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International Linkages in the Term Structure of Interest Rates

INTEREST rates usually differ for assets with different terms to maturity.[1] The term structure of interest rates shows the relationship among the interest rates, or yields to maturity, of different-lived assets and their terms to maturity.[2] Analysts often view the term structure as the link between current and future short- and long-term interest rates. This link is important because of the widely held belief that monetary authorities are able to influence only short-term money market rates, while long-term rates are more relevant in making investment and consumption decisions. An understanding of the transmission mechanism from current short-term rates to future interest rates is crucial, according to this view, in implementing and evaluating monetary policy.

This article extends the analysis of the term structure by examining whether movements in the domestic term structure are influenced by foreign interest rate developments. In the term structure view, if interest rates are related across countries, then foreign short-term interest rate movements are transmitted both directly to changes in domestic short-term rates, and indirectly, via the respective domestic term structures, to changes in long-term interest rates. Thus, short- and long-term interest rate changes are closely correlated across countries and long-term interest rates changes in one country are related to foreign short-term rates as well. This hypothesis is commonly thought to hold for the United States, whose policies are blamed for adverse interest rate developments abroad. This article examines the relationships among the term structures of interest rates in the United States, Canada, the United Kingdom, West Germany and Japan. Our chief focus is on the extent to which movements in short- and long-term interest rates are related internationally and whether changes in foreign interest rates influence domestic interest rates.

[1]A given yield curve implicitly assumes that other characteristics of the short- and long-term assets are identical. Yields on financial assets differ for many reasons, including differences in default risk, marketability and tax treatment. In term structure research, it is typical to examine short- and long-term government securities and to assume that differences in their maturity are the main determinant of the differences in their yields. See Wood (1983).

[2]In this article, the terms interest rate and yield to maturity are used interchangeably. Both measures reflect the average expected rate of return over the remaining life of the underlying financial asset. These measures usually will differ from the holding-period return, which equals the return on an asset over a fixed period. For example, the one-year holding-period return on a 10-year bond is the annual coupon payment plus the capital gain over the year, while the yield to maturity on the same bond is the average of all current and expected future one-year holding-period returns until the end of the bond's life. Only when the holding period and the remaining maturity of the bond are equal will these two measures of return coincide. An approximately linear negative relation holds between the change in the long-term interest rate and the holding period return. For details, see Shiller *et al.* (1983).

TERM STRUCTURE THEORY

The expectations theory is the principal theoretical approach to the term structure of interest rates. This theory assumes that investors view short- and long-term government bonds as perfect substitutes, that is, investors are indifferent to the maturity of holdings of government securities.[3] This assumption implies that every investment strategy in government securities has the same expected return over any given future holding period. For example, suppose that the current one-year rate is 6 percent, while the interest rate on a 10-year bond is 8 percent. If investors expect future one-year rates to remain constant at 6 percent, it is more attractive now to buy the 10-year bond. Over a 10-year holding period, the 10-year bond yields an 8 percent annual rate of return; rolling over a sequence of one-year assets for the same 10-year period yields an expected rate of only 6 percent. Increased purchases of 10-year bonds bid up their price, thereby depressing their yield; similarly, sales of existing one-year securities (to switch into higher-yielding 10-year bonds) lower their price and raise their expected yield. This process continues until the long rate equals an average of current and expected future short rates.

Thus, the interest rates on a three-month bill, a one-year bill and a 30-year bond will differ according to the market's assessment of expected interest rates on short-term assets beyond the life of each instrument. The one-year bill will have a yield that reflects not only the expectation for the next three months embodied in the three-month bill rate, but also the expectations for the subsequent nine months. Similarly, a 30-year bond will have a current yield to maturity that is influenced by the same expectations as the one-year bill for the first year, but also by expectations for the remaining 29 years of its life. If future short-term rates are expected to be higher (lower) than today, a positive (negative) spread, or difference, between today's long- and short-term interest rates will reflect it.

DOMESTIC TERM STRUCTURE EQUATIONS

According to theories of the domestic term structure of interest rates, the current spread between the level of long- and short-term interest rates is directly related to the expectation that future short-term interest rates and, therefore, long-term rates will be higher. Formally, this relationship for the long-term interest rate, R_t, can be written as:

$$(1)\quad \Delta R_t = \beta_0 + \beta_1 S_{t-1} + \varepsilon_t,$$

where S_{t-1} is the lagged spread, $(R_{t-1} - i_{t-1})$, and i_{t-1} is the lagged short-term interest rate. In theory, the parameter β_0 is expected to be negative and β_1 is expected to be positive.[4] The intercept β_0 is the negative of a term or risk premium. Long-term interest rates, on average, will not change ($\Delta R_{t+1} = 0$) when the spread, S_t, equals the ratio of $(-\beta_0/\beta_1)$; this ratio is positive when there is a positive term premium and zero when β_0 is zero. Long-term rates are expected to rise (fall) when the current spread exceeds (is less than) $(-\beta_0/\beta_1)$.

A similar equation can express the same relation for short-term rates (Δi_t). Term structure theory does not provide a theoretical value for the spread coefficient in such an equation, since expected changes in future short rates are not necessarily distributed uniformly over each future period's short rate. Thus, a rise in the spread need not indicate that the short rate will be higher next month, although it does indicate that some unspecified future short rates (and long rates for assets that span the period) will be higher than they are now. When expected future short-term interest rate changes are distributed uniformly or weighted more heavily to the near future, which

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[3]There are several competing theories of the term structure of interest rates. For a detailed description of these theories, see the discussion in a textbook such as Wood and Wood (1985), chapter 19. They *all*, however, have a common foundation in what sometimes is called the traditional expectations theory. The purpose of this article is not to test competing theories of the domestic term structure; instead, it uses a general specification as a point of departure to study international linkages among interest rates.

