Economic Review

Federal Reserve Bank of San Francisco

1994 Number 3

Adrian W. Throop — International Financial Market Integration and Linkages of National Interest Rates

Kenneth Kasa — Finite Horizons and the Twin Deficits

Michael P. Dooley and Kenneth M. Kletzer — Capital Flight, External Debt, and Domestic Policies

International Financial Market Integration and Linkages of National Interest Rates

Adrian W. Throop

Research Officer, Federal Reserve Bank of San Francisco.
The author wishes to acknowledge the able research assistance of Ranjana Gandhi and the helpful comments of the editorial committee consisting of Timothy Cogley, Ramon Moreno, and Brian Motley.

This article finds that even in the 1980s, when barriers to international capital mobility had been largely eliminated, there was no measurable tendency for real interest rates between the U.S. and the major industrial countries to converge. Moreover, the estimated short-run responses of both short-term and long-term real interest rates to one another have been exceedingly weak. As a consequence, it appears that U.S. and foreign central banks have been able to influence their domestic interest rates quite independently from the influence of interest rates abroad, despite a high degree of international capital mobility.

The international integration of financial markets has increased dramatically in the last two decades. In the 1970s government-imposed barriers to the international flow of capital in the major industrialized countries were gradually relaxed, and by the 1980s they had been substantially eliminated.[1] Moreover, the development and growth of new financial instruments, such as currency and interest rate swaps, have further stimulated international financial integration by giving investors a wider range of choices than traditionally available in purely domestic financial markets.

It might be presumed that the international integration of financial markets would reduce divergences between interest rates at home and abroad and increase the degree to which yields in different national markets move together over time. If so, the ability of central banks to influence national interest rates might be importantly constrained by international flows of capital. This presumption would appear to be supported historically by the domestic integration of local financial markets. For example, the development of national money and capital markets in the United States during the latter part of the 19th century reduced regional disparities among interest rates and made these rates increasingly responsive to national as opposed to local conditions. Moreover, after the establishment of the Federal Reserve System in 1914, it became apparent that, because of the ease of capital flows between different regions, monetary policy needed to be made on a national, rather than a regional, basis.

International financial integration need not always work to equalize interest rates between different countries, however. If exchange rates between currencies are fixed, then international financial integration has much the same effect on interest rates as regional financial integration. But if exchange rates are flexible, exchange rate expectations and exchange rate risk may prevent a convergence of real interest rates. As barriers to financial flows across national borders were reduced in the 1970s, the system of exchange rates applying to the major currencies changed from one of fixed to flexible rates. In fact, the flexibility of rates probably contributed to reductions in barriers to financial flows by reducing the need for capital controls to manage payments imbalances. As a result, at the same time that one

1. See, for example, Akhtar and Weiller (1987).

source of interest rate divergence was reduced, another one increased. Earlier empirical studies have provided mixed evidence on whether real interest rates have tended to converge in recent years.[2]

This article uses cointegration tests and error-correction modeling to examine the issue. It first reviews the theoretical literature on the short- and long-run connections between the international mobility of capital and the equalization of national interest rates. It then explains how exchange rate expectations and exchange rate risk in a system of flexible exchange rates can create divergences between real interest rates even in the absence of institutional or governmental barriers to capital flows across national borders. Finally, it examines empirically the linkages between U.S. and foreign real interest rates.

It finds that even in the 1980s, when barriers to international capital mobility had been largely eliminated, there was no measurable tendency for real interest rates between the U.S. and the major industrial countries to converge. Moreover, the estimated short-run responses of both short-term and long-term real interest rates to one another have been exceedingly weak. As a consequence, it appears that U.S. and foreign central banks have been able to influence their domestic interest rates quite independently from the influence of interest rates abroad, despite a high degree of international capital mobility.

I. INTEREST RATE DIFFERENTIALS IN THE SHORT AND LONG RUN

This section reviews the analytics of international interest rate linkages in the short and the long run under flexible exchange rates. The sources of differences between nominal interest rates at home and abroad can be summarized by the following identity:

$$(1) \quad i - i^* = 1/n \,\%s^e + CRISK + DOM + BAR$$

i and i^* are, respectively, nominal interest rates in home and foreign currency denominated assets of a given maturity (n); The variable $\% s^e$ is the expected percentage depreciation in the value of the home currency over the maturity of the investment; *CRISK* constitutes the part of the differential due to the uncertainty in returns from investing in a foreign asset due to the risk of changes in the exchange rate over the period of the investment; *DOM* is the portion of the differential that is due to differences in the characteristics of the assets besides maturity, such as liquidity, credit risk, or tax treatment, which can occur in purely domestic markets; finally, *BAR* represents the part of the differential that is due to government policies and institutional imperfections that effectively impede financial flows across national jurisdictions.[3]

Nominal interest rates are equalized if all the right-hand-side terms of the identity are equal to zero. If *CRISK*, *DOM*, and *BAR* are all equal to zero, then U.S. and foreign assets can be said to be perfect substitutes. In this case, investors are indifferent between domestic and foreign assets, and their expected yields in a common currency are equalized. In addition, if portfolio adjustments are instantaneous, so that the yields in a common currency are equalized continuously, then there is said to be perfect capital mobility. Finally, if $\%s^e$ is zero, then expectations are static in the sense that the exchange rate expected in the future is the same as the current exchange rate. Only if all these conditions are met, giving perfect capital mobility and static exchange rate expectations, will nominal interest rates be equalized continuously at home and abroad under flexible exchange rates.

The well-known Mundell-Fleming model of an open economy assumes that the conditions of perfect capital mobility and static exchange rate expectations hold in the short run under flexible exchange rates.[4] The implications of these conditions would be that monetary policy influences aggregate demand entirely through its effect on the exchange rate, rather than interest rates, and that fiscal policy "crowds out" other expenditures entirely through the exchange rate instead of interest rates. These implications are clearly at variance with even the most casual observation. In the U.S. and other industrialized countries, actions by monetary authorities clearly can alter interest rates in the short run, and fiscal policy appears to have influenced interest rates as well. Therefore, to better understand the behavior of interest rates in the short run, the Mundell-Fleming framework needs to be amended.

The Mundell-Fleming model essentially extends the widely used IS-LM model of income determination to an open economy. Both models assume the price level is fixed in the short run. The Mundell-Fleming model is described by the following set of equations:

2. Pigott (1993-1994) presents evidence to show that the dispersion in national real interest rates has fluctuated considerably over time but without any systematic tendency to decline. Despite this evidence, some observers have argued that integration has increased the synchronization of interest rate movements over the last decade; see, for example, Frankel (1989) and Bank for International Settlements (1988). However, Kasman and Pigott (1988) find no consistent increase in this tendency using different but equally plausible measures of synchronization.

3. For further discussion of the various factors underlying this identity, see Kasman and Pigott (1988).

4. The Mundell-Fleming model was developed in the early 1960s. Mundell's contributions are collected in Mundell (1968). For Fleming's contribution, see Fleming (1962).

(2) $$Y = A(i) + NX(s)$$

(3) $$M/P = L(i,Y)$$

(4) $$i = i^*$$

The first equation describes equilibrium in the goods market. It states that real aggregate output (Y) is equal to real domestic expenditures (A), which vary inversely with the nominal interest rate i, plus net exports, which vary inversely with the value of the home currency. The second equation gives equilibrium in the money market. The supply of real money balances, M/P, equals the demand for them, $L(i,Y)$. The last equation describes the conditions of perfect capital mobility and static expectations for a small country, which produce an equality between the home (i) and an exogenously determined foreign (i^*) interest rate.

