_s and t_f--and the modal estimates of the cost of transactions in securities--t and t^*.

The fraction of the observations bound within the neutral band generated by the cost of transactions during the various periods is reported in Table 3. The computations were made for the traditional as well as the external pairs of securities using the alternative estimates of the cost from Tables 1 and 2. In computing the neutral band, arbitragers were assumed to start from two alternative initial positions. First, where the initial position is in securities so that the cost corresponds to Ω, and second, where the initial position is in cash so that the cost corresponds to Ω_1 and Ω_2; the latter case is reported in Table 3 under the column headed by Ω'. Due to lack of data on external Canadian interest rates, a similar analysis could not be applied to arbitrage between U.S. and Canadian yields in the external market.

Table 3 reveals that the cost of transactions played a very similar and significant role during the tranquil peg (1962-67) and the managed float (1973-75) periods. In both of these periods the cost of transactions

TABLE 3

TRANSACTION COSTS AND NEUTRAL BAND FOR
90-DAY COVERED ARBITRAGE

Period	Arbitrage Between Securities Denominated in	t_s and t_f Estimated as	Observations Bounded within Neutral Band (%)			
			Traditional Pair		External Pair	
			Ω	Ω'	Ω	Ω'
Jan. 1962– Nov. 1967	\$U.S. and £	DM	87.0	82.4	99.7	99.3
	\$U.S. and £	\$C	87.0	82.1	99.7	99.3
	\$U.S. and \$C	\$C	87.6	82.1	N.A.	N.A.
Jan. 1968– Dec. 1969	\$U.S. and £	DM	36.9	35.0	97.1	87.4
	\$U.S. and £	\$C	33.0	30.1	94.2	69.9
	\$U.S. and \$C	\$C	67.0	63.1	N.A.	N.A.
July 1973 May 1975	\$U.S. and £	DM	89.7	87.6	100.0	99.0
	\$U.S. and £	\$C	84.5	81.4	99.0	99.0
	\$U.S. and \$C	\$C	100.0	99.0	100.0	100.0

accounted for a similar fraction of the apparent profit opportunities implied by deviations from the interest parity condition. This result is striking in view of the vast differences in the estimates of the cost of transactions during these two periods. Within each of these periods the proportion of the deviations from the U.S.-U.K. parity line explained by the cost of transactions is similar to the proportion of the deviations from the U.S.-Canada parity line explained by these costs. Thus, during these two periods the role played by transaction costs in accounting for deviations from the interest parity line was almost invariant with respect to the arbitraged assets. The observation that similar fractions of the deviations from parity are explained by the cost of transactions leads to a conclusion that in spite of the large differences in the estimates of the cost, there has been no fundamental structural change concerning the relative role of the cost of transactions. This result is of some interest in view of the basic changes that took place in the international financial system as well as in the exchange rate regime between 1962-1967 and 1973-1975.

The intermediate period of the turbulent peg during 1968-69 seems to differ fundamentally. During that period the cost of transactions accounts for a much smaller proportion of the deviations from the parity. Moreover, the fraction of the deviations that is explained by transaction costs differs between the pairs of the arbitraged assets. However, when we consider the deviations from parity of a different pair of securities--the external pair--almost all of the deviations are accounted for. It thus seems that unlike the periods 1962-67 and 1973-75, the traditional pairs of securities were not comparable during the period 1968-69. The turbulent period of 1968-69 was characterized by financial uncertainty, a reduced cooperation among Central Banks, and related phenomena which comprise the concept of "political risk."[13] Much of these elements of incomparability are removed when the arbitrage is within the Euro-currency market. What remains to be seen, however, is whether the observed deviations from parity (after allowance for transaction costs) imply some sort of market imperfections in the sense of unexploited profit opportunities; this issue is analyzed in the following section.

The comparison of the various periods also suggests that for the study of covered interest arbitrage, periods should be classified by the extent of turbulence, speculative pressures and the like rather than by the legal arrangement of the exchange rate regime (e.g., pegged or flexible exchange rate systems). We will return to examine this implication in Section V.

IV. Unexploited Profits and a Simple Trading Rule

The previous analysis suggests that a significant fraction of the deviations from parity is accounted for by allowing for cost of transactions. Since the remaining observations (most abundant during the period 1968-69) indicate the possibility of unexploited profit opportunities, a closer examination of this phenomenon might be useful.

