The relation between the term structure of interest rates and Canadian economic growth

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Abstract. The Canadian bond market contains valuable information about the future real economic growth. These forecasts, which are based on a simple asset-pricing theory, are more accurate than the ones based on time-series models and compare favourably with professional forecasts. Significantly, the term structure of interest rates in Canada can forecast Canadian economic growth over and above the information contained in the U.S. term structure. In addition, evidence is presented that suggests that the Canadian term structure contains information relevant for forecasting the part of Canadian economic growth that is unrelated to the U.S. business cycle.

La relation entre la structure temporelle des taux d'intérêt et la croissance économique canadienne. Le marché obligataire canadien contient des renseignements importants sur la croissance économique réelle future du pays. Ces prévisions, construites sur une théorie simple du prix des actifs, sont plus précises que celles construites sur les modèles de séries chronologiques et se comparent favorablement aux prédictions des experts. Ce qui plus est, la structure temporelle des taux d'intérêt au Canada a la capacité de prédire la croissance économique canadienne d'une manière plus complète que celle des Etats-Unis pour la croissance économique américaine. De plus, on montre que la structure temporelle canadienne des taux d'intérêt au Canada contient des renseignements pertinents pour la prévision des taux de croissance qui ne sont pas reliés au cycle économique américain.

1. INTRODUCTION

On average, long-term interest rates are higher than short-term interest rates. This implies an upward sloping term structure or yield curve. However, the shape of the

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yield curve changes through time. Harvey (1988) documents a systematic relation between the stage of the business cycle and the shape of the yield curve. While the link between the yield curve and economic activity is implied by many macroeconomic theories, Harvey uses the consumption-based asset-pricing model to derive a forecasting equation that links the stage of the yield curve to expected economic growth. Negatively sloped yield curves (term structure inversions) should precede recessions and positively sloped curves should foreshadow economic recovery. Empirical work using U.S. data, such as Harvey (1989), suggests that the slope of the yield curve is a valuable forecasting variable for the real business-cycle.

The goal of this paper is to explain the link between the bond market and the real business cycle and to apply this analysis to the real business cycle in Canada. While most previous empirical work has focused on the United States, in this paper I measure the ability of the yield curve to predict Canadian economic growth. My analysis indicates that there is important information in the Canadian yield curve that is relevant for forecasting economic growth.

I also analyse whether the predictive power of the Canadian yield curve is spurious. That is, previous empirical work shows that the U.S. term structure predicts U.S. economic growth. Given the correlation between the U.S. and Canadian business cycles and the correlation between U.S. and Canadian interest rates, is there any incremental information in the Canadian term structure? In two tests I show that there is incremental information. First, I show that the part of the Canadian term structure that is uncorrelated with the U.S. term structure is able to predict Canadian economic growth. Second, I show that the part of Canadian economic growth that is uncorrelated with U.S. economic growth can be predicted with the Canadian term structure. Even though Canada and the U.S. capital markets are highly integrated, U.S. interest rate indicators alone are not sufficient to forecast the state of the Canadian economy.

Finally, since the original research was published in the late 1980s, we have experienced another recession. This provides opportunity for an out-of-sample test of the model. In addition, there were a number of contrasts between the most recent Canadian and U.S. recessions. The Canadian recession started earlier, lasted longer, and was much deeper than the U.S. recession. The behaviour of the Canadian and U.S. term structures is consistent with the most recent business cycle episode. The Canadian term structure inverted earlier, the inversion was more severe, and it lasted longer than the U.S. inversion. In sum, there was unique information in the Canadian term structure that was relevant for forecasting Canadian economic growth.

The paper is organized as follows. In the second section, the economic link between the term structure and real activity is examined. Both a consumption and a production-based explanation of the yield curve behaviour are investigated. In the third section the data used are detailed and some initial results are presented. In the fourth section I explore whether the information in the Canadian yield curve adds anything over and above the information in the U.S. yield curve.

II. THE ECONOMIC LINK BETWEEN BOND PRICES AND REAL ACTIVITY

1. Asset pricing theories and the term structure

Modern asset-pricing theories of Merton (1973), Lucas (1978), and Breeden (1979) link expected returns on assets to the investors' expected consumption plans. Consider the representative investor's portfolio and consumption choice problem. The investor receives a stochastic endowment in an exchange economy. This endowment can be consumed or invested in N assets, which may have many different maturities ($j = 1, \ldots, k$). The first-order conditions that characterize the solution to the portfolio choice decision are

$$E\left[\delta^j \frac{U'(C_{t+j})}{U'(C_t)}(1 + R_{i,j,t}) - 1 \middle| Z_t\right] = 0, \quad \text{for} \quad i = 1, \ldots, N;\ j = 1, \ldots, k, \tag{1}$$

where $R_{i,j,t}$ is the real j-period return on asset i from time t to time $t+j$ and δ is the investor's constant time discount factor. Expectations at time t are conditioned on the information set Z_t, which contains all the information about the economy available at t. Of course, the investor cannot spend at time t more than his endowment and the proceeds from any asset sales.

Therefore are $N \times k$ of these conditions, corresponding to the N assets available and k holding periods. Given the focus on the yield curve, let us concentrate only on government bonds. $R_{j,t}$ represents the real yield (or return) on a j-period government instrument.

Equation (1) is the multiperiod (and stochastic) generalization of the standard two-period consumption problem. The consumer has some endowment, E, and can choose to invest some of the endowment at rate r. This investment will reduce consumption today but increase consumption tomorrow. In the two-period problem, optimal consumption is determined by the tangency of the indifference curve to line that represents the trading of consumption from today to tomorrow. In this simple framework, the interest rate is directly linked to consumption opportunities today and tomorrow.

Equation (1) describes a non-linear relation between marginal utility ratios and interest rates. If the real interest rate is known, however, it can be brought outside the expectation operator and we can solve for the expected marginal utility ratio. With many utility functions, the marginal utility ratio can be linked to the growth rate in aggregate consumption expenditures. With this specification, the real interest rate should forecast future economic growth.

In order to use equation (1) in a forecasting model, we assume that the utility function takes the form implied by constant relative risk aversion:

$$U(C, \alpha) = \begin{cases} \dfrac{C^{1-\alpha} - 1}{1 - \alpha}, & \text{if } \alpha > 0,\ \alpha \neq 1; \\ \ln(C), & \text{if } \alpha = 1. \end{cases} \tag{2}$$

We can rewrite (1) as

$$E_t\left[\delta^j \left\{\frac{C_t}{C_{t+j}}\right\}^\alpha (1 + R_{j,t})\right] = 1, \qquad j = 1, \ldots, k, \tag{3}$$

where α is the coefficient of relative risk aversion and E_t represents expectations conditioned on information available at time t.

To obtain a linear forecasting equation, assume that consumption and returns are stationary jointly lognormally distributed. Then (3) implies

$$\ln E_t\left[\delta^j\left\{\frac{C_t}{C_{t+j}}\right\}^{\alpha}(1+R_{j,t})\right] = E_t\left[\ln\left(\delta^j\left\{\frac{C_t}{C_{t+j}}\right\}^{\alpha}(1+R_{j,t})\right)\right] + \frac{1}{2}\operatorname{Var}_t\left[\ln\left(\delta^j\left\{\frac{C_t}{C_{t+j}}\right\}^{\alpha}(1+R_{j,t})\right)\right] = 0. \tag{4}$$

We can rearrange (4):

$$E_t\Delta c_{t:t+j} = E_t\theta r_{jt} + j\theta\rho - \theta v_{jt}/2, \tag{5}$$

where r is the log of one plus the interest rate. Δc represents the log consumption growth rate, ρ is the consumer's rate of time preference (equals $-\ln(\delta)$ or minus the log of the time discount factor), $\theta = 1/\alpha$ is the risk tolerance, and v_{jt} represents the conditional variance of the log interest rate plus the log consumption growth.

Notice that many factors affect the expected economic growth: the expected real interest rate, the tolerance for risk, the consumer's rate of time preference, the expected volatility of interest rates, the expected volatility of economic growth, and the covariance between the interest rates and economic growth.