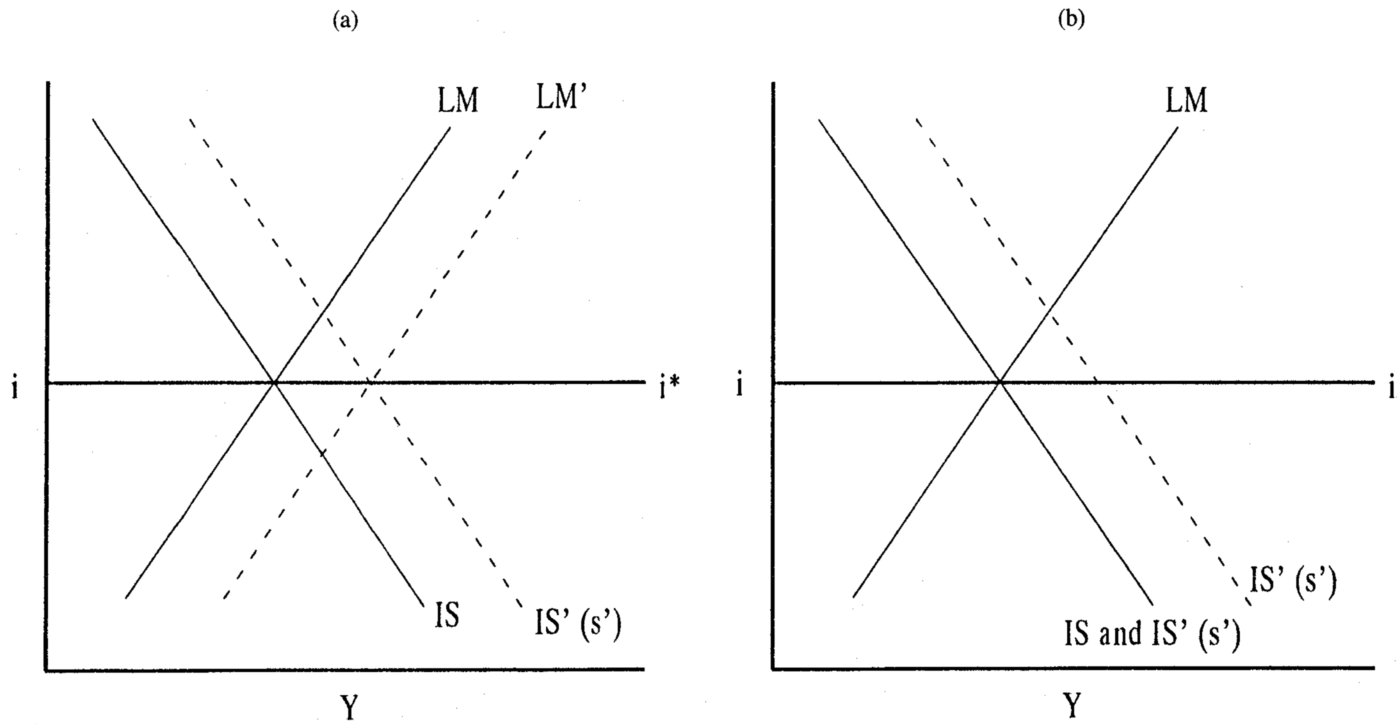
Figure 1 illustrates the behavior of interest rates in the short run in the Mundell-Fleming model with static expectations and perfect capital mobility. In Figure 1a, a shift to the right in the LM schedule because of, say, an action by the monetary authority to expand the money supply initially tends to depress the interest rate at home. But because the expected return on investing at home then would be less than that from investing abroad, the value of the home currency is depressed by capital outflows. Then as soon as the trade balance adjusts to the lower value of the home currency, the IS schedule shifts to the right until the home interest rate is pulled back up to the level of the foreign rate. In this process, there is no net change in the home interest rate. As a result, monetary policy influences aggregate demand entirely through its effect on the exchange rate.

Alternatively, a shift in the IS schedule to the right as in Figure 1b because of, say, an expansionary fiscal policy initially pushes the home interest rate above the foreign interest rate. But the resulting capital inflow then moves up the value of the home currency and reduces net exports until the home interest rate falls back down to the level of the foreign rate. In the process, the fiscal expansion "crowds out" other expenditures entirely through its effect on the exchange rate.

The Mundell-Fleming model assumes a small country. But relaxing this assumption does not change its conclusions with respect to the differential between interest rates.

FIGURE 1

MUNDELL-FLEMING MODEL



This would still tend to zero except for the period during which the trade balance adjusts. However, in practice, the period required for the trade balance to adjust lasts for up to around two years, so that in calendar time the period over which one can say that perfect capital mobility may exist is not trivial.[5] Because of this, the Mundell-Fleming model has limited applicability for periods shorter than two years.

A further important limitation of the Mundell-Fleming model for the short run is its assumption of static expectations. Still retaining the assumption of perfect capital mobility for the relevant time frame, when expectations are not static the identity of equation (1) becomes:

(5) $$i - i^* = 1/n \; \%s^e$$

or

(6) $$\ln s = E(\ln s) + n(i - i^*)$$

where $E(\ln s)$ is the expected value of the natural log of the exchange rate. Furthermore, if $E(\ln s)$ and i^* are fixed, then the value of the home currency, s, becomes simply a function of the home interest rate. This situation is shown in Figure 2, where both i and s are now plotted on the vertical axes. The IS schedule is flatter than before because movement along it now includes the effects on aggregate demand of movements in both the exchange rate and the interest rate, rather than just the interest rate alone.

Consider now the effects of monetary and fiscal policy manifested in shifts in the LM and IS schedules. An expansionary monetary policy that shifts the LM schedule to the right (as in Figure 2a) now drives down the home interest rate even after there has been time enough for the trade balance to adjust to the lower value of the home currency. The differential that is opened up between the home and foreign interest rate is proportional to the expected appreciation of the home currency and would not change as long as the current price level, the expected exchange rate, and the expanded money supply persist. If the economy initially had been at full employment, in the long run the adjustment of the price level and expectations would eventually drive the system back to its original equilibrium with the same IS and LM schedules as before. Even with forward looking rational expectations, however, a differential between real interest rates would persist during the gradual adjustment of the price level until the full employment equilibrium is restored.[6] As a result, monetary disturbances can create persistent and time-varying differentials in real interest rates even with perfect capital mobility while this longer-run adjustment takes place.

5. For evidence on the speed of adjustment of the trade balance, see, for example, Throop (1989).

6. See Dornbusch (1976).

A fiscal expansion similarly causes persistent effects on interest rate differentials when expectations are not static. Lower taxes and/or higher government expenditures shift the IS schedule to the right (as in Figure 2b). Now, rather than just the exchange rate changing, as in the pure Mundell-Fleming model, both the interest rate and the exchange rate are driven up. With the expected value of the exchange rate fixed, a gap is opened up between the home and foreign interest rate that is proportional to the expected depreciation in the value of the home currency. This gap and both the higher interest rate and increase in real output will last as long as fiscal policy remains expansive and the expected exchange rate is unchanged.

As long as the fiscal policy remains expansive, however, the actual exchange rate will be above that which was expected. Then, expectations of the exchange rate may be revised up. If so, the current exchange rate would rise with any given interest rate differential, breaking the original linkage between the interest rate and the exchange rate. The rise in the expected value of the home currency would then shift the IS schedule back toward its original position. It is only at this point that the differential between home and foreign interest rates would be eliminated. This analysis generalizes to any shift in the IS schedule, not just those caused by fiscal policy. Thus, interest differentials could exist more or less continuously and vary considerably under flexible exchange rates due to a variable IS function, as well as a variable LM function, even with relatively perfect capital mobility.

Further relaxing the assumptions of the Mundell-Fleming model, consider now the case of imperfect substitutability between home and foreign assets due to currency risk (*CRISK*), differences in the characteristics of home and foreign assets (*DOM*), or governmental and institutional barriers to international capital flows (*BAR*). These put interest rates in the home country at a premium or discount compared with foreign rates. For simplicity, suppose initially there is no differential between interest rates at home and abroad. A rightward shift in the IS schedule to IS′(s), caused by a fiscal deficit or an investment boom, would put upward pressure on the home interest rate relative to that abroad (Figure 3). With imperfect substitutability of assets, however, the resulting inflow of capital from abroad would tend to raise the required return on U.S. assets relative to foreign assets. The premium would be required in order for investors to absorb a larger proportion of home assets into their portfolios, since the stock of home relative to foreign assets is increased by both the larger capital inflow and the appreciation of the home currency. Instead of being shifted back to IS′(s), the IS schedule would shift back only to IS′(s') due to the appreciation of the home currency. At this point the home interest rate would be