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[13] Viewing the period 1968-69 as a turbulent speculative period suggests that, on theoretical grounds, the exact parity condition need not hold even when due account is given to the cost of transactions (Tsiang 1959, and Kenen 1965). In addition to the cost of transactions the width of the neutral band around the interest parity line depends on the size of the elasticities of the demand and supply in the capital markets and in the foreign exchange markets. The lower the elasticities, the wider becomes the neutral band. In Frenkel and Levich (1975) we have developed the formulae which take account of the possibility that the various elasticities are finite. Applying these formulae to the various periods revealed that, given the cost of transactions, the implied elasticities were very high (reaching at least the value of one hundred) even during the period 1968-69.

The concept of unexploited profit opportunities should be understood in an _ex-ante_ sense. The notion that the operation of an efficient market eliminates unexploited profits does not imply that _ex-post_ one could not identify situations in which profits could be found. Rather, it implies that ex-ante, in the expected value sense, investors behave--subject to the information they possess--so as to eliminate all profit opportunities. Investors may, of course, be wrong by either undertaking investments that prove to carry losses or by neglecting opportunities that prove profitable. An efficient market ensures that such mistakes do not occur systematically. Therefore, in analyzing ex-post data, one needs to verify that (i) the reported prices correspond to actual transaction prices, and (ii) the information conveyed ex-post was available ex-ante.

The first point pertains to aspects of data collection and reporting. Typically, the data that is being reported (e.g., by the _Federal Reserve Bulletin_), is already "consensus data," i.e., the data collector, having various sources, uses a sampling and averaging technique in reporting forward premia and rates of interest. It cannot be inferred that investors actually transacted and therefore made profits at these reported prices. Moreover, a further misspecification is frequently introduced by using midpoint quotation rather than the ask or bid quotations which correspond closer to actual transaction prices.

The second point relates to the timing of transactions and to the stock of information available at each point in time. To the extent that the technology of information gathering and processing introduces a lag between the receipt of information signaling arbitrage profit opportunities and the actual execution of the arbitrage transactions, prices might change to bid away profits. Ex-post computations showing that on some dates there were some profit opportunities do not necessarily imply that an investor could have designed an ex-ante trading rule which would then yield sure profits. The adjective "sure" in the previous sentence is stressed since in the presence of a lag, prices may change so as to introduce a discrepancy between quoted prices and actual transaction prices; under these circumstances covered interest arbitrage is not risk free but rather contains an element of speculation.

To explore the consequences of a possible lag, we have examined the implications of an extremely simple trading rule: investors receive information at period t and whenever there is a possibility of a profit opportunity (after allowing for transactions cost), a transaction is executed at period t+1 (at the prices prevailing at t+1). Table 4 summarizes the implications of such a simple trading rule for the alternative measures of the cost of transactions and for the alternative assumptions concerning the initial positions of arbitragers. If investors were able to transact in quoted prices at period t, there would be N profit opportunities. The implied mean percentage profit is indicated in the corresponding entry with a t-statistic in parentheses below the mean. For example, during the tranquil period 1962-67 the mean percentage profit would have been about 0.05 percent while during 1973-75 it would have been about 0.3 percent. However, when actual transactions are executed at period t+1, some of the profit opportunities turn out to be illusory and the mean percentage profits is reduced to about 0.04 percent during 1962-67 and to about 0.1 percent during 1973-75. The turbulent period 1968-69 proves again to be somewhat of an exception. During that period the number of apparent profit opportunities as well as the mean rate of profit are high, and the simple trading rule still leaves relatively high and statistically significant profits. However, as argued before, during that period the traditional pairs of securities do not seem to be comparable and thus, they do not seem to be appropriate for the analysis of covered interest arbitrage. Indeed, when the same computation is applied to the external pair of securities (see the lower panel of Table 4) the positive and significant mean percentage profit that would have been implied if transactions could be executed at t, turn out to entail significant losses under the simple trading rule.[14]

V. A Time Series Approach

One of the themes of discussion in Section III was a comparison among the various periods. The implication of that comparison was that it might be preferable to classify periods according to the degree of turbulence rather than the legal arrangements of the exchange rate regime. In the present section we pursue further the comparison among periods by examining the time series processes of the various exchange rates.[15]