To study the information in the term structure of interest rates, equation (5) can be written for $j = 1$ (the short-term interest rate) and $j = k$ (the long-term interest rate). Differencing these equations gives us a model to predict one-step ahead economic growth:

$$\Delta c_{t+1:t+k} = a + \theta(\text{Yield Spread})_t + u_{t+k}. \tag{6}$$

To get this simple model, a number of assumptions have been made. First, the intercept captures the conditional variance of the consumption-returns process, which is assumed to be constant. Second, the yield spread will be defined as the difference between nominal *annualized* long-term and short-term yields to maturity. Harvey (1986) shows that the nominal yield spread will closely approximate the expected real yield spread under a number of specifications for the inflation process.[1]

1 For example, for integrated moving-average models of the inflation rate, the annualized inflation forecasts are equal irrespective of the forecasting horizon. Also for first-order autoregressive models where the autoregressive parameter is close to unity, the annualized inflation forecasts are very similar over multiple horizons, as long as the horizons are not too far into the future. While not reported, the Canadian inflation process has these properties. Using the quarterly changes in the real GDP deflator, the AR parameter in an ARMA(1,1) is 0.94 and less than two standard errors from 1.0. In addition, the variance of the residuals is 0.3466. In the IMA(1,1) model, the variance of the residuals is only slightly higher: 0.3499. Hence, the Canadian data fit into these two categories. There is also evidence that the term structure predicts future inflation. Most of this evidence, however, concerns longer-term inflation. See, for example, Garner (1987).

2. Consumption and production interpretations of the yield curve

Now consider the consumption intuition behind the linear forecasting specification (6). In a simple exchange economy, if investors expect a recession next year, they will shift their investments from short-term deposits to a longer-term bond. The bond delivers a pay-off when the investor most needs it. This is the idea of consumption smoothing. Risk-averse investors are willing to give up some of their earnings in good times to protect themselves against much lower earnings in a recession. In other words, there is an incentive to hedge.

The logical vehicles for this hedging are government fixed-income securities. There is virtually no chance of default with a government bond. Furthermore, the nominal pay-offs are known when the bond is purchased. How will this hedging affect the yield curve? Consider the above scenario with investors transferring funds from short-term investments to long-term investments. As more investors demand longer maturity securities, the price is bid upwards (yield moves down). On the short-term side, there is a lower demand and the price drops (yield moves up). The difference between long rates and short rates decreases or may become negative. This implies a flattening or a negatively sloped yield curve.

The insight is that the flattening happens in advance of the downturn. Prices are set today to reflect the expectations of future economic growth. That is, hedging positions are set up well in advance of possible downturns.

The demand for hedging will determine how closely the yield curve moves with the business cycle. The demand for hedging is determined by the *average* risk aversion in the economy. Notice that movement of the yield curve does *not* depend on changing relative risk aversion during the business cycle. The economic model assumes that investors have *constant* relative risk aversion.[2]

A critical ingredient is the average constant relative risk aversion in the economy. If everybody in the economy is risk neutral (zero risk aversion), then investors will not hedge. As a result, the yield curve will not contain information about of future economic growth.

However, most people are risk averse. In order to get people to take the risky investment, the firm must offer a more favourable return. This is why a low-grade or 'junk' bond offers a much higher average return than a government bond. This also explains why stock returns are higher on average than the returns on Treasury bills. As a result, the yield curve should reflect the investors' hedging demands.

The same intuition can be extended to a production economy (see Brock 1982; Cochrane 1991). If firms foresee an economic slowdown, longer-term capital projects become less attractive. Given that firms often match the maturity of their financing with the maturity of the capital projects, the expectation of recession will reduce the number of longer-term corporate bonds coming to the market. This will act to reduce the real yields on longer-term corporate bonds and reduce the slope of the term structure. If firms choose shorter-term capital projects, this could further

2 Of course, constant relative risk aversion implies decreasing absolute risk aversion. That is, as wealth increases, investors become less risk averse. Those with little wealth will exhibit high absolute risk aversion.

reduce the slope of the yield curve by increasing the pressure on the short-term interest rates.

What about other financial assets such as the stock market? Of course, equation (1) can be written in terms of stock returns. A linear forecasting model could be developed linking *expected* real stock returns to future economic growth. However, there are a number of reasons to expect this model to fare poorly. First, there is considerable evidence that the theoretical framework fails when applied to both stock returns and bond returns (see, e.g., Hansen and Singleton 1982; Mehra and Prescott 1985). Second, it is difficult to develop proxies for expected real stock returns. Other researchers, such as Fama (1981) and Cozier and Rahman (1988), have used ex post future returns to proxy for expected returns. With stock returns, however, a large part of the ex post return is unexpected.

The stock returns are much more volatile than bond yields. Unlike the situation for bonds, the cash pay-offs from stocks are not known in advance. While dividends are reasonably predictable, capital gains are not. Furthermore, the stock price, in part, reflects the default risk of the firm – whereas government bonds will not default. Small changes in the assessment of the riskiness of the stock may lead to large swings in the price. As a result, it is difficult to develop ex ante indicators of the stock market.

III. DATA AND RESULTS

1. Data

Equation (6) relates expected consumption growth to the annualized yield spread between short-term and long-term interest rates. The short-term yield is the compounded annual rate for the Bank of Canada ninety-day Treasury bill (DATASTREAM CNB14001). Two longer term rates are considered. The first is the Government of Canada ten-year-and-over bond yield (DATASTREAM CNB14013).[3] The second is Government of Canada one-to-three-year bond yield (DATASTREAM CNB14009). Most of the analysis will concentrate on this second yield, which has a maturity that best reflects the specification of the economic model. These data are available on a monthly basis. The quarterly yields are the arithmetic averages of the yields over the quarter.

The U.S. data includes the bond equivalent yield calculated from the discount rate on the ninety-day U.S. Treasury bill (DATASTREAM USTRB3AV). Two longer rates are also examined: the yield on the constant maturity ten-year bond (DATASTREAM USTRCN10) and the yield on the constant maturity three-year bond (DATASTREAM USTRCN10). Similar to those of the Canadian data, quarterly rates are simple averages of the monthly rates. Both the Canadian and the U.S. interest rate data are available from 1958:Q1 through 1995:Q2.

The asset-pricing model links asset returns to the ratio of marginal utility of

3 There exists a constant-maturity ten-year bond, but the data begin only in 1985.

consumption today to the marginal utility of consumption tomorrow. This ratio determines the rate at which people are willing to borrow or lend funds. Utility is gained from consumption services. Unfortunately, true consumption is never observed. Researchers must use proxies for consumption. Indeed, it is often difficult to interpret tests of the consumption-based model for this reason. Rejections could be driven by misspecification of the model or by the poor quality of the data.

Many tests of the asset-pricing model, such as Hansen and Singleton (1982), use consumption of non-durables and services. Another proxy for the marginal utility ratio is the growth in real Gross National Product. Of course, since true consumption growth is never observed, it is impossible to tell which measure is the best approximation for marginal utility.

Indeed, a large proportion of Gross Domestic Product is personal consumption expenditures. There are some other components that are not directly implied by the model: investment, government spending, and net exports. It is interesting to note that there is a production-based analogue to the consumption model proposed by Brock (1982) and empirically examined by Cochrane (1991). Asset returns are linked to the marginal investment process. Hence, it is of some interest to mix the consumption and investment data.

Perhaps most important, Gross Domestic Product is the most visible of the macroeconomic data. Consumers are more likely to know what the forecast of GDP growth is as opposed to the forecast of real personal consumption of non-durables and services. It is of empirical interest to test whether the term structure is able to predict GDP growth as well as consumption growth.

The output measures include the annual growth in Canadian and U.S. real Gross Domestic Product (both seasonally adjusted) from quarter $t + 1$ to quarter $t + 5$ (DATASTREAM CNGDP...D and USGDP...D). Some of the analysis also examines the annual growth in real Canadian Personal Consumption Expenditures on Non-durables and Services (seasonally adjusted) (DATASTREAM CND20498 and CND20504). Non-durables and services are summed and an annual growth rate is calculated.

2. *Econometric issues*

There are some important econometric issues implied by the timing and overlap of the variables. Since GDP and consumption are available on a quarterly basis, a yield spread observed in the third quarter is used to forecast annual real growth for the next year. The left-hand-side variable is annual growth observed in each quarter. As a result, each growth will have three common quarters. The overlapping nature of the data combined with the fact that yield spread in the third quarter is being used to forecast growth beginning in the *first* quarter of next year induces a fourth-order moving average process in the residuals. The t-statistics from an ordinary least squares regression will be incorrect. The technique of Newey and West (1987) is used to recalculate the t-statistics. The t-statistics are also robust to conditional heteroscedasticity.

3. Predicting Canadian economic growth

Table 1 presents the estimation of (6) over the 1960:1 to 1995:1 period. Three sets of comparisons are presented. First, the predictive power of the three-year yield spread is contrasted with the longer maturity ten-year yield spread. The economic framework suggests that the shorter maturity spread is more appropriate for the estimation. Second, the information in the Canadian term structure relevant for economic growth is contrasted with the information in the U.S. term structure relevant for forecasting U.S. economic growth. Finally, some subperiod analysis is presented (breaking the sample by decades) to assess the stability of the relations between term structures and economic activity.