[4]Theoretical expressions for the values of β_0 and β_1 are found by equating holding-period returns, adjusted for any term premium. Consider a monthly analysis of one-month Treasury bills and 10-year bonds, like that below. The one-month holding-period return on a one-month T-bill is its interest rate, i_t; the one-month holding-period return on a 10-year bond is the interest rate R_t plus the annualized expected capital gain; this capital gain is inversely proportional to the expected one-month change in the 10-year bond rate, ΔR_{t+1}. The equality results in a β_1 measure that is positive, but very small in a monthly analysis, and proportional to the average in-sample long rate; the expression for β_0 equals $(-TP)\beta_1$ where TP is the average term premium. See Mankiw (1986) for an example of this derivation.

generally is the case in theoretical or empirical investigations, the spread coefficient in a short-term rate equation should also be positive.[5]

A variant of the standard term structure equation used in many macroeconomic models is:

$$(2)\ S_t = \alpha_0 + \alpha_1 S_{t-1} + \alpha_2 \Delta i_t + \alpha_3 \Delta i_{t-1} + \varepsilon_t.$$

In equation 2, the long-term interest rate is a long distributed lag of past short-term rates.[6] Equation 2 can be rewritten as:

$$(3)\ \Delta R_t = \beta_0 + \beta_1 S_{t-1} + \beta_2 \Delta i_t + \beta_3 \Delta i_{t-1} + \varepsilon_t.$$

Equation 3 adds information on the current change in the short rate and a lagged value of this change to equation 1.[7] One rationale for adding "news" about the short rate is that short-rate changes reflect new information about expected future short rates beyond the information contained in the recent spread.[8] If markets are efficient and adjust within one period, β_3 should equal zero and β_2 should be positive. Equations like this are widely used to study the term structure of interest rates empirically. Accordingly, we use it as a point of departure in investigating international term structure linkages.

Domestic Macroeconomic Determinants of the Level of Interest Rates

Term structure and asset price theory explain differences in yields over time or among assets, but do not explain the general level of interest rates. Closer scrutiny of the factors influencing both short and long rates might indicate additional domestic determinants of the term structure that would modify equation 3.

The central factors influencing the general level of nominal interest rates, according to Fisher (1930), are the expected real rate of return on capital and the expected inflation rate.[9] Economic theory indicates that the expected real rate of interest is determined by the marginal productivity of capital and the marginal utility of consumption. Numerous economic factors, however, can impinge, at least temporarily, on these rather abstract determinants and, hence, on the real rate of interest.[10]

One approach to analyzing the term structure of interest rates models the effect of domestic macro-

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[5]Estimates of long- and short-rate equations like equation 1 often lack predictive content and are systematically at odds with the theory. See, for example, Shiller (1979), Shiller *et al.* (1983), Mankiw and Summers (1984) and Mankiw (1986). Most studies of the term structure find support for the inclusion of a term, or risk, premium in a term-structure equation: it is common to include a constant and nonzero term premium in characterizations of the expectations theory. See Wood and Wood (1985) or Clarida and Campbell (1987), for examples. Moreover, financial theory indicates that risk premia also are related to returns in other financial markets, like stocks, and to expectations about general economic conditions. For example, Cox Ingersoll and Ross (1981) modify the expectations theory to account for a negative effect on the term premium that is proportionate in magnitude to economic uncertainty. The possibility of a nonzero average, or constant, term premium is included in the estimates below. Specifications like equation 1 implicitly presume that all other influences on interest rates in the next period, beyond the current spread information and the term premium, have zero mean and are uncorrelated with the current spread. Such restrictions are relaxed in empirical models like those below.

[6]See Mankiw (1986). Modigliani and Sutch (1966) used a more famous variation of such an equation; it had a 16-quarter distributed lag on past short rates, instead of the lagged spread term, and so was explicitly backward-looking, rather than forward-looking as the expectations theory emphasizes.

[7]This transformation is found by subtracting S_{t-1} from both sides of equation 2 to obtain ΔS_t, then adding Δi_t to both sides to obtain equation 3. Equation 3 also can be derived from equation 1 and its short-rate variant. This form, however, suggests that one source of a negative coefficient on the lagged spread is that short rates are more sensitive to recent spread changes, which is likely if movements in the current spread are more informative about near-term prospective short rates than about all future short rates. Testing this alternative is beyond the scope or purpose of this paper.

[8]This view implies that an observationally equivalent view of equation 2 is that the lagged spread incorporates unbiased forecasts of future rates as in equation 1, but news reflected in current short-rate movements is informative about revisions of expected future rates. The Modigliani and Sutch variant of equation 2 has been criticized by numerous analysts, including Phillips and Pippenger (1976). The latter show that a forward-looking, efficient markets model rejects the Modigliani-Sutch model without including the lagged spread. The results below suggest that their specifications can be improved, however.

[9]These considerations also suggest that the term structure of nominal interest rates is a combination of a term structure of expected inflation and a term structure of expected real rates. When inflation temporarily accelerates (slows) due to a supply shock, the spread shrinks (widens) because the short-term rate rises (falls) more than the long-term rate. Garner (1987) presents evidence for the United States on the close relationship between the term structure of interest rates and the term structure of inflationary expectations.

[10]The standard laundry list of other macroeconomic factors includes the money stock, the price level, tax rates, government expenditures and other fiscal variables, and other domestic real variables such as private sector aggregate demand for goods and services, the business cycle, the mix between consumption and investment, and risk. Both current values and expectations of future values of these variables and their growth rates affect current and expected future real rates.

economic changes on the two components of both long- and short-term interest rates.[11] If financial markets are efficient, however, investors will have used the available relevant domestic information to price assets, including government bonds of all maturities. Thus, no additional domestic information exists that can improve on the implicit forecast of future interest rates reflected in the current term structure.