FIGURE 2

NONSTATIC EXPECTATIONS

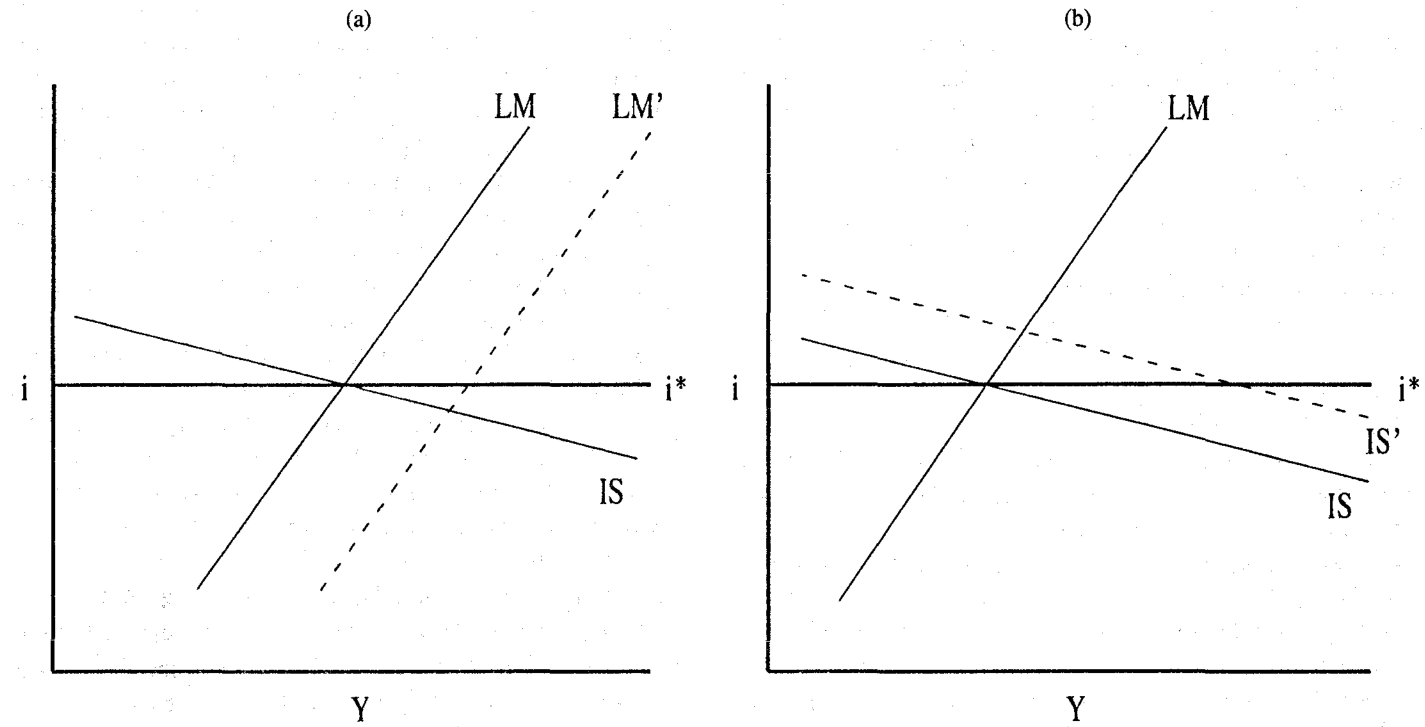
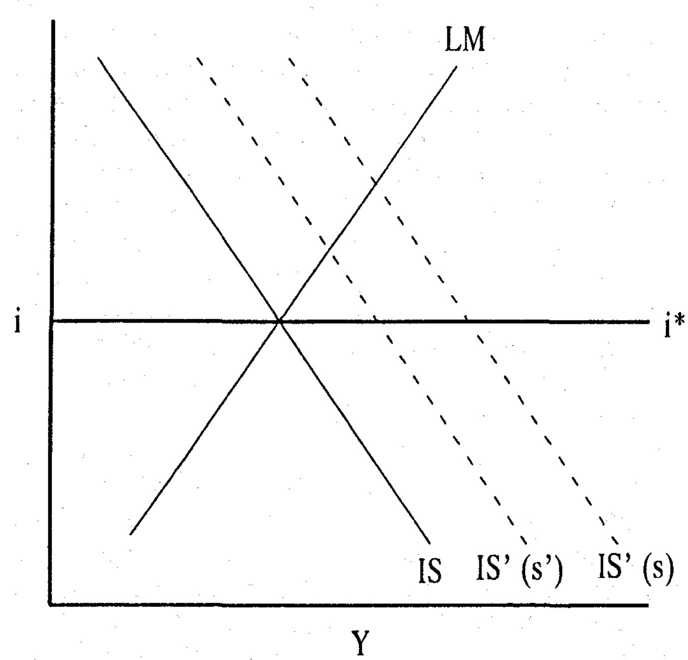


FIGURE 3

IMPERFECT SUBSTITUTES



brought down to the level of the foreign interest rate plus a premium. Here again, the differential between interest rates would vary over time.

Even with a high degree of international financial market integration so that *DOM* and *BAR* are close to zero, imperfect substitutability can still be created by currency risk (*CRISK*). As a result, even with highly integrated markets under flexible exchange rates, home and foreign interest rates may be kept apart not only by expected changes in currency values but also by currency risk.

Finally, and particularly for purposes of empirical implementation, it is necessary to relax the assumption of constant prices in the Mundell-Fleming model. The identity of equation (1) still holds. But it is convenient to rewrite it in real terms as[7]

$$(7)\quad r - r^{*} = 1/n\ \%q^{e} + CRISK + DOM + BAR,$$

7. The identity of equation (1) can be written as:

$$i_t - i_t^{*} = 1/n\,[\ln s_t - E_t(\ln s_{t+n})] + CRISK_t + DOM_t + BAR_t.$$

By definition $\ln s_t = \ln q_t + \ln p_t^{*} - \ln p_t$, where q is the real exchange rate and p^{*} and p are foreign and domestic price levels, respectively. Also by definition,

$$E_t(\ln s_{t+n}) = E_t(\ln q_{t+n}) + \ln p_t^{*} + n\pi_t^{*} - p_t - n\pi_t,$$

where r and r^* are *real* interest rates (nominal interest rates less expected inflation) at home and abroad, $\%q^e$ is the expected percent change in the *real* exchange rate over the maturity of the investment, and the other terms are the same as before.[8] In the case of perfect substitutability and static expectations (with respect to the real exchange rate), capital would flow from one country to another until real interest rates at home and abroad were equalized. In the case of imperfect substitutability, the real interest at home would tend to be equated with the foreign one plus a premium or minus a discount, which itself could vary over time. But with nonstatic expectations, the real exchange rate becomes a function of the real interest rate at home relative to that abroad. Movements of the IS and LM schedules create a variable differential in real interest rates (plus a premium or minus a discount) that is proportional to the expected change in the real value of the exchange rate as it moves towards its equilibrium in the long run.

II. REAL INTEREST RATE RELATIONSHIPS

A trend toward the liberalization of capital controls has been clearly evident since the early 1970s, and in recent years it has become even more pronounced.[9] In fact, by the 1980s both official and institutional barriers to international capital flows had been largely eliminated in the major industrialized countries, at least for large borrowers and lenders. At the short end of the market, this is indicated by a close equality between U.S. and major foreign interest rates when the latter are covered against exchange rate risk in the forward market.[10]

Forward markets are most developed at the 3-month maturity and do not exist at maturities greater than two years, even among well-traded currencies. But in the 1980s the currency swap market became sufficiently developed to hedge exchange rate risk for long-term investments as well. A currency swap is an agreement to exchange a stream of payments in one currency for a stream of payments in another. Like a forward contract, a currency swap allows a domestic investor to hold a foreign currency denominated asset without currency risk. Deviations from a covered parity in interest rates appear to be somewhat larger among long-term assets than among short-term assets, but for the major currencies the differences are small. Moreover, current deviations from covered parity of both short- and long-term interest rates are small compared with periods when capital controls have been considered important. Thus, the increase in international financial capital mobility of the last decade has not been limited to the markets for short-term assets.[11]

With official and insitutional barriers to international capital flows largely eliminated, this leaves only currency risk and expected changes in currency values as sources of differences between real interest rates on similar assets. Figure 4 shows ex ante real U.S. and trade-weighted foreign 3-month money market rates and the differential between them, as well as the corresponding rates and differentials with Canada, Japan, Germany, and the U.K. for the period 1981 to the present. Figure 5 plots the real rates and differentials for the same countries with respect to long-term government bonds. Expected inflation is measured by the percent change in the CPI over the previous year for short rates and by a centered 3-year moving average of CPI inflation for long rates. As other researchers have shown, a contemporaneous equality of ex ante real interest rates, whether short-term or long-term, is easily rejected.[12] Even during the period of relatively high capital mobility in the 1980s, substantial differentials in both short and long real rates existed for significant periods of time. This result is consistent with a Mundell-Fleming model in which exchange rate expectations are not static, so that movements in the IS and LM schedules create variable real interest rate differentials that are proportional to the expected change in the currency towards its equilibrium real value in the long run. Variable premia for currency risk also could produce this result.