The results in table 1 establish that the term structure of interest rates in Canada contain important information about economic growth. Consistent with the economic theory, the three-year term structure explains more variation in economic growth than the ten-year term structure. In the full sample, the three-year term structure can explain 47 per cent of real economic growth. While most of the research concentrated on U.S. growth and U.S. term structures, the results suggest that the Canadian term structure contains more information about Canadian economic growth than the U.S. term structure contains about U.S. economic growth. In the full sample, the U.S. term structure explains 30 per cent of the variation in real GDP growth.

The relation between the term structure and economic growth in Canada is remarkably stable through time. In the overall period, the coefficient is 1.1, which is close to what is implied by log utility. The coefficient is more than seven (heteroscedasticity-consistent) standard errors from zero. In the decade subperiods, the coefficient varies from 1.4 (1960–9), 0.9 (1970–9), 1.0 (1980–9), and 1.0 (1980–95).

In contrast, the relation between the term structure and economic growth in the United States is less stable. The overall coefficient is 1.4, which is consistent with a lower weighted average risk aversion in the United States compared with that of Canada. The coefficient varies from insignificant in the 1960s to 2.2 (1970–9), 1.3 (1980–9), and 1.6 (1980–95). In every subperiod since 1970 the U.S. coefficient is higher than the Canadian coefficient.

The first panel of figure 1 presents a graph of the real Canadian GDP growth against the lagged yield spread. If the two series exactly coincided, it would imply $a = 0$, $\theta = 1$ and an R^2 of unity. Of course, the series do not exactly coincide; nevertheless, there is a strong visual correlation between them. The correlation is particulary evident after 1970. Significantly, the yield curve provides accurate forecasts of major economic downturns, including the most recent recession.

The second panel graphs the three-year and ten-year yield curves. Both term structures distinctively vary with the business cycle. However, the three-year spread has greater variation: the peaks are higher and the troughs are lower. This partially accounts for the difference in forecasting power. From table 1, in the 1970–95 period the three-year spread accounts for 53 per cent of the variation in real GDP growth. The 10-year spread accounts for a considerable, but smaller degree of the variation in real GDP, 42 per cent.

TABLE 1
Term structure forecasts of Canadian and U.S. economic growth

Country	Yield spread	Sample	a	θ	$R^2/\bar{R}^2$
Canada	3yr	1960:1–1995:1	3.035	1.099	0.475
			[10.449]	[7.338]	0.472
United States	3yr	1960:1–1995:1	2.077	1.390	0.301
			[5.543]	[5.640]	0.296
Canada	10yr	1960:1–1995:1	3.827	1.626	0.393
			[13.757]	[6.312]	0.389
United States	10yr	1960:1–1995:1	2.078	0.929	0.289
			[5.475]	[5.046]	0.284
Canada	3yr	1960:1–1969:4	3.601	1.391	0.229
			[4.182]	[2.836]	0.209
United States	3yr	1960:1–1969:4	4.385	−0.541	0.015
			[5.563]	[−0.547]	−0.011
Canada	10yr	1960:1–1969:4	4.425	1.800	0.099
			[5.798]	[1.994]	0.075
United States	10yr	1960:1–1969:4	3.616	0.692	0.043
			[5.383]	[1.302]	0.018
Canada	3yr	1970:1–1979:4	3.280	0.936	0.374
			[8.396]	[5.997]	0.358
United States	3yr	1970:1–1979:4	1.303	2.233	0.538
			[2.598]	[6.549]	0.526
Canada	10yr	1970:1–1979:4	4.424	0.738	0.116
			[10.849]	[2.653]	0.093
United States	10yr	1970:1–1979:4	1.391	1.534	0.532
			[2.587]	[6.240]	0.520
Canada	3yr	1980:1–1989:4	3.084	0.996	0.443
			[6.979]	[3.502]	0.429
United States	3yr	1980:1–1989:4	1.738	1.263	0.478
			[4.112]	[4.766]	0.465
Canada	10yr	1980:1–1989:4	3.719	1.440	0.396
			[8.262]	[3.424]	0.380
United States	10yr	1980:1–1989:4	1.634	0.932	0.470
			[3.853]	[4.620]	0.456
Canada	3yr	1980:1–1995:1	2.449	0.957	0.484
			[5.972]	[5.074]	0.476
United States	3yr	1980:1–1995:1	1.446	1.321	0.479
			[3.947]	[5.417]	0.470
Canada	10yr	1980:1–1995:1	3.185	1.557	0.447
			[7.794]	[5.194]	0.438
United States	10yr	1980:1–1995:1	1.293	0.892	0.464
			[3.384]	[5.727]	0.455
Canada	3yr	1970:1–1995:1	2.719	1.031	0.528
			[8.660]	[6.943]	0.523
United States	3yr	1970:1–1995:1	1.480	1.550	0.471
			[4.489]	[6.636]	0.465

TABLE 1 (*Concluded*)

Country	Yield spread	Sample	a	θ	$R^2/\bar{R}^2$
Canada	10yr	1970:1–1995:1	3.545	1.509	0.417
			[11.291]	[5.827]	0.411
United States	10yr	1970:1–1995:1	1.417	1.034	0.446
			[4.243]	[6.620]	0.441

NOTES
The model estimated is: $\Delta GDP_{t+1:t+5} = a + \theta\ \text{YSX}_t + u_{t+5}$. ΔGDP is the annual growth in Canadian or U.S. real Gross Domestic Product (both seasonally adjusted) from quarter $t + 1$ to quarter $t + 5$ (DATASTREAM CNGDP...D and USGDP...D). YSX yield spread of either (i) Government of Canada ten-year and over (DATASTREAM CNB14013) less the compounded annual rate for the ninety-day Treasury bill (DATASTREAM CNB14001); (ii) Government of Canada one-to-three-year (DATASTREAM CNB14009) less the compounded annual rate for the ninety-day Treasury bill; (iii) the U.S. constant maturity ten-year bond (DATASTREAM USTRCN10) less the bond equivalent yield calculated from the discount rate on the ninety-day U.S. Treasury bill (DATASTREAM USTRB3AV); or (iv) the U.S. constant maturity three-year bond (DATASTREAM USTRCN10) less the U.S. Treasury bill. The quarterly yields are the arithmetic average of the yields over the quarter. t-ratios are in brackets. The standard errors are corrected for the implied fourth-order moving average process and for conditional heteroscedasticity.

The first panel of figure 2 presents the U.S. GDP growth and the lagged three-year spread. Similar to the pattern of the Canadian graph, the variation in the term structure mimicks variation in real GDP growth. From the graph, it is obvious that the term structure has very low variance in the 1960s. This is consistent with the insignificant relation during this period estimated in table 1. After 1970 the term structure successfully forecasts all of the economic downturns, including the difficult-to-forecast 'double-dip' recessions in 1980–3. In panel B three spreads are graphed: three-year, five-year, and ten-year. Similar to the findings of the Canadian analysis, different term structure measures in the United States move together.

There is an interesting difference between the U.S. term structure's ability to forecast U.S. growth and the Canadian term structure's ability to forecast Canadian economic growth. In particular, during the most recent recession, the U.S. term structure experienced a very mild inversion, which correctly signalled a recession. However, the magnitude of the recession was not forecast correctly. In contrast, the Canadian inversion was more dramatic and it correctly signalled a deep recession. Indeed, the Canadian inversion was the most severe in the sample. The most recent recession was also the most serious for Canada in the last thirty years.

Table 2 replicates the analysis for real consumption of non-durables and services growth. The results are broadly consistent with those reported in table 1. In the full sample the three-year yield spread is able to explain 26 per cent of the variation in the growth in personal consumption of non-durables and services. The theta coefficient is 0.5, reflecting the fact that consumption growth is less volatile than GDP growth. Aside from an insignificant relation in the 1960s, the coefficient is also stable: 0.6 (1970–9), 0.5 (1980–9), and 0.4 (1980–95).