International Term Structure Linkages

Whether additional information on foreign interest rates influences the domestic term structure depends on the exchange rate regime. Under a fixed-exchange-rate system, domestic interest rates and monetary policy are not independent of foreign developments. Inflation rates tend to be equal across the countries that have a fixed-rate commitment; they equal the rate of depreciation of the purchasing power of the commodity or the money against which the exchange value of the currencies are fixed. In addition, if capital markets are integrated internationally, a change in the real rate of return in any one country is transmitted to all nominal rates both domestically and abroad as investors attempt to maximize real rates of return.[12] Since in this case the expected inflation rate and real rate are closely linked across countries, the nominal interest rate, at all maturities, is also closely linked. Economic developments at home or abroad could influence the interest rates common to all countries, but foreign factors would not have an independent influence on a domestic term structure like that shown in equation 3; news of such developments would be fully captured in the Δi_t term for the domestic economy.

The relation of interest rates across countries for a given maturity, called the covered interest parity condition, is

$$(4)\quad i = i^* + \frac{(f-e)}{e}n,$$

where

i and i* = the domestic and foreign interest rates, respectively, for comparable assets with respect to maturity and risk,

e = the current or spot exchange rate expressed as the number of domestic currency units per unit of foreign currency,

f = the corresponding forward rate one period in the future, and

n = the annualizing factor for the term of assets being compared, which equals 12 divided by the number of months to maturity.

Under a credible fixed rate regime, the expected forward rate would equal the spot rate at all maturities, so that countries would have the same term structure of interest rates. Domestic news in one country that affects domestic rates and the term structure would be immediately transmitted abroad, so that $(i = i^*)$ would hold for all maturities.

Even in the absence of a credible fixed-rate commitment, monetary authorities may still have a long-run exchange-rate objective and may periodically intervene in the exchange market or conduct policy to further that goal.[13] If they do, international rates could still be related, although the relationship would be looser, and changes in short rates especially would not be systematically coincident.

[11]Wood and Wood (1985) have noted an interpretation problem with such a procedure; do such variables enter as determinants of a term premium, via a "segmented markets" argument, for example, or do they provide additional information on the time path of expected future real interest rates? This problem mediates against the arbitrary introduction of current information for such variables. Moreover, the long list of potentially relevant macroeconomic factors and the dynamics of their effects operating through lags indicate that this approach is difficult and invariably controversial to implement. Even if undertaken successfully, however, the effort could be quite misleading.

[12]For a more detailed description of interest rate relations across countries, see Bisignano (1983) and Kirchgassner and Wolters (1987). Glick (1987) provides evidence on the real-interest-rate linkage between the United States and the Pacific Basin countries.

[13]In the absence of risk premia in foreign exchange markets, the forward rate would equal the expected future spot rate, so the second term on the right-hand side would equal the expected rate of appreciation of the foreign currency. Even if risk premia exist in foreign exchange markets, the forward rate will be a close approximation of the future spot rate in most situations, so the second term will approximate the expected rate of appreciation of foreign currency. Meese and Rogoff (1983) argue that this approximation is often unsatisfactory. Covered interest parity has been tested widely and successfully for short-term rates; such tests are typically restricted to short-term assets to ensure that there is an active market in forward contracts for foreign exchange for a comparable period. See Frenkel and Levich (1975, 1977) or, more recently, papers that reject the stronger variant called the "Fisher open" hypothesis or uncovered interest parity, such as Cumby and Obstfeld (1984). The strength of international linkages also depends on the extent to which assets of the same maturity across countries are substitutes; different tax regimes, transactions costs or other factors can impair the international interest rate linkage.

In a "pure float," or regime with no exchange-rate commitments, interest rates across countries can be independent if countries pursue independent inflation rate objectives and if the real interest rate is constant. Movements in foreign interest rates can be reflected in the prospective change in the exchange value of the domestic currency, rather than in domestic interest rates. Even in this case, however, the implicit exchange rate change can have undesirable effects on other policy objectives, such as the price level, so that interest rates will still not be independent across countries.

In particular, a rise (fall) in a foreign interest rate need not spill over to the domestic rate if the domestic currency is free to appreciate (depreciate) relative to the foreign currency. But the appreciation (depreciation) of the domestic currency can depress (raise) the domestic price level as well as, temporarily, the inflation rate. While there may not be an explicit exchange rate objective, an inflation or other objective can be at odds with such exchange rate effects and, therefore, require policy actions to raise (lower) interest rates. Hence, foreign interest rate changes can result in equal domestic rate changes despite the absence of an exchange-rate commitment.[14] Finally, when domestic short-term interest rate movements are only temporarily insulated from foreign movements by central bank intervention, long rates will still reflect these foreign changes immediately. In this case, foreign short-term rates would exert an independent effect on domestic long-term interest rates, given domestic short-term rates.

THE EMPIRICAL RELATIONSHIPS

To analyze domestic and international interest rate relationships, end-of-month observations of representative short- and long-term interest rates for the United States, Canada, the United Kingdom, West Germany and Japan were selected for the period from April 1977 to June 1987. This period was chosen on the basis of data availability.[15]

The Data: Some Simple Statistics

The top panel in table 1 shows the means and standard deviations of the levels and monthly changes of these interest rates and spreads in each country. The levels of rates show considerable variability, but the mean long rate exceeds the mean short rate in each country. The mean level of short rates in Canada and the United Kingdom are not significantly different from each other.[16] The same is true for West Germany and Japan, but their mean interest rate levels are lower than those in the other three countries. The mean U.S. short rate is significantly higher than in Japan and West Germany but lower than in Canada and the United Kingdom.