The more interesting and also more difficult question to answer is whether shocks to the IS and LM schedules are infrequent and transitory enough, and variations in currency risk premiums small enough, that a tendency towards a convergence of real interest rates can be observed over the longer run. Evidence suggesting that this may *not* be the case is that real interest rate differentials have been shown to be an important force moving real

---

where π_t^* and π_t are the market's expectations at time t of the inflation rate over n periods at home and abroad, respectively. Substituting these two relationships into the identity gives:

$$(i_t - \pi_t) - (i_t^* - \pi_t^*) = 1/n\,[\ln q_t - E\,(\ln q_{t+n})] + CRISK + DOM + BAR.$$

8. The real value of the home currency, s, is defined as: $q = s(p/p^*)$, where p and p^* are the home and foreign price levels, respectively.

9. This trend is documented in International Monetary Fund's annual report on *Exchange Arrangements and Exchange Restrictions.*

10. For the evidence on covered returns on short-term assets, see Pigott (1993-1994), Caramazza et al. (1986), and Frankel (1988).

11. Evidence on the covered returns on long-term assets is provided by Popper (1990).

12. See, for example, Cumby and Obstfeld (1984), Mishkin (1984), Merrick and Saunders (1986), and Gaab, Granziol, and Horner (1986).

FIGURE 4

U.S. AND FOREIGN SHORT-TERM REAL INTEREST RATES AND THEIR DIFFERENTIALS

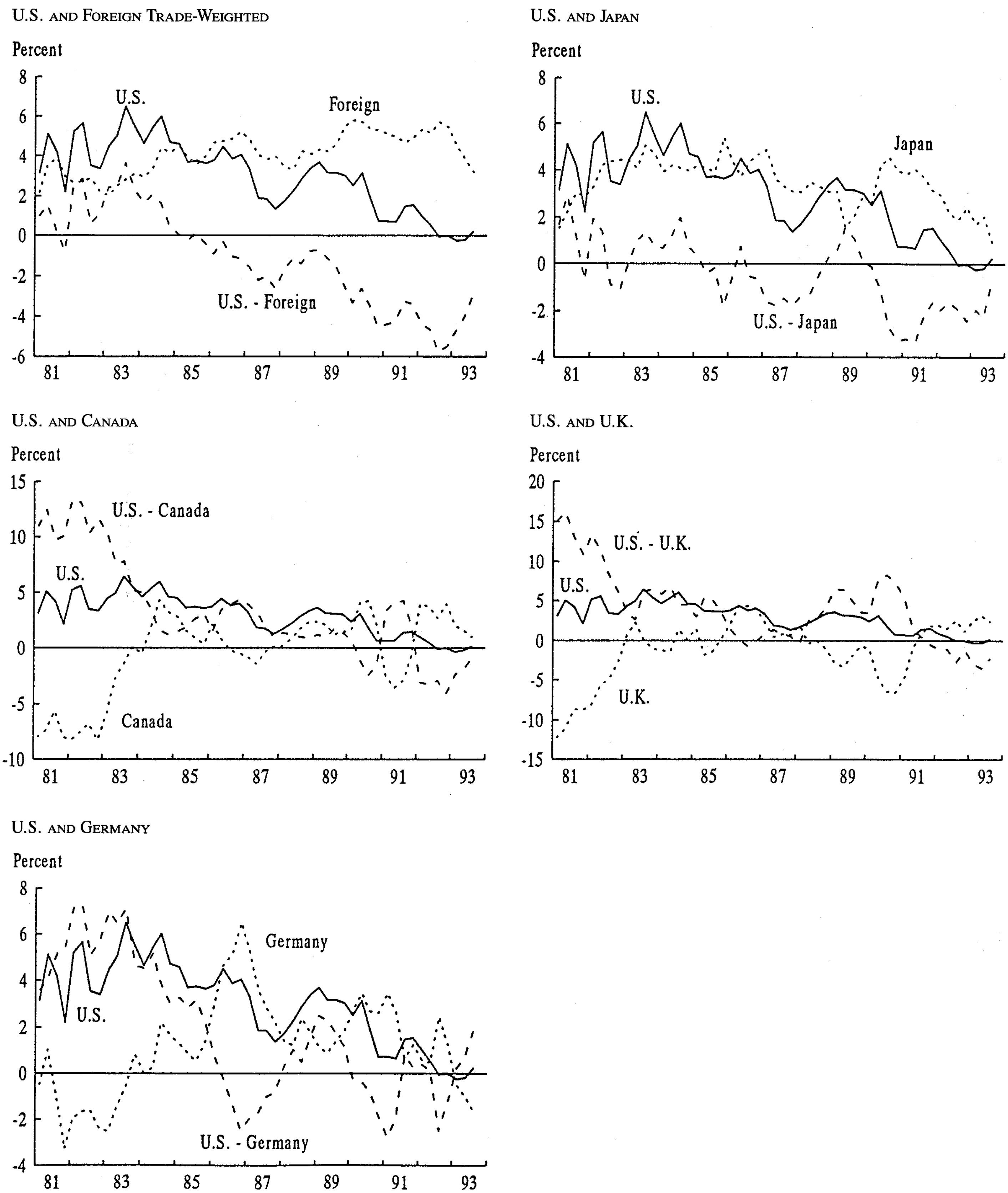
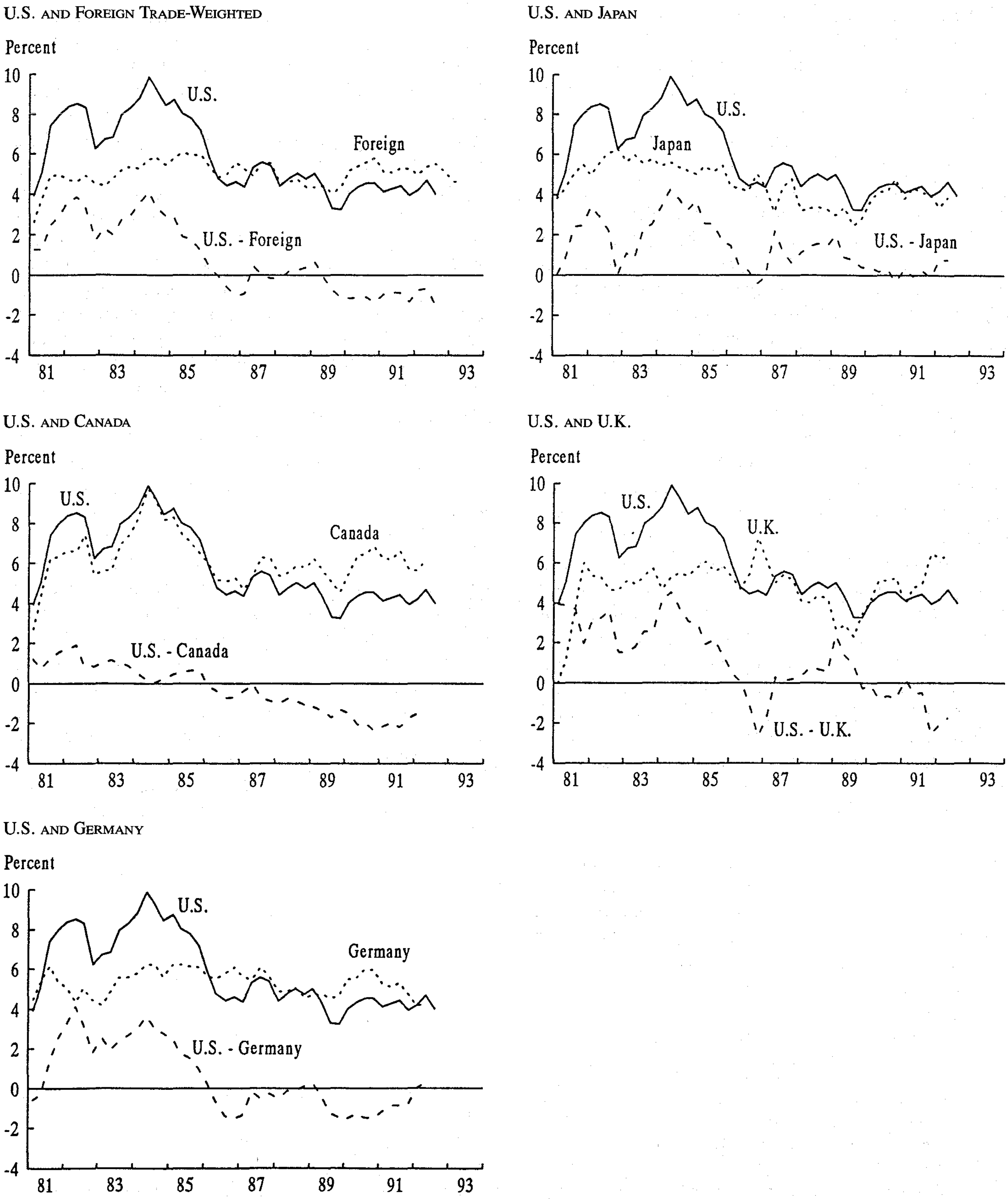