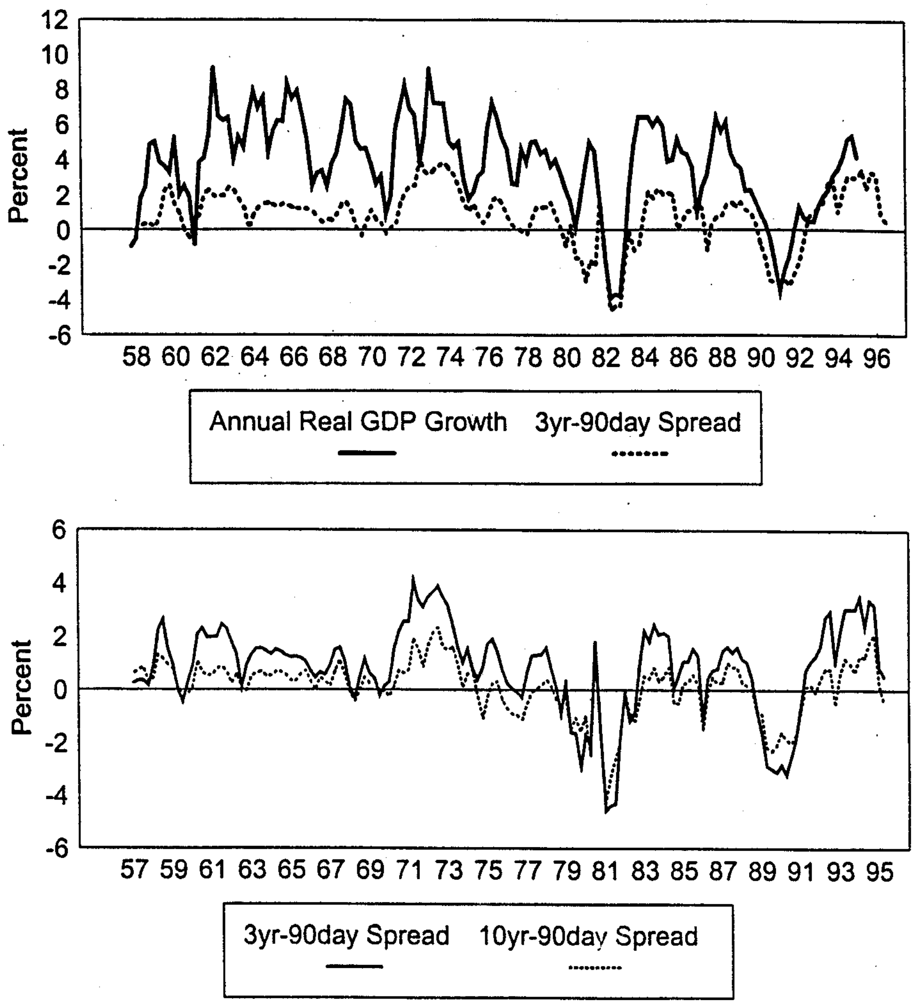

FIGURE 1 Canadian annual real GDP growth and lagged yield spreads

NOTE

In panel A, GDP is the annual growth in Canadian real Gross Domestic Product (seasonally adjusted) (DATASTREAM CNGDP...D). The yield spread is Government of Canada one-to-three-year (DATASTREAM CNB14009) less the compounded annual rate for the ninety-day Treasury bill (DATASTREAM CNB14001) and it is lagged five quarters. The quarterly yields are the arithmetic average of the yields over the quarter. In panel B, two yield spreads are plotted: the Government of Canada ten-year and over (DATASTREAM CNB14013) less the compounded annual rate for the ninety-day Treasury bill (DATASTREAM CNB14001) and Government of Canada one-to-three-year (DATASTREAM CNB14009) less the compounded annual rate for the ninety-day Treasury bill. Neither spread is lagged.

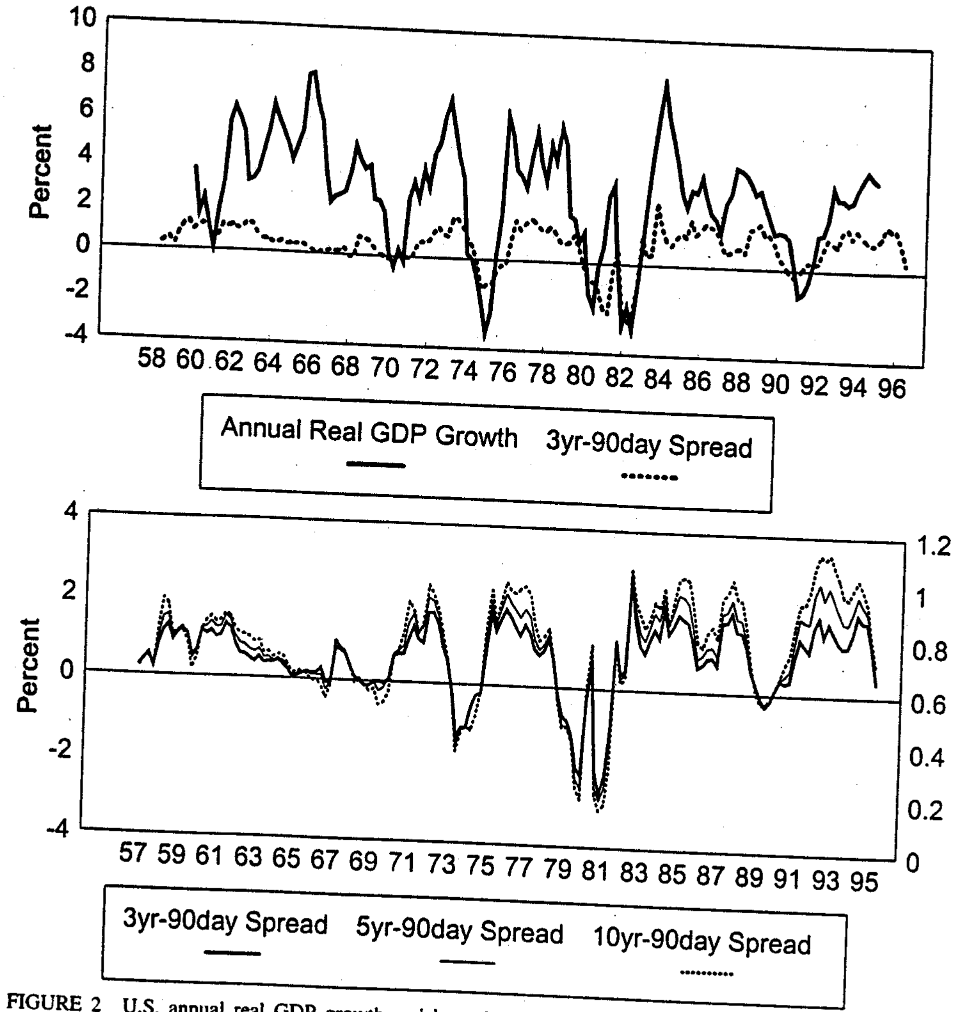

FIGURE 2 U.S. annual real GDP growth and lagged yield spreads

NOTES
In panel A, GDP is the annual growth in U.S. real Gross Domestic Product (seasonally adjusted) (DATASTREAM USGDP...D). The yield spread is the U.S. constant-maturity three-year bond (DATASTREAM USTRCN10) less the bond equivalent yield calculated from the discount rate on the ninety-day U.S. Treasury bill (DATASTREAM USTRB3AV) which is lagged five quarters. The quarterly yields are the arithmetic average of the yields over the quarter. In panel B, three yield spreads are compared: the U.S. constant-maturity ten-year bond (DATASTREAM USTRCN10) less the bond equivalent yield calculated from the discount rate on the ninety-day U.S. Treasury bill (DATASTREAM USTRB3AV), the U.S. constant maturity five-year bond less the U.S. Treasury bill, and the U.S. constant-maturity three-year bond (DATASTREAM USTRCN10) less the U.S. Treasury bill.

TABLE 2
Term structure forecasts of Canadian real consumption of non-durables and services growth

Yield spread	Sample	a	θ	$R^2/\bar{R}^2$
3yr	1960:1–1995:1	2.947	0.509	0.262
		[14.207]	[4.554]	0.257
10yr	1960:1–1995:1	3.310	0.859	0.281
		[16.270]	[6.251]	0.276
3yr	1960:1–1969:4	4.078	−0.104	0.003
		[9.273]	[−0.321]	−0.024
10yr	1960:1–1969:4	3.759	0.458	0.013
		[8.047]	[0.659]	−0.013
3yr	1970:1–1979:4	3.245	0.580	0.274
		[7.894]	[5.617]	0.255
10yr	1970:1–1979:4	3.893	0.613	0.153
		[9.713]	[2.864]	0.131
3yr	1980:1–1989:4	2.937	0.541	0.484
		[11.020]	[3.553]	0.470
10yr	1980:1–1989:4	3.297	0.820	0.474
		[13.917]	[4.528]	0.461
3yr	1980:1–1995:1	2.408	0.370	0.246
		[7.737]	[2.575]	0.233
10yr	1980:1–1995:1	2.724	0.672	0.283
		[8.396]	[3.427]	0.270
3yr	1970:1–1995:1	2.774	0.518	0.345
		[11.975]	[4.674]	0.338
10yr	1970:1–1995:1	3.197	0.829	0.326
		[13.078]	[5.876]	0.319

NOTES
The model estimated is: $\Delta CCN_{t+1:t+5} = a+\theta \text{ YSX}_t + u_{t+5}$. ΔGDP is the annual growth in real Canadian Personal Consumption Expenditures on Nondurables and Services (seasonally adjusted) from quarter $t+1$ to quarter $t+5$ (DATASTREAM CND20498 and CND20504). YSX yield spread of either (i) Government of Canada ten-year and over (DATASTREAM CNB14013) less the compounded annual rate for the ninety-day Treasury bill (DATASTREAM CNB 14001); (ii) Government of Canada one-to-three-year (DATASTREAM CNB14009) less the compounded annual rate for the ninety-day Treasury bill. The quarterly yields are the arithmetic average of the yields over the quarter. t-ratios are in brackets. The standard errors are corrected for the implied fourth-order moving average process and for conditional heteroscedasticity.