The rank ordering of the mean long rates is the same as for short rates, but the mean levels of the long rate are significantly different for each pairwise comparison of countries. The mean spread is not significantly different for four of the country pairs: the United Kingdom and Canada, the United Kingdom and Japan, the United Kingdom and Germany, and Japan and West Germany; in the other six pairwise comparisons (four of which are for the United States), the mean spreads are significantly different. The mean of changes in interest rates is approximately zero for each country and maturity class. In each country, the standard deviation of changes in the short rate far exceeds the standard deviation of changes in the long rate, indicating the greater volatility of short rates in all five countries.[17]

The bottom panel of table 1 shows correlation coefficients for both levels and changes of short rates, long rates and the spread for each country. A correlation of 0.18 or larger in absolute value is statistically different from zero at the 5 percent significance level. The evidence suggests that the short and long rates are highly correlated within each country. Similarly, monthly changes in short and long rates are highly correlated in each country except Japan.

The spread is dominated by the short rate; this is indicated by the significant negative correlation between the spread and the short rate in all five countries and the absence of a significant positive correlation for the spread and the long rate in any country. The level of the long rate and the spread are insignificantly correlated for the United States

[14] The theoretical and empirical basis of this absence of independence under floating exchange rates has been developed extensively by Mussa (1979) and Swoboda (1983).

[15] A description of the data is contained in the appendix to this article.

[16] The tests of differences in the means in table 1 use a "pooled t-test" with a 5 percent significance level.

[17] This smaller long-rate variability reflects the notion that, if the long rate is a weighted average of current and expected future short rates, some short-rate variability over time is expected to average out.

Table 1
The Term Structure Data For Five Countries (April 1977 to June 1987)

	United States		United Kingdom		Japan		Germany		Canada	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Levels										
Short-Rate (i)	8.75%	2.77%	11.67%	2.95%	6.30%	1.66%	6.44%	2.71%	10.98%	3.20%
Long-Rate (R)	10.51	2.32	12.39	1.88	7.23	1.27	7.65	1.34	11.49	2.20
Spread (R − i)	1.76	1.59	0.72	1.92	0.93	1.16	1.21	1.62	0.52	1.76
Changes (Δ)[1]										
Short-Rate (Δi)	0.01	1.18	0.01	0.92	−0.02	0.56	−0.01	0.63	0.01	0.84
Long-Rate (ΔR)	0.01	0.54	−0.00	0.59	−0.03	0.28	−0.00	0.31	0.01	0.55
Spread (ΔR − Δi)	−0.00	1.01	−0.01	0.83	−0.01	0.59	0.01	0.57	0.00	0.75
Correlation of Interest Rates Within Each Country[2]										
(i, R)	0.82		0.77		0.71		0.90		0.85	
(i, Spread)	−0.55		−0.78		−0.65		−0.93		−0.76	
(R, Spread)	0.03		−0.21		0.07		−0.68		−0.31	
(Δi, ΔR)	0.52		0.47		0.13		0.43		0.49	
(Δi, Δ Spread)	−0.89		−0.78		−0.89		−0.87		−0.76	
(ΔR, Δ Spread)	−0.07		0.19		0.35		0.07		0.19	

Data sources listed in the appendix to this article.
[1]Data for changes are from May 1977 to June 1987.
[2]Critical value for 95 percent confidence level is 0.18; for 99 percent confidence level, it is 0.23.

and Japan. For the other three countries, this correlation is even negative. In first differences, the correlations between the long rate and the spread are always positive, though significantly so only in the United Kingdom, Japan and Canada, while the changes in the short rates remain significantly negatively correlated with the changes in the spread.

Table 2 presents correlations of rates across countries that allow a preliminary assessment of whether and how rates are linked internationally; the critical level for 5 percent significance is the same as in table 1, 0.18. All long rates appear to be highly correlated in levels. This correlation is strongest among the United States, Canada and West Germany. The same is true for the level of short rates. While changes in long rates are significantly positively correlated across all five countries, only the United States and Canada exhibit a strong significant positive correlation between changes in short-term interest rates. Changes in short-term rates in West Germany and Canada, as well as in West Germany and Japan, are marginally significantly related but the other seven country pair correlations are not.

The strong and significant correlations for both long-term interest rate levels and changes across all five countries suggest that these countries experienced strongly similar inflationary developments between 1977 and 1987.[18] The fact that there is generally an absence of a significant correlation between contemporaneous short-rate changes is important for at least two reasons. First, it suggests that the period was characterized by a free float. Second, it suggests that the strong positive correlation of changes in long rates does not arise through a term structure transmission mechanism that runs from foreign short rates (and associated

[18]Monthly rates of increase in consumer prices also support this suggestion. The smallest pairwise correlation over this period is 0.17 for Germany and Japan, and for Canada and the United Kingdom; these are significant at a 6.5 percent significance level. The other eight pairwise correlations exceed 0.33 and are significant at a 1 percent level. On the same basis (and like the long-rate results above), the mean inflation rate is not significantly different for Germany and Japan, for the United States and Canada, or for Canada and the United Kingdom. The other seven pairwise comparisons are significantly different from zero and the rank ordering is the same as for long rates.

Table 2

Correlations of Levels and Changes of Interest Rates in Five Countries (April 1977 to June 1987)

	United States	United Kingdom	Japan	Germany	Canada
Short-term rate[1]					
United States	1.00				
United Kingdom	0.58	1.00			
Japan	0.43	0.57	1.00		
Germany	0.80	0.68	0.63	1.00	
Canada	0.88	0.63	0.43	0.90	1.00
Long-term rate					
United States	1.00				
United Kingdom	0.71	1.00			
Japan	0.68	0.71	1.00		
Germany	0.91	0.80	0.80	1.00	
Canada	0.97	0.73	0.64	0.91	1.00
Changes in the short-term rate[2]					
United States	1.0				
United Kingdom	−0.01	1.0			
Japan	0.01	−0.03	1.0		
Germany	0.13	0.05	0.19	1.0	
Canada	0.34	0.17	0.09	0.18	1.0
Changes in the long-term rate[2]					
United States	1.0				
United Kingdom	0.33	1.0			
Japan	0.35	0.35	1.0		
Germany	0.52	0.32	0.53	1.0	
Canada	0.80	0.32	0.30	0.48	1.0

[1]Critical value for 95 percent confidence level is 0.18; for 99 percent confidence level, it is 0.23.
[2]Data for changes are from May 1977 to June 1987.

foreign long-rate movements) to domestic short rates and, again via a term structure, to domestic long rates. These implications can be tested more directly using domestic term structure equations.