FIGURE 5

U.S. AND FOREIGN LONG-TERM REAL INTEREST RATES AND THEIR DIFFERENTIALS



exchange rates over extended periods in the 1970s and 1980s, consistent with an assumption of nonstatic expectations in the Mundell-Fleming model.[13] This has been especially true for the U.S. dollar in the first half of the 1980s, when a combination of easy fiscal policy and tight monetary policy in the U.S. pushed up U.S. real interest rates relative to those abroad. As a result, it may be that tendencies for the equalization of national real interest rates are not easily discernible in this period.

This analysis looks at tendencies toward the convergence of real interest rates for both the period of relatively high capital mobility since the early 1980s as well as the whole period of floating exchange rates since 1973 since the former period may be too short to uncover such tendencies. If there were a significant tendency for real interest rates to converge over the longer period but not the shorter one, one could say that capital controls in the 1970s were not sufficient to offset the tendency towards convergence, but that convergence can take quite a long time under flexible exchange rates. On the other hand, if there were no significant tendency observable in either period, all that could be said would be that although a tendency towards convergence could not be found for the period of high capital mobility since the early 1980s, such a tendency might be uncovered if a longer period of high capital mobility with flexible exchange rates could be observed.

The strongest hypothesis with respect to long-run convergence of national real interest rates would be that there is a tendency towards equality. Statistically, this would imply that real interest differentials are stationary, i.e., they do not have a tendency to trend either up or down through time. Stationarity of both short- and long-term real interest rate differentials for both the short period of full financial market integration since the early 1980s and the longer period of floating rates since 1973 was examined using the augmented Dickey-Fuller test.[14] The null hypothesis of nonstationarity was accepted at the 1 percent level of significance in all cases.

Thus, only a weaker form of convergence may exist. A weaker hypothesis would be that real interest rates at home and abroad are cointegrated in the sense that they do not tend to drift apart over time. Statistically, this means that a linear combination of the two interest rates would be stationary. Thus, if r and r^* are cointegrated, then the cointegrating vector, $r - \alpha_0 - \alpha_1 r^*$, would be stationary. For long-run equality, $\alpha_0 = 0$ and $\alpha_1 = 1.0$. But different national tax rates could cause α_1 to be different from 1.0, and currency risk premiums or other factors might cause α_0 to differ from zero. So cointegration would appear to be a better criterion for convergence than equality.

The Engle-Granger two-step procedure could be used to test for the cointegration of pairs of real interest rates. This procedure would estimate $r = \alpha_0 + \alpha_1 r^*$ by ordinary least squares and test for the stationarity of the residuals by means of the Dickey-Fuller test.[15] But a more powerful test is the Johansen procedure, which estimates the cointegrating vector within the context of a complete error-correction model.[16] Estimation of this type of model also has the advantage of providing estimates of the dynamics of the response of one interest rate to another, and therefore the time it takes for the system to reach a long-run equilibrium.

This vector error-correction model consists of regressions of changes in each of the two real interest rates on past changes in its own rate, past changes in the other rate, and a lagged error-correction term equal to the cointegrating vector. Assuming that the real interest rates are nonstationary, the regressions are in change form (except for the error-correction term) in order to avoid spurious correlations that otherwise might result from unit roots in the data. The error-correction term is included in the regressions if it can be shown that the real interest rates are cointegrated, in the sense that they tend toward a stable long-run equilibrium relationship. The error-correction term is equal to the difference between the actual and long-run predicted values of each interest rate. This ensures that the system moves toward a long-run equilibrium if one exists. Using this two equation system, impulse-response functions are derived to examine the estimated short- and long-run responses of each real interest rate to shocks to either rate. Formally, this two-equation system is written as:[17]

$$\Delta r = \sum_{i=1}^{4} B_{11i}\Delta r^*_{-i} + \sum_{i=1}^{4} B_{12i}\Delta r_{-i} + P_1(r - \alpha_0 - \alpha_1 r^*)_{-1} + e_1 \tag{8}$$

$$\Delta r^* = \sum_{i=1}^{4} B_{21i}\Delta r^*_{-i} + \sum_{i=1}^{4} B_{22i}\Delta r_{-i} + P_2(r - \alpha_0 - \alpha_1 r^*)_{-1} + e_2. \tag{9}$$

13. See Throop (1993) and references therein to the extensive literature on the subject. Besides confirming the importance of real interest rate differentials in explaining the behavior of real exchange rates since 1973, Throop (1993) also shows that the market's expectation of the long-run equilibrium of the real value of the dollar tends to be importantly affected by the real price of oil, budget deficits, and the relative price of traded versus nontraded goods.

14. For a discussion of the augmented Dickey-Fuller test, see Charemza and Deadman (1992), chapter 5.

15. See Engle and Granger (1987), Engle and Yoo (1987), and Charemza and Deadman (1992), chapter 5.

16. See Johansen and Juselius (1990).

17. Four lags on past changes in rates were used in estimating the cointegrating vector. Also, constant terms in the vector autoregressions were restricted to zero, maximizing the chance of finding cointegration.

Augmented Dickey-Fuller tests indicate that all short-term and long-term real interest rates are nonstationary in levels, but stationary in first differences for the period 1981 to the present, as well as for the full period of the float, consistent with regressions in first difference form. To determine whether error-correction terms should be included in each of the regression equations, we test for cointegration between pairs of real interest rates. If a linear combination of the two (nonstationary) interest rates is stationary, then they are cointegrated. Tables 1 and 2 compare the maximum eigenvalue and trace statistics of the Johansen test for cointegration with their critical values. These statistics show that the foreign trade-weighted short-term real interest rate is the only foreign rate that is cointegrated with the U.S. real short-term rate for the period of high capital mobility in the 1980s. If the sample period is extended to the period of the full float, the foreign trade-weighted short-term real rate ceases to be cointegrated with the U.S. rate, presumably because of increased barriers to capital mobility, but the Japanese real rate now becomes cointegrated with the U.S. real rate, despite such barriers.