4. Out-of-sample forecasting

Some statistics on out-of-sample forecasting evaluation for Canadian real GDP and consumption growth are provided in table 3. The following is the methodology. The model is initially estimated with growth data through 1978:4. These coefficients are used along with the yield spread in 1978:4 to obtain a forecast for the period 1979:1–1980:1. For each new quarter the model is re-estimated.

While this is an out-of-sample exercise in the sense that coefficients are not fit over the period being forecast, it is in-sample given that regressions over the full sample have already been estimated. However, previous empirical work has concentrated on data ending in the 1980s. Table 3 presents a second evaluation period from 1990:1. These forecasts can be considered strictly out of sample.

Out-of-sample evaluation of four different models are presented: the three-year spread, the ten-year spread, an autoregressive model, and a model based on the index of leading indicators (DATASTREAM CN100031). Two forecast evaluation statistics are provided: mean absolute error (MAE) and root mean squared error (RMSE). The RMSE provides a rough measure of the standard deviation of the forecast. The MAE measures the average forecasting error. MAE is often considered more 'robust' because it gives a smaller weight to extreme forecast errors. The appropriateness of either of these measures, however, depends on the relevant loss function.

Table 3 also provides a test of whether the MSE of the three-year spread model is lower than the MSE of the other models. The test is based on the intuition presented in Ashley, Granger, and Schmalensee (1980) and Granger and Newbold (1986):

$$E[(\epsilon_{1t} - \epsilon_{2t})(\epsilon_{1t} + \epsilon_{2t}) = \mathrm{MSE}_1 - \mathrm{MSE}_2, \tag{7}$$

where ϵ_1 represents the forecast error from the three-year spread model and ϵ_2 represents the forecast error the alternative model. There are two problems with implementing this test in the traditional way. First, the statistic that Granger and Newbold present is not robust to departures from normality. Second, in my application, the forecast errors have an induced moving-average process.

Table 3 presents a p-value from a test statistic based on the moment condition:

$$E(\epsilon_{1t} - \epsilon_{2t})(\epsilon_{1t} + \epsilon_{2t}) - \phi_{12} = 0.$$

Using Hansen's (1982) generalized method of moments, it is straightforward to test whether ϕ_{12} is different from zero. This test is robust to conditional heteroscedasticity and a moving-average process in the residuals.[4]

The results from the forecast evaluation from 1980:1 suggest that the three-year yield spread model has the lowest forecast errors. For GDP growth, the MAE of the three-year spread model is 2.0 per cent. This compares to 2.1 per cent for the ten-year model; 2.7 per cent for the autoregressive model and 2.6 per cent for the model based on the index of leading indicators. The test statistics indicate that the three-year yield spread MSE is significantly lower than the MSEs for the autoregressive model and the leading indicator model.

The evidence for the consumption forecasting is not as clear cut. The MAE for the three-year spread is 1.3 per cent, which is only slightly lower than the autoregressive and the leading index models. The test statistics indicate that it is difficult to distinguish the forecast errors of the different models.

4 Also see, Mizrach (1992a,b) for a related test.

TABLE 3
Out-of-sample performance of the forecasting models

Prediction of	Model	Forecasts begin	Mean absolute error	Root mean squared error	*P*-value: Is MSE(3yr) lower?
GDP	3yr	1980 : 1	1.993	2.319	
GDP	10yr	1980 : 1	2.132	2.488	0.166
GDP	Lagged GDP	1980 : 1	2.685	3.539	0.040
GDP	Leading index	1980 : 1	2.576	3.422	0.047
Cons.	3yr	1980 : 1	1.274	1.652	
Cons.	10yr	1980 : 1	1.202	1.577	0.810
Cons.	Lagged cons.	1980 : 1	1.287	1.786	0.351
Cons.	Leading index	1980 : 1	1.489	1.953	0.147
GDP	3yr	1990 : 1	2.127	2.434	
GDP	10yr	1990 : 1	2.125	2.498	0.433
GDP	Lagged GDP	1990 : 1	3.168	3.846	0.125
GDP	Leading index	1990 : 1	3.064	3.721	0.128
Cons.	3yr	1990 : 1	1.897	2.233	
Cons.	10yr	1990 : 1	1.782	2.070	0.834
Cons.	Lagged cons.	1990 : 1	1.619	2.046	0.608
Cons.	Leading index	1990 : 1	2.052	2.313	0.435

NOTES
The model estimated is: $\Delta Y_{t+1:t+5} = a_t + \theta_t X_t + u_{t+5}$. ΔY is either the annual growth in Canadian real Gross Domestic Product (seasonally adjusted) from quarter $t+1$ to quarter $t+5$ (DATASTREAM CNGDP...D) or the annual growth in real Canadian Personal Consumption Expenditures on Non-durables and Services (seasonally adjusted) (DATASTREAM CND20498 and CND20504). X represents either (i) Government of Canada ten-year and over (DATASTREAM CNB14013) less the compounded annual rate for the ninety-day Treasury bill (DATASTREAM CNB14001); (ii) Government of Canada one-to-three-year (DATASTREAM CNB14009) less the compounded annual rate for the ninety-day Treasury bill [the quarterly yields are the arithmetic average of the yields over the quarter]; (iii) lagged GDP or consumption growth; or (iv) the change in the index of leading indicators (DATASTREAM CN100031). t-ratios are in brackets. The standard errors are corrected for the implied fourth-order moving-average process and for conditional heteroscedasticity. The coefficients have time subscripts to denote that the regressions are re-estimated at every point in time series. The autoregressive model uses the growth rate from $t-4$ to t forecast annual growth from $t+1$ to $t+5$.

In the evaluation period that begins in 1990, the yield spread model continues to provide the lowest forecast errors. The MAE of the three-year model is 2.1 per cent. This is much lower than the errors resulting from the autoregressive model (3.2 per cent) and the model based on the index of leading indicators (3.1 per cent). In addition, the yield spread mean absolute error is similar when measured over the 1980–95 period (2.0 per cent) or the 1990–5 period (2.1 per cent).

5. A comparison with other macroeconomic forecasters

One of the advantages of the yield spread model is its simplicity. A single variable is used to form a forecast of GDP or consumption growth. The model's ability to outperform a time-series model is impressive, but a much more rigorous test would involve comparison with a macroeconometric model of the Canadian economy. The macroeconomic models often involve hundreds of equations and numerous identities tying the equations together. To calibrate the quality of the yield spread forecasts, a comparison of forecasting accuracy with one of these large models is conducted.

Table 4 provides a comparison of the yield spread forecasts, forecasts based on the average projections of a Financial Post survey, and forecasts made by a commercial econometric forecasting service, Data Resources Inc. (DRI). The Financial Post forecasts were available from 1974–94. The DRI forecasts are available from 1982–94.[5]

The timing of the forecasts is important. The yield spread forecast for the next year is based on information at the end of September in the prior year. The DRI forecast for the next year is released in the last week of the year and is based on data available through mid-December. In contrast to the yield spread model and the DRI forecasts, the Financial Post survey of forecasts is based on information up to April 1 of the year being forecast. The forecasters surveyed by the Financial Post have the benefit of knowing what happened in the first quarter of the year they are forecasting.[6]

Table 4 shows the year-by-year forecast errors from the three sources. In the 1974–94 period the average absolute error for the Financial Post survey is 1.7 per cent per year, while the same measure is 1.9 per cent for the yield spread model. When the heteroscedasticity-consistent test for the difference in MSE in (8) is used, there is no significant difference between the forecast errors (p-value is 0.83). The implication is that the yield spread model provides forecasts which are remarkably close to the survey forecast which is complete six months later (with knowledge of the first quarter's growth).

A fairer comparison involves the yield spread model and the DRI forecasts. Over the 1982–94 period the yield spread MAE is 2.4 and also 2.4RMSE. The heteroscedasticity-consistent test of whether the MSEs are equal does not provide any evidence against the null hypothesis (p-value of 0.38). Hence, the yield spread forecast is not dominated by the forecasts from one of the leading econometric services.[7]

5 I appreciate an anonymous referee's supplying me with the Financial Post data. Rob Hoffman at DRI provided for DRI forecasts.