Domestic Term Structure Estimates

The domestic term structure equation 3 is used to examine international linkages.[19] The coefficient β_1 involves the constraint that the effect of R_{t-1} is equal and opposite to that of i_{t-1}, given Δi_t and Δi_{t-1}. Viewed another way, the term i_{t-1} enters equation 3 through three right-hand-side terms $(S_{t-1}, \Delta i_t, \Delta i_{t-1})$. Therefore, unconstrained estimates of the equation are used to avoid any bias imposed by the constraint and to examine each term in the equation. The unconstrained version of equation 3 used here is:

$$(5)\quad \Delta R_t = \beta_0 + \beta_1 R_{t-1} + \beta_2 \Delta i_t + \beta_4 i_{t-1} - \beta_3 i_{t-2} + \varepsilon_t.$$

If the constraint in equation 3 holds, β_4 equals $(\beta_3 - \beta_1)$. Insignificant terms generally are omitted in the estimates of equation 5 that are reported in table 3. In particular, the i_{t-2} term is generally insignificant and omitted. In this case, β_4 would equal $-\beta_1$ if the spread constraint holds; β_4 can be compared directly with the coefficient on R_{t-1}. Additional lags of long-term and of short-term rates up to four months earlier were checked for significance, but their addition to the table 3 equations was uniformly rejected.

[19]Estimates (not reported) of equation 1 for ΔR_t and a short-rate equation for Δi_t have little or no explanatory power; only four of the 20 intercept and slope terms are significantly different from zero. These are the positive lagged spread coefficients in the short-rate equations for the United States, United Kingdom and Japan, and a significant negative constant in the Japanese equation. Often (three of five cases), the insignificant lagged-spread coefficient (β_1) in the long-rate equation is negative, contrary to the theory.

Table 3

Domestic Long Interest Rate Regressions (September 1977 to June 1987)

	$\bar{R}_2$	DW	h	SE	$\hat{\rho}$
United States					
$\Delta R_t = 0.30 + 0.26\Delta i_t + 0.09 i_{t-1} - 0.10 R_{t-1}$	0.33	2.04	−0.23	0.45	–
(1.49) (7.28) (3.42) (−3.34)					
Canada					
$\Delta R_t = 0.50 + 0.33\Delta i_t + 0.07 i_{t-1} - 0.11 R_{t-1}$	0.27	2.00	0.00	0.48	–
(1.93) (6.20) (2.66) (−2.85)					
United Kingdom					
$\Delta R_t = -0.01 + 0.30\Delta i_t - 0.12\Delta i_{t-1}$	0.24	1.87	–	0.52	–
(−0.12) (5.81) (−2.33)					
West Germany					
$\Delta R_t = 0.91 + 0.23\Delta i_t + 0.08 i_{t-1} - 0.18 R_{t-1}$	0.25	1.86	1.40	0.27	0.28
(2.32) (6.14) (2.17) (−2.36)					(2.17)
Japan					
$\Delta R_t = -0.02 + 0.06\Delta i_t$	0.01	1.92	–	0.27	–
(−0.90) (1.39)					

For the United States, Canada and West Germany, the coefficient on the lagged spread, indicated by that on R_{t-1} in table 3, is negative.[20] The observation of a negative and significant coefficient for β_1 is a rejection of the expectations hypothesis, but, as noted above, there may be sound reasons for this common empirical result. For our purposes, all that is important is that R_{t-1} has a statistically significant effect on ΔR_t in three of the countries and, therefore, should be controlled for in testing international linkages.

In Japan, neither the lagged long rate nor short rate have any significant effect; in fact, the change in the long rate is essentially uncorrelated with any domestic interest rate information. No lagged short rate changes enter significantly in equation 5, except in the United Kingdom, where β_3 and β_4 are equal in magnitude but β_1 is zero. The current change in the short rate is the most powerful explanatory variable for the change in the long rate; for all countries except Japan, a 1 percent change in the short-term interest rate raises the long rate by about a quarter of a percent in the same month.

Table 4 contains similar domestic regression results for the change in the short rate in each country. Past values of both short-term and long-term interest rates for up to four periods were examined sequentially, both individually and jointly, to see if they provided statistically significant explanatory power for the change in the short-term interest rates. For all countries, there is a significant positive relation between the current change in the short rate and the first or second month's lagged change in the long rate.[21] This is broadly consistent with the expectations theory that indicates the change in the current long rate reflects changes in expected future short rates. If these expectations are realized, the change in the long rate presages these future short-rate changes.

In the Canadian case, the short rate is a three-month rate instead of the one-month rate that is available for the other countries; the use of a three-month rate imparts a natural second-order moving average process in the residuals of this

[20] These three equations in table 3, and in table 6 below, include lagged dependent variables so the Durbin-Watson d-statistic (labeled DW in the tables) is not the appropriate test for autocorrelation. This problem arises in tables 4 and 5 below, as well. The Durbin h-statistic is computed whenever the number of observations is not too large to prevent this calculation. In tables 3 and 6, h-statistics can be computed and they reject the presence of significant autocorrelation. The critical value is 1.65. For the equations for West Germany, a correction for first-order serial correlation is necessary and its estimated coefficient, p, is indicated in the tables. There is no indication of further significant autocorrelation in the equations, however.