These results suggest that on average there was a statistically significant long-run linkage between U.S. and for-

TABLE 1

JOHANSEN TEST FOR COINTEGRATION: SHORT REAL RATES

MAXIUMUM EIGENVALUE TEST			Statistic		Critical Values	
U.S. and:	Null	Alternative	1981.Q1–1993.Q3	1974.Q1–1993.Q3	5%	10%
Canada	r = 0	r = 1	11.3	7.8	15.8	13.8
	r ≤ 1	r = 2	2.5	4.8	9.1	7.6
Germany	r = 0	r = 1	8.2	8.7	15.8	13.8
	r ≤ 1	r = 2	3.6	6.8	9.1	7.6
Japan	r = 0	r = 1	11.2	17.5**	15.8	13.8
	r ≤ 1	r = 2	1.2	4.9	9.1	7.6
U.K.	r = 0	r = 1	10.8	7.2	15.8	13.8
	r ≤ 1	r = 2	2.5	6.3	9.1	7.6
Trade-weighted	r = 0	r = 1	26.3**	7.1	15.8	13.8
	r ≤ 1	r = 2	3.4	3.7	9.1	7.6
TRACE TEST						
U.S. and:						
Canada	r = 0	r > 1	13.7	12.6	20.2	18.0
	r ≤ 1	r = 2	2.5	4.8	9.1	7.6
Germany	r = 0	r > 1	11.8	15.5	20.2	18.0
	r ≤ 1	r = 2	3.6	6.8	9.1	7.6
Japan	r = 0	r > 1	12.4	22.5**	20.2	18.0
	r ≤ 1	r = 2	1.2	4.9	9.1	7.6
U.K.	r = 0	r > 1	13.3	13.5	20.2	18.0
	r ≤ 1	r = 2	2.5	6.3	9.1	7.6
Trade-weighted	r = 0	r ≥ 1	29.7**	10.9	20.2	18.0
	r ≤ 1	r = 2	3.4	3.7	9.1	7.6

NOTE: ** indicates statistical significance at the 5% level.

eign trade-weighted real short-term interest rates in the period of high capital mobility. However, examination of the estimated cointegrating vector, shown in Table 3, reveals that the U.S. and foreign trade-weighted short-term rates are estimated to have moved *inversely* with one another in the long run. This is not consistent with a tendency toward convergence of real interest rates. On the other hand, in the case of the Japanese short rate over the longer period, the U.S. and Japanese rate are estimated to move *positively* with one another in the long run, consistent with convergence. However, a Chi Square test rejects the restriction that the foreign real interest rate is equal to the home real interest rate in the long run in both cases, and it also rejects the restriction that the foreign interest rate differs from the home interest rate by at most a constant. So even where a tendency towards the long-run convergence of interest rates is found, as in the case of Japan, it is relatively weak.

Turning to long rates, there is no evidence of any significant cointegration between U.S. and foreign real rates in the period of high capital mobility since the beginning of the 1980s (see Table 2). But significant cointegration between the real long-term U.S. rate and the corresponding rates abroad is indicated for Germany and Japan for the full

TABLE 2

JOHANSEN TEST FOR COINTEGRATION: LONG REAL RATES

MAXIUMUM EIGENVALUE TEST			Statistic		Critical Values	
U.S. and:	Null	Alternative	1981.Q1–1992.Q2	1974.Q1–1992.Q2	5%	10%
Canada	r = 0	r = 1	8.6	6.5	15.8	13.8
	r ≤ 1	r = 2	5.4	4.0	9.1	7.6
Germany	r = 0	r = 1	10.1	14.1*	15.8	13.8
	r ≤ 1	r = 2	6.3	4.3	9.1	7.6
Japan	r = 0	r = 1	9.9	17.1**	15.8	13.8
	r ≤ 1	r = 2	1.8	7.2	9.1	7.6
U.K.	r = 0	r = 1	5.4	11.5	15.8	13.8
	r ≤ 1	r = 2	4.8	4.0	9.1	7.6
Trade-weighted	r = 0	r = 1	7.6	8.1	15.8	13.8
	r ≤ 1	r = 2	5.4	4.2	9.1	7.6
TRACE TEST						
U.S. and:						
Canada	r = 0	r > 1	14.1	10.8	20.2	18.0
	r ≤ 1	r = 2	5.4	4.0	9.1	7.6
Germany	r = 0	r ≥ 1	16.4	18.4*	20.2	18.0
	r ≤ 1	r = 2	6.3	4.3	9.1	7.6
Japan	r = 0	r ≥ 1	11.7	24.3**	20.2	18.0
	r ≤ 1	r ≥ 2	1.8	7.2	9.1	7.6
U.K.	r = 0	r ≥ 1	10.3	15.5	20.2	18.0
	r ≤ 1	r = 2	4.9	4.0	9.1	7.6
Trade-weighted	r = 0	r ≥ 1	13.0	12.3	20.2	18.0
	r ≤ 1	r = 2	5.4	4.2	9.1	7.6

NOTE: ** and * indicate statistical significance at the 5 and 10 percent levels, respectively.

TABLE 3

JOHANSEN TEST FOR RESTRICTION ON COINTEGRATING VECTOR

COUNTRY	PERIOD	RATES	ESTIMATED COINTEGRATING VECTOR	CHI-SQUARE TEST ON (1.0, 0.0, −1.0) RESTRICTION	CHI-SQUARE TEST ON (1.0, α_0, −1.0) RESTRICTION
Trade-weighted	1981.Q1–1993.Q3	Short	(1.0, −11.3, 2.1)	23.5 (.005)	22.6 (.005)
Japan	1974.Q1–1993.Q3	Short	(1.0, 5.6, −2.4)	10.8 (.005)	8.5 (.005)
Japan	1974.Q1–1992.Q2	Long	(1.0, −76.1, 16.0)	10.8 (.005)	8.5 (.005)
Germany	1974.Q1–1992.Q2	Long	(1.0, 7.8, −2.6)	5.5 (.050)	9.9 (.005)

NOTE: Significance levels are in parentheses.

period of the float. The German and the U.S. long rates are estimated to be *positively* related in the long run, consistent with convergence. But a *negative* long-run relation is found between U.S. and Japanese real long-term interest rates. Moreover, the restriction of either a one-to-one long-run relationship between U.S. and foreign real long-term rates or a constant difference between them is rejected by a Chi Square test in both cases (Table 3).

Impulse-response functions from the estimated vector error-correction systems are examined next. The response of the foreign rate to a shock to the U.S. rate is determined by shocking the error term, e_1, in equation (8) by one percentage point. It is assumed that any correlation between e_1 and e_2 in equations (8) and (9) is attributable to an effect of e_2 on e_1, rather than the other way around. This implies that e_2 is not affected by this shock and that the foreign rate is influenced only through the remaining terms in equation (9). This procedure avoids a possibly spurious element of contemporaneous causation in the simulated response, but it also may underestimate the effect of the U.S. rate on the foreign rate if there is in fact some contemporaneous causation of e_2 by e_1. Similarly, in the case of the response of the U.S. rate to the foreign rate, it is assumed that any correlation between e_1 and e_2 is attributable to the effect of e_1 on e_2. However, if it is assumed that the causation between the correlated elements of the error terms runs in opposite directions, the simulated impulse-response functions are not changed to any significant extent.

For short rates, estimates are for the period of high capital mobility since the early 1980s, except in the case of Japan where there was a stronger linkage of interest rates for the full period of the float. Error-correction terms are included in the systems for the U.S. and foreign trade-weighted rates and for the U.S. and Japanese rates, although in the former case the signs of the coefficients in the error-correction term are not consistent with a positive association between interest rates in the long run. The impulse-response functions for long-run rates also are from the period since the beginning of the 1980s, except for Germany and Japan, which are for the full period of the float. Error-correction terms are included in the case of those two countries as well. But only in the case of Germany do the signs of the coefficients indicate a positive association between interest rates on U.S. and foreign assets in the long run.

Figure 6A shows the simulated impact on the foreign rate over 16 quarters of a permanent 1 percentage point shock to the U.S. real short-term interest rate, while Figure 6B plots the simulated response of the U.S. real short rate to a permanent 1 percentage point shock to the foreign rate. The dotted line indicates a 95 percent confidence interval around the estimated impulse-response functions.[18] The response of foreign short rates to a shock to the U.S. short rate is not significantly different from zero for either the trade-weighted rate or the four national interest rates. The response of the U.S. short rate to a shock to the U.K. short rate is significantly positive but small, after 16 quarters. But the response of the U.S. short rate to the foreign trade-weighted short rate is significantly negative, and the response of the U.S. short rate to the three other national rates is not significantly different from zero.

The impact of a shock to the U.S. rate on the U.S. rate after 16 quarters is generally not significantly different

18. This confidence interval was established by replicating the impulse-response 1,000 times according to the observed distribution of errors. Lags on past changes in rates were reduced to two in the case of short rates and three for long rates due to a lack of statistical significance of longer lags. This helped to tighten up the confidence bands around the impulse-response functions.