6 The Financial Post ran a contest from 1974 through 1993 on forecasting the main economic aggregates. The participants were commercial banks, large corporations, securities firms, and commercial forecasting services (including DRI). We use the mean forecast of all of the participants. For 1994 I use the Financial Post's survey of forecasters that was published in the 31 December 1993 year-end review issues. The 1994 forecast is the only forecast that does not use information into the year being forecasted.

7 DRI Canada forecasts hundreds of time series. Given that they are fitting many different series, it is reasonable to think that they might sacrifice some forecasting precision in one variable to reduce the overall errors of their model. Real GDP, however, is considered a 'first line' forecasting quantity. As a result, DRI told me that they would not sacrifice forecasting precision in this variable for any other variable.

TABLE 4

A Comparison of the forecasts of annual growth in Canadian real Gross National Product from the Data Resources Inc. (DRI) econometric model Financial Post survey of financial institutions and the model based on the term structure: 1974–94 twenty-one annual forecasts)

Year	Actual GDP Growth	3yr yield curve forecast made end Q3 prior yr	Financial Post forecast made end Q1 current yr	DRI forecast made end Q4 prior yr
1974	2.93	5.20	4.23	
1975	3.34	4.04	1.21	
1976	5.25	5.07	4.58	
1977	4.60	3.57	4.01	
1978	4.37	4.93	3.75	
1979	3.29	3.78	3.01	
1980	1.74	2.11	0.81	
1981	1.68	5.45	1.74	
1982	−3.77	0.27	−0.26	2.10
1983	6.47	2.52	1.60	3.10
1984	6.37	6.11	4.01	4.70
1985	5.17	3.48	3.08	2.20
1986	0.96	5.13	3.56	2.20
1987	6.43	4.27	2.35	3.00
1988	3.76	4.92	3.09	2.90
1989	1.72	3.92	2.78	2.50
1990	−1.91	0.26	1.25	1.60
1991	0.03	0.62	−1.02	1.40
1992	0.49	4.46	2.08	4.20
1993	3.14	6.66	3.12	3.30
1994	5.42	6.56	4.20	3.50
Mean absolute error (1974–94)	–	1.92	1.66	–
Root mean squared error (1974–94)	–	2.38	2.12	–
Mean absolute error (1982–94)	–	2.39	2.17	2.37
Root mean squared error (1982–94)	–	2.74	2.57	2.82

NOTES

The yield spread model estimated is: $\Delta Y_{t+1:t+5} = a_t + \theta_t X_t + u_{t+5}$. ΔY is the annual growth in Canadian real Gross Domestic Product (seasonally adjusted) from quarter $t+1$ to quarter $t+5$ (DATASTREAM CNGDP. . .D). X represents the Government of Canada one-to-three-year (DATASTREAM CNB14009) less the compounded annual rate for the ninety-day Treasury bill (DATASTREAM CNB14001); (the quarterly yields are the arithmetic average of the yields over the quarter); The coefficients have time subscripts to denote that the regressions are re-estimated at every point in time series after 1979:4. The Financial Post forecasts are based on an average forecast of a number of financial institutions and commercial forecasters. The deadline for submitting a forecast to the Financial Post was 1 April of the year being forecast. Hence, participants already know one quarter of data into the year being forecast. In constrast, the DRI forecasts are made at the end of the quarter in the prior year.

IV. CANADIAN AND U.S. EXPECTED BUSINESS CYCLES

1. Economic growth

It is well known that Canadian economic growth is highly correlated with U.S. growth. The two economies have strong trading links. Since the U.S. economy is roughly ten times the size of the Canadian economy, movements in U.S. GDP affect Canadian GDP. It is also well known that Canadian and U.S. capital markets are highly integrated. Movements in U.S. interest rates affect interest rates in Canada. An obvious question arises: is the predictive power of the Canadian yield curve in forecasting Canadian economic growth spurious? That is, the predictive ability due to the fact that the term structures are correlated and the economic growth is correlated?

The first panel of figure 3 establishes that the GDP growth rates in the two countries are correlated. It is interesting to note that the Canadian economy does not appear to lag behind the U.S. economy when annual growth rates are compared. The two economies generally move in the same direction. It is interesting that in the most recent recession the Canadian economy appears to have led the U.S. economy by two quarters. Over the entire sample, the two economies have grown at very similar rates, especially since 1980.

Figure 3 also reveals that the Canadian business cycle does not appear more volatile than the U.S. business cycle. It is popularly thought that a U.S. recession causes a more severe recession in Canada. The assertion is not generally supported by the historical data. For example, in the 1982 recession Canada experienced slightly lower growth rates than the United States, while the 1974 recession was much more severe in the United States than it was in Canada. This, of course, can be partially explained by the differential effect the oil prices increases had on the two economies.

2. Financial integration

The Canadian and U.S. financial markets are also highly integrated. Stock returns and bond yields in the two countries are highly correlated.[8] The second panel of figure 3 provides a plot of the yield curves in the two countries. Their interest rate spreads move in a similar way, but there are some differences.

An important difference between the yield curves occurs in 1972–4, when the Canadian yield spread is on average 2 per cent higher than the U.S. yield spread. This period coincides with a business-cycle turning point (strong growth followed by recession) for both countries. Significantly, the U.S. recession during this time was much more severe than the Canadian recession. This is precisely what is forecast by the difference between the two yield curves.

A less dramatic difference at another business cycle turning point is the pattern of the yield curves in 1982. The Canadian yield curve in panel B of figure 3 is negative

8 Harvey (1991), in a study of world equity-market integration, finds that expected stock returns in Canada and the United States are generated by similar information variables.

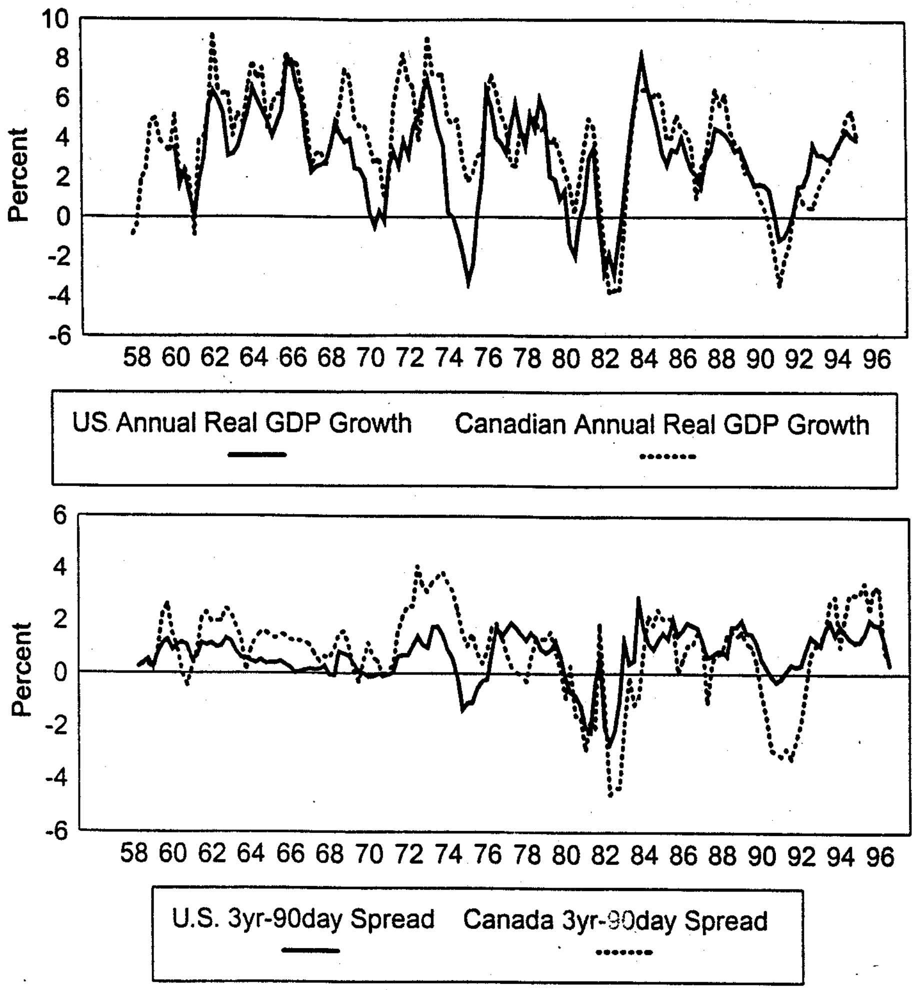

FIGURE 3 A comparison of U.S. and Canadian annual real GDP growth

NOTES
In panel A, the annual growth in Canadian and U.S. real Gross Domestic Product (both seasonally adjusted) (DATASTREAM CNGDP...D and USGDP...D). In panel B, the Canadian yield spread is Government of Canada one-to-three-year (DATASTREAM CNB14009) less the compounded annual rate for the ninety-day Treasury bill (DATASTREAM CNB14001) and it is lagged five quarters. The U.S. yield spread is the U.S. constant maturity three-year bond (DATASTREAM USTRCN10) less the bond equivalent yield calculated from the discount rate on the ninety-day U.S. Treasury bill (DATASTREAM USTRB3AV), which is lagged five quarters. The quarterly yields are the arithmetic average of the yields over the quarter.

and below the U.S. yield curve. From panel A of figure 3, Canada experienced the more severe downturn during this recession. Again, this is precisely what the spread in the yield curves suggested.