In estimating the time series processes we apply the Box-Jenkins time-series approach. We first differenced the series of the logarithms of the various exchange rates and then estimated the sample autocorrelation functions so as to identify the models, which were then estimated. The maximum likelihood parameter estimates for the spot and the forward exchange rates are reported in Tables 5 and 6. As can be inferred from the Q-statistics,

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[14]While the above results illustrate the relevance of distinguishing between the ex-ante and ex-post concepts of profit opportunities and the possible implications of a simple trading rule, they should be viewed with caution. A conclusive test of the trading rule requires much more refined data than used in the present computation. Ideally, the difference between t and t+1 should correspond to consecutive transactions or at most to daily data. Since the results of Table 4 are based on weekly data, they should be viewed only as illustrative.

[15]A more detailed analysis of the time series models is contained in Levich (1976). For a clear introduction to the applications of the approach see Nelson (1973).

TABLE 4

MEAN PERCENTAGE PROFITS OF A SIMPLE TRADING RULE
(TRADITIONAL PAIR)

Period	Arbitrage between Securities Denominated in	t_s and t_f Estimated as	N		t Mean Profit		t+1 Mean Profit	
			Ω	Ω'	Ω	Ω'	Ω	Ω'
Jan. 1962-Nov. 1967	\$U.S. and £	DM	40	54	0.055 (7.2)	0.058 (8.4)	0.038 (3.7)	0.045 (5.4)
	\$U.S. and £	\$C	40	55	0.056 (7.3)	0.058 (8.4)	0.039 (3.8)	0.044 (5.4)
	\$U.S. and \$C	\$C	38	55	0.058 (7.8)	0.058 (8.7)	0.046 (3.8)	0.041 (4.2)
Jan. 1968-Dec. 1969	\$U.S. and £	DM	65	67	0.577 (9.6)	0.585 (9.8)	0.540 (8.3)	0.550 (8.6)
	\$U.S. and £	\$C	69	72	0.606 (10.2)	0.607 (10.4)	0.572 (9.1)	0.586 (9.4)
	\$U.S. and \$C	\$C	34	38	0.107 (6.8)	0.120 (7.9)	0.086 (4.1)	0.102 (5.2)
July 1973-May 1975	\$U.S. and £	DM	10	12	0.261 (4.3)	0.272 (4.6)	0.076 (0.8)	0.097 (1.1)
	\$U.S. and £	\$C	15	18	0.304 (5.1)	0.306 (5.3)	0.115 (1.2)	0.187 (2.0)
Jan. 1968-Dec. 1969 (External Pair)	\$U.S. and £	DM	3	13	0.310 (4.1)	0.154 (3.2)	-0.319 (6.4)	-0.210 (2.7)
	\$U.S. and £	\$C	6	31	0.193 (2.2)	0.104 (3.9)	-0.357 (3.08)	-0.055 (1.5)

Note: t-statistic in parentheses.

TABLE 5

TIME SERIES MODELS FOR SPOT EXCHANGE IN THREE PERIODS[a]

Time Period	Country	Moving Average Coefficients θ_1	θ_2	θ_3	$10^{-5}\ \hat{\sigma}^2_a$	Q (k)	2 ln λ (r)
1962-67 (N = 306)	England	-.06 (1.0)	-.06 (1.1)	-.11 (1.9)	.021	22.8 (21)	1.46 (3)
	Germany	-.10 (1.6)	-.14 (2.3)	--	.050	17.2 (22)	6.08* (2)
	Canada	-.10 (1.6)	-.17 (3.1)	--	.334	12.4 (22)	9.92* (2)
1968-69 (N = 99)	England	-.10 (0.9)	-.07 (0.7)	+.15 (1.5)	.167	16.2 (21)	1.18 (3)
	Germany	-.10 (0.9)	--	--	3.420	6.9 (23)	-2.05 (1)
	Canada	+.14 (1.4)	-.16 (1.7)	--	.123	12.3 (22)	1.60 (2)
1973-75 (N = 96)	England	-.16 (1.6)	+.10 (1.0)	-.40 (4.1)	7.480	16.3 (21)	10.22* (3)
	Germany	+.10 (1.0)	-.47 (5.5)	+.18 (2.0)	20.500	18.4 (21)	16.32* (3)
	Canada	-.10 (1.0)	-.24 (2.3)	--	.852	18.1 (22)	4.19** (2)

[a]Moving average coefficients in the model

$$W_t = \ln S_t - \ln S_{t-1} = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \theta_3 a_{t-3}$$

with t-statistics in parentheses.