[21] The computed h-statistics indicate the absence of significant autocorrelation. The statistic cannot be computed for the short-term interest rate equations in table 4 for Canada or the United Kingdom. In these countries, Durbin's alternative test that regresses errors on the lagged error and all right-hand-side variables is used. The coefficient on the lagged error term provides the test statistic for autocorrelation. This coefficient is not statistically significant in either country, so no correction for autocorrelation was computed.

Table 4

Domestic Short-Rate Regressions (September 1977 to June 1987)

	$\bar{R}_2$	DW	h	SE
United States				
$\Delta i_t = 1.15 - 0.13i_{t-1} + 0.73\Delta R_{t-1}$	0.14	1.96	0.21	1.11
(3.22) (−3.36) (3.83)				
Canada				
$\Delta i_t = 0.61 + 0.24\Delta i_{t-1} - 0.05i_{t-2} + 0.35\Delta R_{t-1}$	0.20	2.01	N.C.	0.76
(2.38) (2.49) (−2.45) (2.41)				
United Kingdom				
$\Delta i_t = -0.31 - 0.25\Delta i_{t-1} - 0.13i_{t-2} + 0.57\Delta R_{t-1}$	0.13	2.11	N.C.	0.87
(−0.55) (−2.39) (−2.80) (3.69)				
$+ 0.15R_{t-2}$				
(2.09)				
West Germany				
$\Delta i_t = -0.00 - 0.16\Delta i_{t-1} + 0.46\Delta R_{t-2}$	0.06	2.03	−0.55	0.62
(−0.02) (−1.82) (2.48)				
Japan				
$\Delta i_t = -0.06 - 0.14i_{t-1} + 0.50\Delta i_{t-3}$	0.35	1.73	1.60	0.46
(−0.24) (−3.65) (6.71)				
$+ 0.45\Delta R_{t-1} + 0.13R_{t-2}$				
(2.80) (2.46)				

N.C. means the h-statistic cannot be computed.

equation.[22] Correction for this simply affects the standard error of the reported coefficients; except for the constant and lagged dependent variables, no standard error is reduced (or t-statistic raised) by more than 5 percent, so that the variable selection process is unaffected.[23]

Although in most countries the dynamics appear to be more complicated for the short rates than the long rates, the explanatory power of the estimated equation is rather low, except in Japan. In Japan, most of the explanation comes from the three-period lagged change in the short rate. Outliers are not the source of this curious dynamic relation whose explanation is unknown to us. In general, only a small fraction of future short-rate changes is explained with such domestic information; current changes in the short rates are largely unexplained.[24]

Foreign Influences on Domestic Rates

The estimates in table 3 generally show that typical determinants of the domestic term-structure, like lagged spread information and current short-rate changes, provide significant and similar information across countries. These estimates can be used to examine whether foreign short-term interest-rate changes exert an independent influence on the domestic term structure. The correlation evidence above indicates that long rates are systematically linked across countries.

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[22] Hansen and Hodrick (1980) point out this problem for equations such as this. Note that this problem could also arise for the United States for data after April 1984 because of data problems described in the appendix, but we could find no evidence of bias due to this in the U.S. equations in tables 4 or 5.

[23] The differences in the information content apparently shows up in the positive coefficient on Δi_{t-1}, unlike the negative coefficients for this variable in other countries. For one-month rates in other countries, a rise in the rate is systematically related to a subsequent decline; a rise in the three-month rate in Canada is related systematically to a rise in the next month's three-month rate.

[24] Bisignano (1983) specifies a long-rate term structure equation that includes either the realized change in the short rate or the news in the short rate; the difference is marginal. He also concludes that current short-rate changes are unpredictable. Krol (1986) examines the impact of current and lagged domestic short-term interest rate changes on Eurodollar bond rates and doesn't find a significant effect for lagged changes; only current, U.S. short-term interest rate changes appear to be relevant in explaining Eurodollar bond rate changes.

Table 5

Short-Rate Regressions with Changes in Foreign Short Rates as Explanatory Variables (September 1977 to June 1987)

	$\bar{R}_2$	DW	h	SE	$\hat{\rho}$
United States					
$\Delta i_t^{US} = 1.22 - 0.14 i_{t-1}^{US} + 0.44 \Delta R_{t-1}^{US} + 0.41 \Delta i_t^{CA}$	0.21	2.10	−0.50	1.07	–
(3.53) (−3.69) (2.16) (3.17)					
Canada					
$\Delta i_t^{CA} = 0.42 + 0.27 \Delta i_{t-1}^{CA} - 0.04 i_{t-2}^{CA} + 0.26 \Delta R_{t-1}^{CA}$	0.29	2.23	−0.20	0.72	–
(1.70) (2.97) (−1.77) (1.89)					
$+ 0.21 \Delta i_t^{US} + 0.15 \Delta i_t^{UK}$					
(3.57) (2.06)					
United Kingdom					
$\Delta i_t^{UK} = -0.31 - 0.25 \Delta i_{t-1}^{UK} - 0.13 i_{t-2}^{UK} + 0.57 \Delta R_{t-1}^{UK}$	0.13	2.11	N.C.	0.87	–
(−0.55) (−2.39) (−2.80) (3.69)					
$+ 0.15 R_{t-2}^{UK}$					
(2.09)					
West Germany					
$\Delta i_t^{WG} = 0.00 - 0.43 \Delta i_{t-1}^{WG} + 0.35 \Delta R_{t-2}^{WG} + 0.32 \Delta i_t^{JP}$	0.11	1.95	N.C.	0.60	0.32
(0.05) (−3.52) (1.82) (3.41)					(2.35)
Japan					
$\Delta i_t^{JP} = -0.03 - 0.16 i_{t-1}^{JP} + 0.53 i \Delta i_{t-3}^{JP} + 0.41 \Delta R_{t-1}^{JP}$	0.40	1.79	1.36	0.44	0.24
(−0.08) (−3.09) (7.39) (2.64)					(2.09)
$+ 0.15 R_{t-2}^{JP} + 0.17 \Delta i_t^{WG}$					
(2.16) (2.75)					

N.C. means the h-statistic cannot be computed.