Finally, there is a sharp deviation with the most recent data. There is a sharp inversion of the Canadian yield curve in the fourth quarter of 1988 (the U.S. curve does not invert until the second quarter of 1989). According to the model, this difference signalled a significantly worse recession for Canada than for the United States. In addition, the length of the Canadian inversion was longer than that of the United States, implying that the Canadian recession was to be longer than the U.S. recession.

3. The contribution of the U.S. term structure to Canadian growth forecasts

Although there are differences between the Canadian and U.S. term structures, the shape of the U.S. term structure provides some additional power to Canadian economic growth. This is confirmed in table 5. For example, the adjusted R^2 of the predicting Canadian economic growth with the Canadian yield curve from 1980–1995:1 is 47 per cent. This measure increases marginally to 48 per cent when the U.S. yield curve measure is introduced.

The contribution of the U.S. spread for the prediction of Canadian economic growth and the t-ratios on the yield spreads are difficult to interpret because of the inherent correlation between the yield spreads of the two countries. In the final column of table 5 a regression is reported using the orthogonalized Canadian yield spread and the U.S. yield spread. The Canadian measure is orthogonalized by regressing on the U.S. spread and capturing the regression residuals. It is clear that the U.S. spread contributes importantly to Canadian economic growth.

The out-of-sample exercise in table 3 is repeated in table 6 adding the U.S. spread. In the 1980:11–1995:1 evaluation period the MAE and RMSE is very similar to those reported in table 3 when the Canadian spread alone is used. In the 1990:11–1995:1 evaluation period, the MAE and RMSE are slightly lower when the Canadian spread alone is used. This reflects the fact that the Canadian spread moved much more clearly with the Canadian business cycle than with the U.S. business cycle in the 1990s.

At the bottom line, the Canadian terms structure is not redundant in forecasting Canadian economic growth. Part of the explanatory power of the Canadian term structure can be attributed to its correlation with the U.S. term structure. The Canadian term structure, however, contains information over and above the information in the U.S. term structure.

4. The contribution of the Canadian term structure to forecasting 'Canadian' growth

The final question to resolve is 'whose growth is being forecasted?' Is the power of the Canadian term structure to forecast Canadian economic growth due only to the correlation between Canadian and U.S. economic growth? To answer this question, a 'Canadian' growth series is created by projecting Canadian economic

TABLE 5
Forecasting Canadian economic growth with both Canadian and U.S. term structures

Spread	Sample	Intercept	θ_c(Canada)	θ_u(United States)	$R^2/\bar{R}^2$	$\theta_u^{\perp}$(United States)
3yr	1960:1–1995:1	3.056	1.115	−0.051	0.476	1.065
		[9.149]	[6.468]	[−0.146]	0.468	[3.561]
10yr	1960:1–1995:1	3.644	1.518	0.192	0.401	0.678
		[11.389]	[5.454]	[0.889]	0.393	[3.458]
3yr	1960:1–1969:4	3.965	1.719	−1.327	0.283	0.004
		[4.982]	[3.927]	[−1.751]	0.244	[0.006]
10yr	1960:1–1969:4	4.123	1.273	0.791	0.134	1.166
		[5.627]	[1.021]	[1.015]	0.087	[2.108]
3yr	1970:1–1979:4	2.968	0.818	0.712	0.471	0.997
		[8.521]	[5.253]	[3.130]	0.443	[4.753]
10yr	1970:1–1979:4	3.717	0.776	0.730	0.343	0.709
		[9.055]	[2.628]	[4.192]	0.308	[4.015]
3yr	1980:1–1989:4	2.892	0.805	0.335	0.454	1.182
		[5.565]	[2.442]	[0.752]	0.425	[2.918]
10yr	1980:1–1989:4	3.099	0.938	0.451	0.437	0.908
		[5.693]	[2.168]	[1.471]	0.406	[3.067]
3yr	1980:1–1995:1	2.389	0.919	0.088	0.485	1.249
		[4.512]	[3.986]	[0.174]	0.467	[3.208]
10yr	1980:1–1995:1	2.978	1.425	0.123	0.450	0.853
		[5.398]	[3.703]	[0.420]	0.431	[3.768]
3yr	1970:1–1995:1	2.631	0.973	0.181	0.532	1.186
		[7.450]	[6.306]	[0.569]	0.522	[3.971]
10yr	1970:1–1995:1	3.205	1.322	0.289	0.439	0.760
		[9.776]	[5.205]	[1.464]	0.427	[3.898]

NOTES
The model estimated is: $\Delta Y_{t+1:t+5} = a + \theta_c \text{YSC}_t + \theta_u \text{YSU}_t + u_{t+5}$. ΔY is the annual growth in Canadian real Gross Domestic Product (seasonally adjusted) from quarter $t+1$ to quarter $t+5$ (DATASTREAM CNGDP...D). YSC is the yield spread of either (i) Government of Canada ten-year and over (DATASTREAM CNB14013) less the compounded annual rate for the ninety-day Treasury bill (DATASTREAM CNB14001); or (ii) Government of Canada one-to-three-year (DATASTREAM CNB14009) less the compounded annual rate for the ninety-day Treasury bill. YSU is the yield spread of either: (i) the U.S. constant maturity ten-year bond (DATASTREAM USTRCN10) less the bond equivalent yield calculated from the discount rate on the ninety-day U.S. Treasury bill (DATASTREAM USTRB3AV); or (ii) the U.S. constant maturity three-year bond (DATASTREAM USTRCN10) less the U.S. Treasury bill. The final coefficient results from regressing economic growth on the orthogonalized Canadian yield spread (residuals from the Canadian spread regressed on the U.S. spread) and the U.S. spread. The quarterly yields are the arithmetic average of the yields over the quarter. t-ratios are in brackets. The standard errors are corrected for the implied fourth-order moving-average process and for conditional heteroscedasticity.

growth on U.S. growth and capturing the residuals. These residuals represent the idiosyncratic part of Canadian economic growth (the part uncorrelated with U.S. economic growth).

These results are presented in table 7. In the full sample, the three-year term

TABLE 6
Out-of-sample performance of the Canadian GDP forecasting models that use both Canadian and U.S. term structures

Model	Forecasts begin	Mean absolute error	Root mean squared error
Canada and United States 3yr	1980 : 1	2.028	2.362
Canada and United States 10yr	1980 : 1	2.229	2.632
Canada and United States 3yr	1990 : 1	2.219	2.513
Canada and United States 10yr	1990 : 1	2.559	2.901

NOTES
The model estimated is: $\Delta Y_{t+1:t+5} = a_t + \theta_t \mathrm{YSX}_t + u_{t+5}$. ΔY is the annual growth in Canadian real Gross Domestic Product (seasonally adjusted) from quarter t+1 to quarter t+5 (DATASTREAM CNGDP...D). YSX yield spread of either (i) Government of Canada ten-year and over (DATASTREAM CNB14013) less the compounded annual rate for the ninety-day Treasury bill (DATASTREAM CNB14001); (ii) Government of Canada one-to-three-year (DATASTREAM CNB14009) less the compounded annual rate for the ninety-day Treasury bill; (iii) the U.S. constant maturity ten-year bond (DATASTREAM USTRCN10) less the bond equivalent yield calculated from the discount rate on the ninety-day U.S. Treasury bill (DATASTREAM USTRB3AV); or (iv) the U.S. constant maturity three-year bond (DATASTREAM USTRCN10) less the U.S. Treasury bill. The quarterly yields are the arithmetic average of the yields over the quarter. t-ratios are in brackets. The standard errors are corrected for the implied fourth-order moving-average process and for conditional heteroscedasticity. The coefficients have time subscripts to denote that the regressions are re-estimated at every point in time series. The autoregressive model uses the growth rate from $t-4$ to t to forecast annual growth from $t+1$ to $t+5$.

structure can explain 24 per cent of the idiosyncratic Canadian economic growth. While the relation is the weakest in the 1980s, from 1970:1–1995:1, the Canadian term structure can explain almost 30 per cent of the variation in Canadian economic growth. Although it was not reported in the table, I also regressed idiosyncratic Canadian economic growth on idiosyncratic Canadian term structure movements. Similar explanatory power is found and displayed in figure 4. This shows that much of the information in the Canadian term structure is related to Canadian-specific information. This information is relevant for forecasting the part of economic growth that is unrelated to U.S. economic growth.