$\hat{\sigma}^2_a$ = residual variance in series

Q = Box-Pierce test statistic for autocorrelation of residuals. Distributed as χ^2 with k degrees of freedom.

2 ln λ = Zellner-Palm test statistic for significance of fitted model against null hypothesis that the series is a random walk. Distributed as χ^2 with r degrees of freedom

* = significant at 5% level

** = significant at 20% level

TABLE 6

TIME SERIES MODELS FOR FORWARD EXCHANGE IN THREE PERIODS[a]

Time Period	Country	Moving Average Coefficients θ_1	θ_2	θ_3	$10^{-5}\ \hat{\sigma}_a^2$	Q (k)	2 ln λ (r)
1962-67 (N = 306)	England	-.08 (1.4)	+.02 (0.4)	-.25 (4.5)	.033	31.3* (21)	12.60* (3)
	Germany	-.13 (2.2)	--	--	.041	20.3 (23)	4.42* (1)
	Canada	-.05 (0.9)	-.16 (2.9)	--	.354	11.0 (22)	6.84* (2)
1968-69 (N = 99)	England	-.05 (0.5)	-.04 (0.4)	-.05 (0.5)	1.900	18.9 (21)	-2.64 (3)
	Germany	-.07 (0.7)	--	--	3.180	14.[illegible] (23)	-2.20 (1)
	Canada	+.07 (0.7)	--	--	1.690	16.2 (23)	-0.59 (1)
1973-75 (N = 96)	England	-.06 (0.6)	+.02 (0.2)	-.37 (3.8)	9.800	19.4 (21)	8.43* (3)
	Germany	+.05 (0.5)	-.40 (4.5)	--	2.230	14.3 (22)	16.38* (2)
	Canada	-.10 (1.0)	-.22 (2.1)	--	.788	18.2 (22)	3.12 (2)

[a] For an explanation see footnotes on Table 5.

the residuals are not serially correlated (except for one case) and thus the transformation reduced the observed data to random noise.[16]

In comparing the general characteristics of the time series properties of spot and forward rates, the first pattern to notice is that in the first and last periods the random walk hypothesis is rejected at the 5 percent level in nine of the twelve series (as is evident from the Zellner-Palm test). On the other hand, during the turbulent peg period (1968-69) we cannot reject the random walk model for any of the six series.[17]

A closer examination reveals further similarities between the tranquil peg and the managed float periods. Consider for example the pound spot rate: both the tranquil peg and the managed float periods contain a significant third moving-average term which is not significant in the turbulent peg period. This phenomenon is even more striking when we compare the estimates for the British pound's forward rates in Table 6: during the tranquil peg the estimates of the moving-average coefficients are (-.08, +.02, -.25) while during the managed float the respective coefficients are (-.06, +.02, -.37) with significant third moving-average terms.[18] The similarity in the

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[16]In fitting the series and deciding whether to add additional terms we have used the Zellner-Palm (1974) likelihood ratio analysis which tests objectively the hypothesis that additional terms reduce the residual variance. The Zellner-Palm test statistic is reported in the last columns of Tables 5 and 6.

[17]Since exchange rates reflect the outcomes of economic policies, there is nothing special in the random walk hypothesis and no inference concerning efficiency may be inferred from rejecting the random walk. Our purpose in this section is more descriptive with the intent of showing that the first and the third periods are similar.

[18]The appearance of what seems to be a three weeks cycle in the British pound has also been recorded by Grubel (1966) and more recently by Upson (1972) who applies a spectral analysis.

sign and magnitude of these coefficients for these two periods stands in contrast with the estimated time series process for the turbulent peg which appears to follow a random walk.

The Canadian exchange rate also provides an example: during the tranquil peg and the managed float periods the second moving-average coefficients are significant for both the spot and the forward rates in contrast with the turbulent peg period for which the exchange rates series may be characterized as random walk. The German-mark case is somewhat weaker although the 1962-67 and 1973-75 periods seem to have more in common with each other than with the 1968-69 period.