The absence of systematic significant positive correlations of changes in short rates, however, raises the question of whether and how short or long rates are linked internationally through a term structure relation. The question examined is whether current interest-rate changes abroad exert an independent influence on domestic interest rates beyond the influence of domestic information.[25]

Table 5 shows the international linkages between short rates. For each country, current changes in all foreign short rates are added to the domestic equation from table 4; insignificant additions (individually or as a group) are omitted.[26] The data show a strong two-way relationship between changes in short rates in the United States and Canada. A similar relationship exists between Japan and West Germany. No foreign influence is significant for the United Kingdom, suggesting that the British authorities followed relatively independent policies, especially with regard to the exchange rate.[27] The interaction between the U.S. and Canadian financial markets reflects the large degree of integration of these economies and their geographical relation.

The lack of a relationship between changes in short rates in the United States and those in West Germany and Japan could be surprising to many analysts. Monetary authorities in West Germany and Japan generally are assumed to have at least

[25]Lagged information from foreign markets should not be important for current domestic changes. Even if such lagged variables were significant, those patterns should be unstable over time, reflecting specific occurrences without having anything to do with stable transmission mechanisms. The significance of lagged information was examined; it is significant in some cases, but not stably so. Thus, the results are omitted.

[26]As in table 4, correction for a second-order moving-average process in the Canadian equation has no effect on the coefficients, summary statistics or variable selection. The h-statistic reported for Canada is that found from the moving-average-corrected standard error of the coefficient for the lagged dependent variable. The h-statistic indicates that first-order autocorrelation is rejected for the United States, Canada and, after correction, Japan. In the United Kingdom and West Germany, the alternative test discussed in footnote 21 above rejects autocorrelation.

[27]Over the sample period, the United Kingdom was not part of any exchange-rate system nor was it the focus of international cooperation arrangements. Most of the discussion of international policy coordination focused on the United States vs. West Germany and Japan.

Table 6
Long-Rate Regressions with Changes in Foreign Short Rates As Explanatory Variables (September 1977 to June 1987)

	$\bar{R}_2$	DW	h	SE	$\hat{\rho}$
United States					
$\Delta R_t^{US} = 0.28 + 0.23\Delta i_t^{US} + 0.07 i_{t-1}^{US} - 0.08 R_{t-1}^{US}$	0.34	2.04	−0.20	0.45	–
(1.39) (5.82) (2.39) (−2.55)					
$+ 0.11\Delta i_t^{CA}$					
(1.89)					
Canada					
$\Delta R_t^{CA} = 0.34 + 0.23\Delta i_t^{CA} + 0.07 i_{t-1}^{CA} - 0.10 R_{t-1}^{CA}$	0.40	1.93	0.35	0.44	–
(1.45) (4.49) (3.06) (−2.84)					
$+ 0.17\Delta i_t^{US} + 0.10\Delta i_t^{UK}$					
(4.72) (2.30)					
United Kingdom					
$\Delta R_t^{UK} = -0.01 + 0.27\Delta i_t^{UK} - 0.13\Delta i_{t-1}^{UK} + 017\Delta i_t^{CA}$	0.29	1.96	–	0.50	–
(−0.15) (5.43) (−2.53) (3.07)					
West Germany					
$\Delta R_t^{WG} = 0.57 + 0.18\Delta i_t^{WG} + 0.06 i_{t-1}^{WG} - 0.12 R_{t-1}^{WG}$	0.48	1.88	0.78	0.23	0.23
(2.10) (5.53) (2.26) (−2.28)					(2.05)
$+ 0.07\Delta i_t^{US} + 0.13\Delta i_t^{CA} + 0.04\Delta i_t^{UK}$					
(3.72) (4.52) (1.88)					
Japan					
$\Delta R_t^{JP} = -0.02 + 0.05\Delta i_t^{JP} + 0.05\Delta i_t^{US} + 0.08\Delta i_t^{CA}$	0.14	1.98	–	0.26	–
(−1.02) (1.18) (2.19) (2.82)					

implicit exchange-rate objectives with respect to the U.S. dollar, even if they otherwise try to remain as independent as possible from the United States. Nevertheless, no significant linkages between news in the United States, as reflected in its change in the short-term interest rate, and short-rate changes in West Germany and Japan were found.

The significant relationship between changes in short-term interest rates in West Germany and Japan may also surprise analysts. Yet this positive relationship, and the absence of one for the United States and either West Germany or Japan, are stable results; both characteristics are found in estimates for only the first or the last half of the sample period.

Central bank exchange-rate policies may not be so sufficiently rigid and automatic that foreign developments are incorporated instantaneously in domestic short rates. If there is a longer-run exchange-rate objective, however, foreign changes in short rates will contain information about future changes in domestic short rates; therefore, they should produce immediate revisions of domestic long rates. Table 6 displays evidence examining this hypothesis. All foreign short-rate changes were added to the preferred equations from table 3; only the significant terms are reported in table 6.

An interesting result is that the Canadian short-rate change affects most countries. This phenomenon probably arises because of the use of a three-month rate for Canada. Changes in this yield are more forward-looking, reflecting the expected yield for the month *and* the subsequent two months.[28] Thus, the Canadian yield used here contains more information than the other short-term rates, so its significance may arise because of this difference rather than unusual properties of the Canadian financial market.