V. CONCLUSION

The yield curve predictions of economic growth are based upon an asset-pricing framework that links bond yields to expected economic growth. This paradigm provides a remarkably simple forecasting model. Calibration of the model suggests that the Canadian yield curve forecasts of economic growth are more accurate than time-series model forecasts and models based on the index of leading indicators. A comparison with commercially available economic forecasts shows that these forecasts do not dominate those based on the yield curve.

This paper also resolves the question of whether the forecasting power of yield curve is spurious. That is, is the forecasting power due to the correlations of the Canadian and U.S. yield curves and the correlations of Canadian and U.S. business

TABLE 7
Can the Canadian term structure explain the idiosyncratic variation in Canadian economic growth?

Yield spread	Sample	a	θ	$R^2/\bar{R}^2$
3yr	1960:1–1995:1	−0.387	0.500	0.238
		[−1.671]	[4.108]	0.232
10yr	1960:1–1995:1	−0.032	0.878	0.277
		[−0.158]	[4.954]	0.272
3yr	1960:1–1969:4	−0.276	0.239	0.024
		[−0.564]	[0.868]	−0.002
10yr	1960:1–1969:4	−0.135	0.311	0.010
		[−0.353]	[0.547]	−0.016
3yr	1970:1–1979:4	−1.174	0.770	0.385
		[−4.001]	[4.230]	0.369
10yr	1970:1–1979:4	−0.351	0.913	0.271
		[−1.397]	[3.990]	0.252
3yr	1980:1–1989:4	−0.008	0.233	0.107
		[−0.023]	[1.224]	0.084
10yr	1980:1–1989:4	0.173	0.414	0.145
		[0.612]	[1.790]	0.123
3yr	1980:1–1995:1	−0.005	0.179	0.065
		[−0.017]	[1.427]	0.050
10yr	1980:1–1995:1	0.162	0.357	0.091
		[0.535]	[2.101]	0.076
3yr	1970:1–1995:1	−0.333	0.535	0.294
		[−1.217]	[4.142]	0.287
10yr	1970:1–1995:1	0.114	0.934	0.330
		[0.445]	[4.893]	0.324

NOTES
The model estimated is: $\Delta CGDP_{t+1:t+5} = a + \theta\ YSX_t + u_{t+5}$. $\Delta CGDP$ is the annual growth in Canadian real Gross Domestic Product (both seasonally adjusted) from quarter $t + 1$ to quarter $t + 5$ (DATASTREAM CNGDP...D) orthogonalized with respect to U.S. real Gross Domestic Product (residuals from regressing Canadian GDP growth on U.S. GDP growth). YSX yield spread of either (i) Government of Canada ten-year and over (DATASTREAM CNB14013) less the compounded annual rate for the ninety-day Treasury bill (DATASTREAM CNB14001); or (ii) Government of Canada one-to-three-year (DATASTREAM CNB14009) less the compounded annual rate for the ninety-day Treasury bill. The quarterly yields are the arithmetic average of the yields over the quarter. t-ratios are in brackets. The standard errors are corrected for the implied fourth-order moving-average process and for conditional heteroscedasticity.

cycles? The evidence suggests that while some of the forecasting power of the Canadian yield curve can be attributed to its correlation with the U.S. yield curve, there is unique information in the Canadian term structure. Furthermore, once all effects of U.S. economic growth are removed from Canadian GDP growth, the Canadian term structure has explanatory power. That is, the Canadian term structure is able to forecast the part of Canadian economic growth that is unrelated to U.S. economic growth. It is also able (through its correlation with the U.S. term structure)

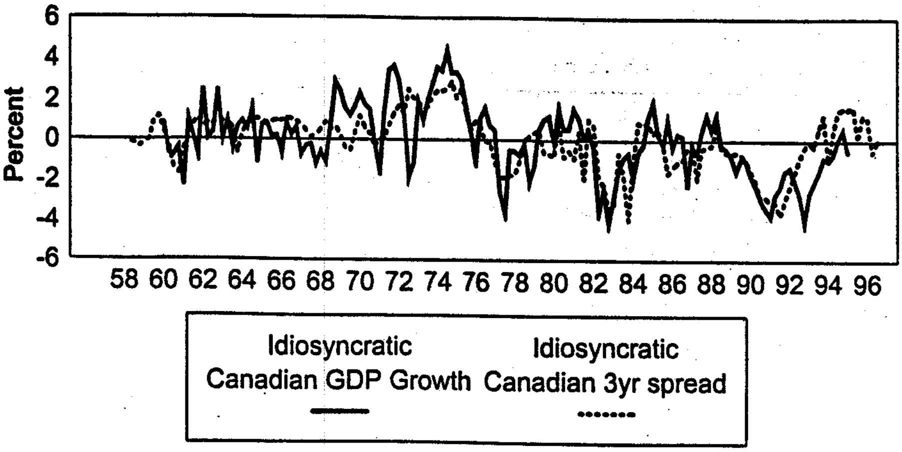

FIGURE 4 Do Canadian yield curve residuals explain Canadian-U.S. output deviations?

NOTES
Canadian yield curve residuals are defined as the residuals from regressing the Canadian three-year yield spread on the U.S. three-year yield spread. Idiosyncratic Canadian GDP growth is defined as the residuals from regressing the Canadian GDP growth on the U.S. GDP growth. The yield curve residuals are lagged five quarters in the graph.

to forecast the part of Canadian economic growth that is due to the correlation to the two countries' business cycles.

REFERENCES

Ashley, R., C.W.J. Granger, and R. Schmalensee (1980) 'Advertising and aggregate consumption: an analysis of causality. *Econometrica* 48, 1149–68

Breeden, D.T. (1979) 'An intertemporal asset pricing model with stochastic consumption and investment opportunities.' *Journal of Financial Economics* 7, 265–96

Brock, W.A. (1982) 'Asset prices in a production economy. In *The Economics of Uncertainty and Information*, ed. John J. McCall (Chicago: University of Chicago Press)

Cochrane, J. (1991) 'Using production based asset pricing to explain the behavior of stock returns over the business cycle.' *Journal of Finance* 46, 209–37

Cozier, B.V., and A.H. Rahman (1988) 'Stock returns, inflation, and real activity in Canada.' This *Journal* 21, 759–74

Fama, E.F. (1981) 'Stock returns, real activity, inflation and money.' *American Economic Review* 71, 545–65

Fisher, I. (1907) *The Rate of Interest* (New York: Macmillan)

Fox, B.J., and C.R. Harvey (1982) 'The yield curve and Gross National Product: an examination of the leading relationship in Canada 1953:1981.' Unpublished term paper, York University

Garner, C.A. (1987) 'The yield curve and inflation expectations.' *Economic Review*, Federal Reserve Bank of Kansas City, 72:8, 3–15

Granger, C.W.J., and P. Newbold (1986) *Forecasting Economic Time Series* (New York, Academic Press)

Hansen, L.P., and K.J. Singleton (1982) 'Generalized instrumental variables estimation of nonlinear rational expectations models.' *Econometrica* 50, 1269–85

Harvey, C.R. (1986) 'Recovering expectations of consumption growth from an equilibrium model of the term structure of interest rates.' Unpublished dissertation, University of Chicago

— (1988) 'The real term structure and consumption growth.' *Journal of Financial Economics* 22, 305–34

— (1989) 'Forecasts of economic growth from the bond and stock markets.' *Financial Analysis Journal* (September/October), 38–45

— (1991) 'The world price of covariance risk.' *Journal of Finance* 46, 111–57

Lucas, R.E., Jr. (1978) 'Asset prices in an exchange economy.' *Econometrica* 46, 1429–1445

Merton, R.C. (1973) 'An intertemporal capital asset pricing model.' *Econometrica* 41, 867–87

Mizrach, B. (1992a) 'Multivariate nearest-neighbor forecasts of EMS exchange rates.' *Journal of Applied Econometrics* 7, S151–63

— (1992b) 'Forecast comparison in L2.' Working paper. Federal Reserve Bank of New York

Newey, W.K., and K.D. West (1987) 'A simple, positive semi-definite, heteroskedasticity consistent and autocorrelation consistent covariance matrix.' *Econometrica* 55, 703–8