To sum up, the evidence from the time-series analysis seem to be consistent with the interpretation that the tranquil peg and the managed float periods are similar to each other while both differ from the turbulent peg period.

VI. Concluding Remarks

In this paper we examined the effects of transaction costs on the efficacy of covered interest arbitrage during three periods: 1962-67--the tranquil peg; 1968-69--the turbulent peg, and 1973-75--the managed float.

Several conclusions emerge; first, the cost of executing transactions associated with covered interest arbitrage has risen dramatically during the managed float period as compared with the previous periods; second, in spite of the vast differences in the estimates of the cost, they played a similar quantitative role in accounting for deviations from parity during the tranquil peg and the managed float periods. The exceptional period was that of the turbulent peg. This pattern is also consistent with evidence provided by the time series characteristics of the various exchange rates. It suggests that for the purpose of analyzing covered interest arbitrage, it might be preferred to classify periods by the degree of turbulence rather than by the legal arrangement of the exchange rate regime.[19] The third conclusion concerns the efficacy of arbitrage in eliminating profit opportunities. The data suggest that--after allowing for transaction costs and ensuring that the arbitraged assets are comparable--covered interest arbitrage does not seem to entail unexploited opportunities for profit.

We turn now to some of the policy implications of the foregoing analysis. The evolution of the system into a new regime of managed float is expected to increase the need for forward cover. The smooth operation of the system requires the development of hedging facilities that could be provided automatically in response to the rise in demand for such services [see Friedman (1953) and Johnson (1969)]. A relevant question, however, is whether the competitive system will provide for the socially optimal amount of these services. To the extent that private and social cost of the provision of these services differ, a case may be made for some governmental intervention. Private and social cost may differ in aspects of collecting, processing, identifying and securing relevant information.

The case for governments actively encouraging the development of forward markets and hedging facilities may be especially relevant for the period of transition towards a well functioning floating rate system. It seems quite obvious that what might have been optimal depth and breadth of the forward markets during the tranquil-peg period would be sub-optimal for a floating rate regime. During the tranquil-peg period exchange rates were

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[19] For a similar classification see Stein (1962).

relatively stable and the expected rate of return from investment in precise forecasting of future exchange rates was relatively low. Under these conditions the demand for hedging services could be met by relatively thin markets. The transition towards a system of floating rates associated with a larger variability of exchange rates increases the expected rate of return from accurate forecasting, and increases the demand for forward cover. The existing facilities, inherited from the pegged rate regime, could not, in the short run, supply the larger amount of services without rising cost. Thus, the sharp rise in cost might reflect short-run adjustment.

Even if perfect competition were to result in the optimal provision of hedging facilities, it is the role of government to secure a legal framework conducive for the operation of such a competitive system. To secure a competitive environment among dealers some legislation may be required concerning the entry into the trade, the role of licensing and enforcement of antitrust laws. The role of government becomes even more important in view of the imperfect competition among dealers outside the U.S. Cartel-like agreements among leading banks are widespread in the various European financial centers. Even Switzerland with its highly developed foreign exchange market tolerates monopolistic practices among the leading banks which cooperate in fixing the margins between buying and selling prices.[20]

In view of the monopolistic practices prevailing in the various financial centers, it is unlikely that, in the absence of some intervention, the market will provide the optimal amount of hedging services. An active role taken by the U.S. government is in the interest of both the international community as well as the U.S. economy. The breadth and depth

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[20]For further evidence on restrictive practices see Machlup (1970).

of the New York capital market makes it a natural place for the development of the world center for futures market.[21] The special role of the dollar in international transactions, the existing legal structure together with financial stability, provide a presumption that the U.S. may possess a comparative advantage in the provision of the services of forward markets. To the extent that monopolistic competition from abroad coupled with uncertainty about the evolution of the international monetary system deter the private sector from providing the optimal amount of hedging facilities, a case can be made for governmental intervention. This case for intervention is analytically similar to the infant industry argument for protection and calls for eliminating the discrepancy between private and social cost. Governmental intervention should provide the information and secure the legal structure that is conducive for the development of a competitive environment capable of providing the socially optimal size and diversity of futures market in foreign currencies.