FIGURE 6

IMPULSE-RESPONSE FUNCTIONS: SHORT-TERM RATES

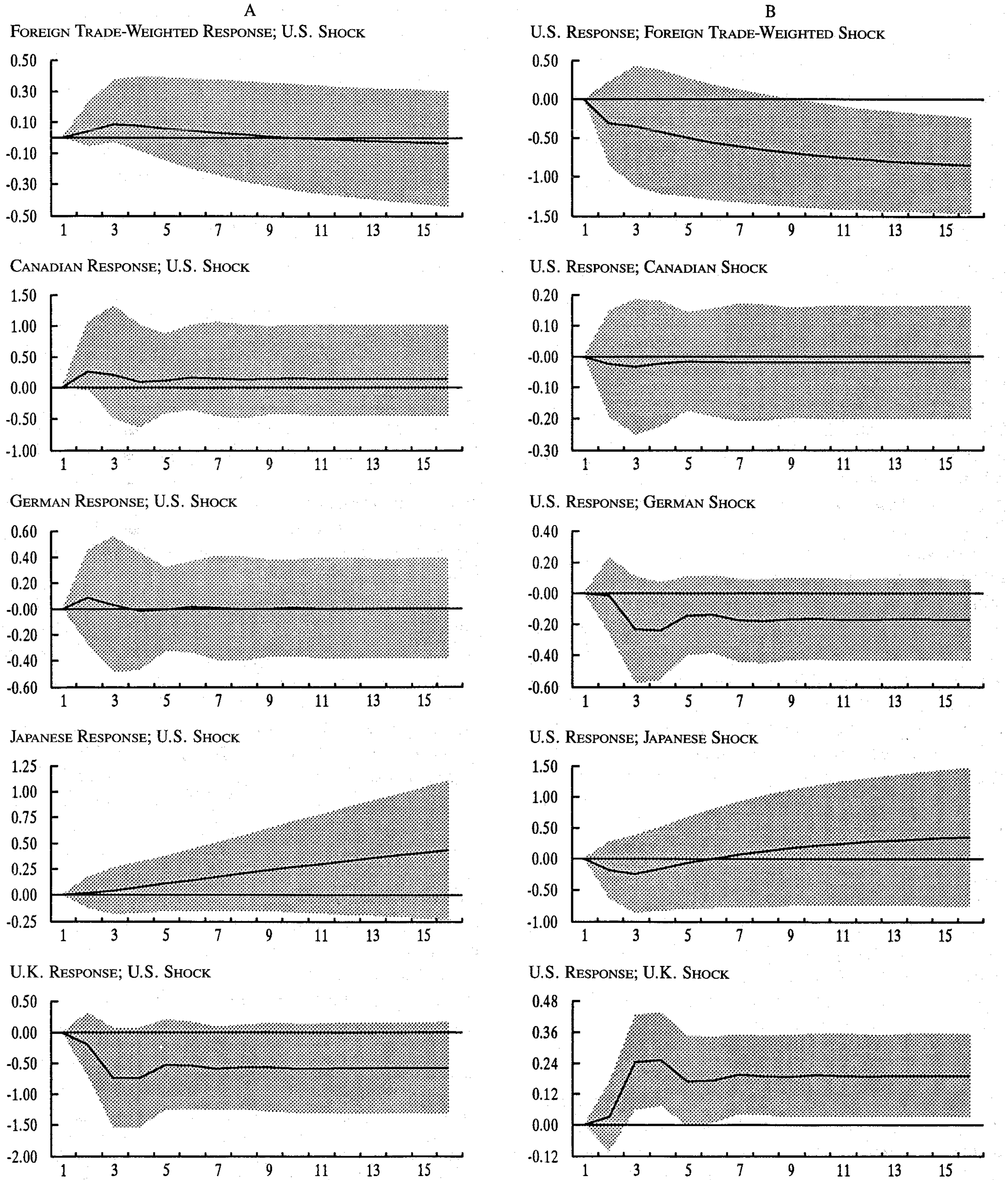
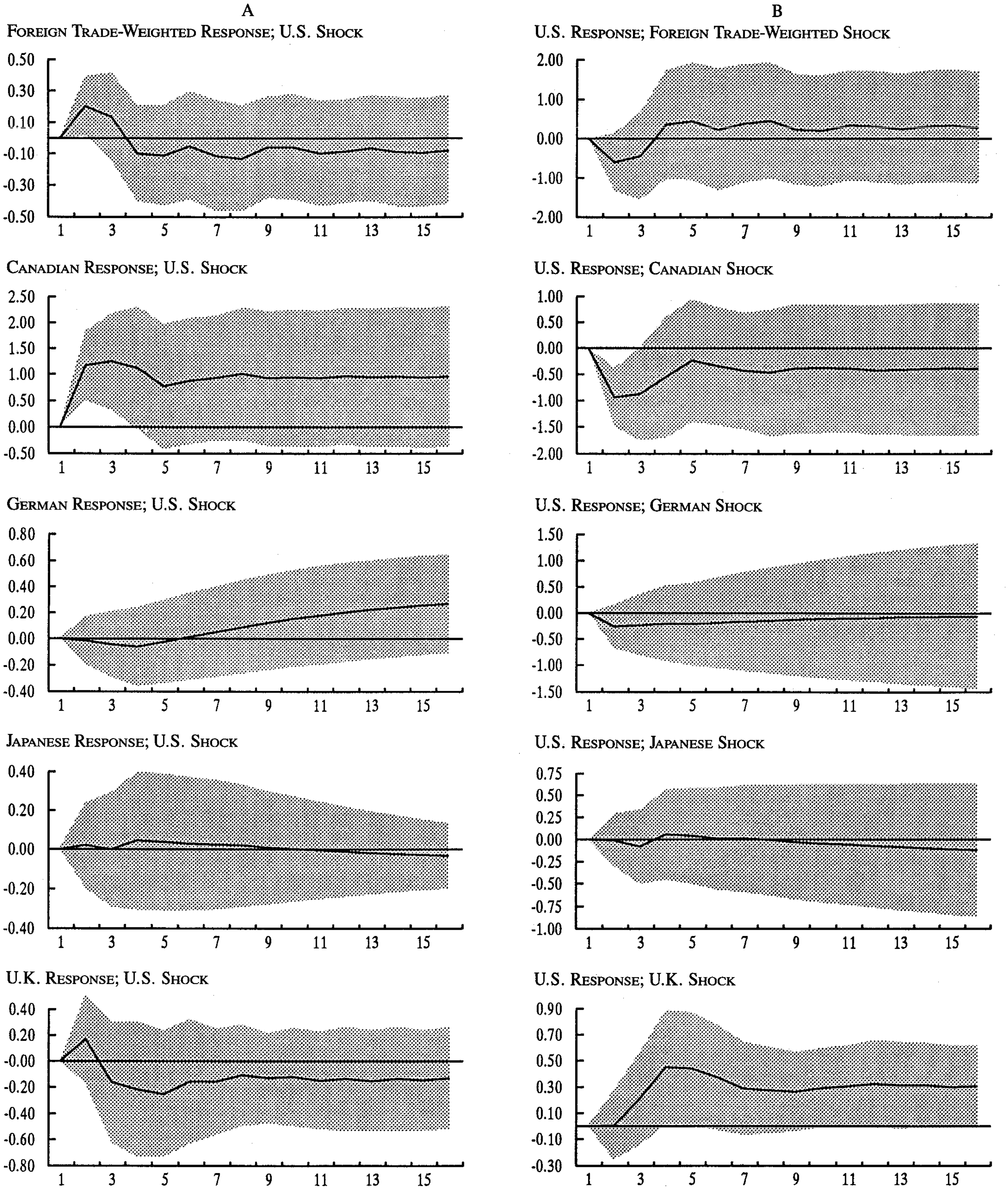


FIGURE 7

IMPULSE-RESPONSE FUNCTIONS: LONG-TERM RATES



from 1 percentage point, as is the response of the foreign rates to a 1 percentage point shock to them. As a result, there is no significant tendency for real short rates to come back together once they have been pulled apart by a shock. This appears to be due to the absence of static expectations and a time-varying currency risk premia in a sample that is too short to allow one to observe the long-run interest-equalizing effects of capital mobility.[19]

Figure 7 shows the responses of real long-term interest rates to shocks to real long-term rates in other countries. As before, the effect of a 1 percentage point shock after 16 quarters on the rate that is shocked is never significantly different from 1 percentage point. But the effect of that shock on the other real long-term interest rate is never significantly different from zero. So once a shock drives national real long-term interest rates apart, there is no measurable tendency for them to be brought together again. Again this is not evidence against capital being highly mobile internationally among the major countries. However, it does indicate that such mobility tends to make real interest rates converge only over very long periods of time.