[28] At a point in time, the same information is used to determine both the one-month and the three-month interest rate. The latter, however, reflects expectations for the two months beyond the current one and is influenced not only by current information influencing this month's one-month rate, but also by current information that is specific to the subsequent two months. In the simplest expectations model, the three-month rate is approximately equal to the arithmetic average of the current and two prospective expected one-month rates, or the one-month rate plus two-thirds of the expected change in the one-month rate, one month from now and one-third of the change in the one-month rate, two months from now.

The change in the long rate in the United States, given the influence of the current change of the U.S. short rate, is independent of all foreign short-rate movements. The change in the Canadian rate is included in the U.S. equation, despite the fact that it is marginally insignificant, because it is strongly significant in the other three countries. On the other hand, the change in the U.S. short rate enters significantly in the long-term rate equations for Canada, Japan and West Germany, suggesting that these three countries follow implicit exchange-rate policies that involve infrequent and variable interventions in money and currency markets, with lags beyond one month. The long-rate equations for Canada and West Germany improve considerably with the inclusion of foreign short rates. The U.K. long rate is not significantly affected by the U.S. short rate. The results, with the exception of the U.K. equation, are consistent with a view of the world in which foreign financial markets react to movements in U.S. short-term interest rates.

Except for the problematical Canadian influence, the international linkages shown in table 6 are sensitive to the period chosen. One of the simplest ways to test for temporal stability of regression estimates is to break the sample period in half to investigate whether the estimates are significantly different across the periods. Based on such a consideration, the equations in table 6 were re-estimated for each half of the sample period. The significance of foreign influences virtually vanishes when only the last half of the sample period (1982:7–1987:6) is used. Only the Canadian rate change remains significant in the U.S. and U.K. equations, and even this variable disappears in the equations for West Germany and Japan. All the other significant foreign influences shown in table 6 drop out; the remaining estimates in the table are virtually unaffected. Thus, although foreign changes in short-term rates sometimes influence domestic long rates, this influence is not robust.[29]

The results in table 2 show that correlations between changes in long rates internationally are pairwise significant in all cases; this result persists even when the sample is split into approximately equal subperiods. While long rates are not linked strongly through currency and money markets, there are significant and stable relationships between them. Apparently, the integration of international capital markets assures that nominal long-term rates move together, despite the fact that this integration usually is quite direct and does not arise from the short-term considerations in currency and money market emphasized by term structure explanations.

SUMMARY AND CONCLUSION

This article explores international linkages among interest rates. The framework used for this purpose is a conventional model of the domestic term structure. In a term-structure framework, a change in a foreign short-term rate would be expected to alter the foreign long-term rate and, if interest rates are linked internationally, to alter domestic short-term rates as well. The latter change, again via a domestic term-structure relation, would change domestic long-term rates. This article tests these relationships. It also tests whether foreign short-term rate changes exert an independent term structure influence, given the current change in the domestic short-term rate.

When foreign interest rates are added to the domestic, short-term interest rate equations, there is some marginal, though segmented, connection between rates across countries. Changes in short-term rates in either Canada or the United States affect short-term rates in the other. In addition, changes in the U.K. short-term rate directly influence interest rates in Canada. There is a similar bidirectional connection between short-term rates in Japan and West Germany. There is no significant linkage, however, between changes in U.S. short-term interest rates and changes in short-term rates in the United Kingdom, Japan or West Germany, over the full period examined here.

The evidence suggests that long-term nominal interest rates are related closely and directly across countries. The addition of changes in foreign short-term rates to the domestic long-term

[29]The foreign influences in table 5 are somewhat more robust in a similar test. For the latter half of the sample period, the significant influences of Canadian short rates on U.S. short rates, U.K. short rates on Canadian short rates and short rates in Japan on those in Germany remain significant. The bidirectional elements from the United States to Canada and from Germany to Japan disappear. Thus, no short-run influence is left running from U.S. short rates to those in any of the countries.

rate equations, however, generally provides no significant information. Also, short-term interest rate changes are not contemporaneously correlated across countries. Thus, the relationship between long-term nominal interest rates does not arise indirectly through an international term-structure transmission or through common short-term-rate movements that are transmitted through the domestic-term structures. Neither of these channels is found to be significant.

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Appendix
The Interest Rate Data

All data are end-of-month values.

Canada

Short rate: interest rate on three-month Treasury bill rates from the database of the Federal Reserve Board.
Long rate: interest rate on government bonds with a remaining maturity of 10 years from the database of the Federal Reserve Board.

Japan

Short rate: one-month Gensaki rate provided by the Bank of Japan.
Long rate: average yield to maturity on a number of government bonds with a constant remaining maturity of nine years, provided by the Bank of Japan.

United Kingdom

Short rate: one-month interbank deposit rate from the *Financial Times.*
Long rate: average yield to maturity on a number of government bonds with remaining maturity between eight and 12 years from the *Financial Times.*

United States

Short rate: Until April 1984, the yield on one-month T-bill rates was available. From May 1984 to June 1987, the series was updated using the interest rate on three-month T-bill rates. A test of the adequacy of this approximation was performed by regressing the one-month T-bill rate on a constant and the three-month T-bill rate over the period when both were available, January 1978 to April 1984. The constant is not significantly different from zero, while the coefficient on the three-month rate is not significantly different from one. The other statistics also justified the approximation. The one-month data were provided by Professor Alex Kane. The three-month data came from the database of the Federal Reserve Board.
Long rate: the series is the yield to maturity of government securities bonds with remaining maturity of 10 years from the database of the Federal Reserve Board.

West Germany

Short rate: one-month interbank deposit rate from the *Frankfurter Allgemeine.*
Long rate: average yield to maturity on a number of government bonds with remaining maturity over eight years from the *Frankfurter Allgemeine.*