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[21] For further details of these arguments see Friedman (1971).

APPENDIX ON DATA

I. Foreign Exchange Market

Exchange rates involving the U.S. dollar and used to display the behavior of the series (Figure 1) and to calculate the cost of transactions (Table 1) for the period 1962-1969 are taken from the International Financial Statistics (IFS), International Monetary Fund (IMF), Washington, D.C. These data were collected by the IMF as follows: the \$U.S./£ rates are the closing prices in London as reported in the Financial Times. The \$U.S./\$C rates are the noon-time interbank prices in Toronto as reported by the Bank of Canada and the \$U.S./DM rates are the 11:00 a.m. Official Session Quotation of the Bundesbank in Frankfurt. Data on the latter period used in Figure 1 are from the Weekly Review of International Money Markets, Harris Bank, Chicago, Illinois. These data are the closing bid prices from the New York interbank market for the last trading day of the week. For the purpose of computing transaction costs during 1973-75, data involving the \$U.S. are from the International Monetary Market Year Book, and the Daily Information Bulletin published by the staff of the International Monetary Market (IMM) of the Chicago Mercantile Exchange and are closing mid-points.

The exchange rates involving the U.K. pound sterling (DM/£) and (\$C/£) are from the Montagu Monthly Review, Samuel Montagu and Co., Ltd., London, England. The spot rates are the mid-points of the daily range. The forward rates were obtained by adding the mid-points of the closing forward spreads to the estimates of the spot rates (described above).

Ideally, in computing transaction costs one should allow for the fact that some transactions use the ask-price while some use the bid-price. Our use of the mid-points may introduce some noise but need not introduce a systematic bias. Similarly, the various exchange rates should be quotations at the same moment in time; since our data sources report prices that are few hours apart, an additional source of noise is introduced. To allow for these inaccuracies, we have used conservative measures which bound 95 percent of the deviations from triangular arbitrage.

II. Security Market

All three-month treasury bill rates used in the analysis of the interest parity for the traditional pairs of securities for the period 1962-1969 are taken from the Federal Reserve Bulletin, various issues. In fact, since the Federal Reserve Bulletin reports the latest three-month rate, some of the rates used are for bills that are slightly less than three months by two or three days. For the period 1973-75 the data source was the Weekly Review of International Money Markets, Harris Bank, Chicago, Ill.

The external rates used for the period 1962-1969 are Euro-sterling deposits in Paris and Euro-dollar deposits in London: both are three-month middle closing rates taken from the Bank of England Quarterly Bulletin, various issues. For the period 1973-1975 these rates are three-month deposits in Frankfurt taken from the Money Manager (New York).

The computation of the cost of transactions in securities (Table 2) are based on the percentage ask-bid spread. The bid price and the ask price (expressed as a percentage of par) were computed according to (i) bid price = 100 - (bid yield x days to maturity)/360, (ii) ask price = 100 - (ask yield x days to maturity)/360 and the percentage spread is (ask price-bid price)/ask price. The data on the bid yield and ask yield on U.S. treasury bills for the period 1962-1969 are from Solomon Brothers Monthly Bond Report, while for the later period they are from the Money Manager. Since 90-day treasury bills are not issued on every day, for each observation date, we have computed the ask-bid spread on the treasury bill whose maturity was closest to 90 days. The range of maturities accepted was between 87 and 93 days. The ask-bid spread on the external deposits for the period 1973-1975 were taken from the Money Manager, and for the period 1968-69 from the Bond Buyer (which in 1972 changed its name to the Money Manager).

In the absence of information on ask-bid spreads on the U.K. and the Canadian treasury bills, we have assumed that those are equal to the spread on the U.S. bills and thus that, for the traditional pairs of securities, $t=t^*$. Since transaction costs are expected to be inversely related to the width of the market, the assumption that $t=t^*$ might have introduced a downwards bias in the estimate of the cost. As indicated in the discussion of Table 2, we had no estimates, for the period 1962-67, of the cost of transactions in Euro-dollar and Euro-sterling deposits. In Tables 3-4 for that period we have used instead the cost of transactions in the 90-day U.S. treasury bills. For the reason indicated above, this might have resulted in a conservative estimate of the cost of transactions in the external market for the early sub-period.

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