III. SUMMARY AND CONCLUSION

The impulse-response functions that have been examined in this study show that there have been virtually no causal linkages between U.S. and foreign short-term or long-term real interest rates for periods of up to 16 quarters. Moreover, in instances where longer-run linkages could be identified, the association between U.S. and foreign real rates was positive only half of the time. Yet, since the early 1980s differentials between U.S. and foreign interest rates when covered for exchange rate risk in either the forward market or by currency swaps have been close to zero. This eliminates government or institutional barriers to capital mobility as sources of disparities between real interest rates on similar assets and leaves only exchange rate expectations and premia for exchange rate risk as the contributing factors.

It is difficult to gauge the relative importance of these two factors with precision. But there is independent evidence that both factors have been important to some extent. The evidence for the importance of expectations is that real interest rate differentials have been shown to be an important force driving real exchange rates away from their long-run equilibrium values for extended periods of time. This has been especially true for the U.S. dollar in the first half of the 1980s when the combination of easy fiscal policy and tight monetary policy in the U.S. raised U.S. real interest rates relative to foreign rates. As a result, the real value of the dollar deviated significantly from its expected long-run equilibrium value, and the condition of static expectations required for a short-run equalization of real interest rates was far from satisfied.

The importance of premia for exchange rate risk in contributing to divergences in real interest rates is suggested by evidence from surveys of market expectations of future exchange rates. If exchange risk premia were small, we would expect that differences in anticipated returns on comparable assets calculated using survey data as a measure of expected exchange rate changes would be fairly small. But in fact this is not the case.[20] Therefore, changing currency risk premia probably also contribute to variation in differentials between real national interest rates. Unfortunately, however, empirical studies to date have had little success in isolating the fundamental economic factors that tend to cause changes in these currency risk premia.[21]

19. Using multivariate time-series modeling of real interest rate *differentials,* as opposed to the real rates themselves, Modjtahedi (1988) reaches quite different conclusions with respect to one-month Eurocurrency rates over fairly short sample periods (1973 through 1979 and 1979 through 1986). First, he finds that national real interest rates are generally cointegrated, although not always equal in the long run. Second, he estimates that it takes approximately six months for the differentials to converge to their long-run values. This estimated speed of adjustment is difficult to square with the approximately two years that it takes for the trade balance to adjust to changes in the exchange rate, and hence also to changes in interest rates. Rapid adjustment also is inconsistent with extended swings in the real value of the dollar that have been observed to be associated with similar movements in real interest rate differentials.

20. See, for example, Pigott (1993-1994).

21. Studies on the existence of exchange risk premia include Frankel (1982), Hansen and Hodrick (1983), Hsieh (1982), Hodrick and Srivasta (1984), and Fama (1984). Attempts to explain exchange risk premia in terms of the capital asset pricing model include Engle and Rodrigues (1989) and Lewis (1988).

References

Akhtar, M.A., and K. Weiller. 1987. "Developments in International Capital Mobility: A Perspective on the Underlying Forces and the Empirical Literature" in *Research Papers on International Integration of Financial Markets and U.S. Monetary Policy.* Federal Reserve Bank of New York, pp. 71–188.

Bank for International Settlements. 1989. *International Interest Rate Linkages and Monetary Policy.* Spring Economists' Meeting (March).

Caramazza, Francesco, Kevin Clinton, Agathé Côté, and David Langworth. 1986. *International Capital Mobility and Asset Substitutability: Some Theory and Evidence on Recent Structural Changes.* Bank of Canada Technical Report no. 44.

Charemeza, Wojciech and Derik F. Deadman. 1992. *New Direction in Econometric Practice.* Aldershot, England: Edward Elgar Publishing.

Cumby, R.E., and M. Obstfeld. 1984. "International Interest Rate and Price Level Linkages under Flexible Exchange Rates: A Review of Recent Evidence." *Exchange Rate Theory and Practice,* John F.D. Bilson and Richard C. Marston eds. Chicago, Illinois: University of Chicago Press.

Dornbusch, Rudiger. 1976. "Expectations and Exchange Rate Dynamics." *Journal of Political Economy* (December) pp. 1161–1176.

Engle, Charles, and Anthony Rodrigues. 1989. "Tests of International CAPM with Time-varying Covariances." *Journal of Applied Econometrics* 4 (2) pp. 119–138.

Engle, Robert F., and Byung-Sam Yoo. 1987. "Forecasting and Testing in Cointegrated Systems." *Topics in Applied Regression and Time Series Analysis,* Supplement to *Journal of Econometrics,* pp. 143–159.

__________, and C. W. J. Granger. 1987. "Cointegration and Error Correction: Representation, Estimation, and Testing." *Econometrica* 55 (2) pp. 251–276.

Fama, Eugene F. 1984. "Forward and Spot Exchange Rates." *Journal of Monetary Economics* 14, pp. 319–338.

Fleming, J. Marcus. 1962. "Domestic Financial Policies under Fixed and under Floating Exchange Rates." *IMF Staff Papers* (November) pp. 369–379.

Frankel, Jeffrey. 1989. "International Financial Integration, Relations Among Interest Rates, and Exchange Rates and Monetary Indicators" in *International Financial Integration and U.S. Monetary Policy.* Proceedings of a Federal Reserve Bank of New York Colloquium. Ed. by Charles Pigott (October).

__________. 1988. "International Capital Flows and Domestic Economic Policies" in *The United States in the World Economy* ed. by Martin Feldstein. Chicago: University of Chicago Press.

__________. 1982. "In Search of the Exchange Rate Premia: A Six Currency Test Assuming Mean Variance Optimization." *Journal of International Money and Finance* 1 (3) pp. 255–74.

Gaab, W., M. J. Granziol, and M. Horner. 1986. "On Some International Parity Conditions: An Empirical Investigation." *European Economic Review* 30 (3) pp. 683–713.

Hansen, Lars P., and Robert J. Hodrick. 1983. "Risk Averse Speculation in the Forward Exchange Market: An Economic Analyses of Linear Models, in *Exchange Rates and International Economies* ed. by J. A. Frankel. Chicago: University of Chicago Press for the National Bureau of Economic Research.

Hodrick, Robert J., and Sanjov Srivastova. 1984. "An Investigation of Risk and Return in Forward Foreign Exchange." *Journal of International Money and Finance* 3 (1) pp. 5–29.

Hsieh, David A. 1982. "Tests of Rational Expectations and No Risk Premium in Forward Exchange." *National Bureau of Economic Research Working Paper* No. 843.

Johansen, Soren, and Katrina Juselius. 1990. "Maximum Likelihood Estimation and Inference on Cointegration—With Applications to the Demand for Money." *Oxford Bulletin of Economics and Statistics* (May) pp. 169–210.

Kasman, Bruce, and Charles Pigott. 1988. "Interest Rate Divergences among the Major Nations." Federal Reserve Bank of New York *Quarterly Review* (Autumn) pp. 28–44.

Lewis, Karen. 1988. "Inflation Risk and Market Disturbances: The Mean-Variance Model Revisited." *Journal of International Money and Finance* (September) pp. 273–288.

Merrick, John J. and Anthony Saunders. 1986. "International Expected Real Interest Rates: New Tests of the Parity Hypothesis and U.S. Fiscal Policy Effects." *Journal of Monetary Economics* 18, pp. 313–322.

Mishkin, Frederic S. 1984. "Are Real Interest Rates Equal Across Countries? An Empirical Investigation of International Parity Conditions." *Journal of Finance* 39, pp. 1345–1357.

Modjtahedi, Baghar. 1988. "Dynamics of Real Interest Rate Differentials: An Empirical Investigation." *European Economic Review* 32 (6) pp. 1191–1211.

Mundell, Robert A. 1968. *International Economics.* New York: Macmillan.

Pigott, Charles. 1993–1994. "International Interest Rate Convergence: A Survey of the Issues and Evidence." Federal Reserve Bank of New York *Quarterly Review* (Winter) pp. 24–37.

Popper, Helen. 1990. "International Capital Mobility: Direct Evidence from Long-term Currency Swaps." Board of Governors of the Federal Reserve System. *International Finance Discussion Paper* no. 382 (June).

Throop, Adrian W. 1993. "A Generalized Uncovered Interest Parity Model of Exchange Rates." Federal Reserve Bank of San Francisco *Economic Review* 2, pp. 3–16.

__________. 1989. *A Macroeconometric Model of the U.S. Economy.* Federal Reserve Bank of San Francisco Working Papers in Applied Economic Theory (89–01).