The Yield Curve and Real Activity

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This paper attempts to formalize the link between the yield curve and real economic activity. A closed-form formula for the term structure of interest rates is derived. The paper then documents the use of bond market data for predicting GDP growth in the G-7 industrial countries. The results suggest that a simple measure of the slope of the yield curve, namely the yield spread, serves as a good predictor of future economic growth. The out-of-sample forecasting performance of the yield spread compares favorably with that of the alternative stock price–based model and a univariate time series (ARMA) model. [JEL E32, G12]

THE DAILY FINANCIAL PRESS frequently runs stories suggesting a close association between the term structure of interest rates and future real activity. Banks, bond dealers, and Wall Street pundits often claim that the shape of the yield curve says something about economic prospects. An upwardly sloping yield curve, for example, is interpreted as a sign of a strong economy ahead; a flattening or inverting yield curve is seen as a foreshadowing of recession. The goal of this paper is to formalize the link between the yield curve and real activity and examine the alleged predictive power of yield curve variables.

A number of studies have examined the relationship between short-term and long-term interest rates (see Shiller, Campbell, and Schoenholtz (1983) and Mankiw and Summers (1984)). In particular, Fama (1984, 1990a), Mishkin (1990a, 1990b), and Campbell and Shiller (1991) have found that the term structure predicts future spot rates and inflation. Clearly, economists and policymakers are also concerned with the link between movements in long-term and short-term interest rates and

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macroeconomic fluctuations in real output. Recent work by Stock and Watson (1989), Harvey (1989), Chen (1991), and Estrella and Hardouvelis (1991) has provided evidence that the U.S. term structure can also be used to predict growth in real GNP.

This study documents the forecasting power of the yield curve variables for predicting gross domestic product in the Group of Seven (G-7) industrial countries. The paper sets out a simple model that gives rise to a closed-form solution of the term structure of interest rates. It is shown that the slope of the yield curve has a linear relation with the expected growth in real output. After briefly discussing measurement issues and data sources, the paper then examines empirically whether the main implications of the model are borne out by data from a set of industrial countries. The focus is on investigating the predictive power of a simple measure of the term structure—the yield spread between long-term and short-term government bonds—for subsequent economic growth.

I. The Model

The term structure of interest rates measures the relationship among the yields on default-free bonds of varying maturities. Equilibrium asset pricing theories shed light on how underlying economic variables determine this relationship. The current paper asks the opposite question: whether one can extract from the yield curve information about future real activities.

This paper presents an intertemporal equilibrium model. In the empirical part of the paper, observed interest rate variables are used to predict future output growth. The model is built on the work of Merton (1973), Lucas (1978), Brock (1982), Cox, Ingersoll, and Ross (1985), and especially Breeden (1979, 1986).

Consider an infinite-horizon economy made up of a single agent, a single production technology, and a single physical commodity that can be allocated to either consumption or investment. Let (Ω, F, P) be a filtered probability space for the continuous time set $T = [0, \infty)$, where $F = \{F_t, t \geq 0\}$ is the filtration of a standard Brownian motion B. The consumption set C comprises those positive predictable processes $c = \{c_t, t \geq 0\}$ that satisfy

$$E\left\{\int_0^T e^{-\rho t} u[c(t)]\, dt\right\} < \infty, \tag{1}$$

almost surely for all $T \geq 0$. The agent has preferences over positive

stochastic consumption processes c given by the lifetime utility functional:

$$U(c) = E\left\{\int_0^{\infty} e^{-\rho t} u[c(t)]\, dt\right\}, \tag{2}$$

where $c(t)$ is the time t rate of consumption, $E(\cdot)$ is an expectations operator, ρ is the rate of time preference, and $u(\cdot)$ is the instantaneous utility function. To derive an analytic characterization of the term structure, $u(\cdot)$ is restricted to be the logarithmic function: $u[c(t)] = \log[c(t)]$.

Assume that the shocks to the productivity of capital can be described by a single sufficient statistic or state variable, $x(t)$, defined by

$$dX_t = \mu_x(X,t)dt + \sigma_x(X,t)dB_t, \tag{3}$$

where $\mu_x(x,t)$ and $\sigma_x(x,t)$ are predictable processes, and the standard Brownian motion, B_t, is a martingale under the filtered probability measure.

The gross output in this economy is given by the following stochastic integral equation:

$$Y_t = Y_0 + \int_0^t \mu_y(Y,X,s)ds + \int_0^t \sigma_y(Y,X,s)dB_s. \tag{4}$$

Further impose the restrictions that both the drift and diffusion terms in equation (4) are homogeneous of degree one in Y:

$$\mu_y(Y,X,s) = Y\mu_y(X,s),$$

and

$$\sigma_y(Y,X,s) = Y\sigma_y(X,s).$$

These restrictions imply that the production technology has stochastic constant returns to scale.

The consumer can borrow or lend the consumption good at the instantaneously riskless interest rate r. The consumer can also hold a default-free zero-coupon bond that delivers one unit of the consumption good at maturity date T. Without loss of generality, assume that this default-free bond is the only financial security available. The value of the default-free zero-coupon bond, $P(t,T)$, will in general depend on the state variable $X(t)$ as well as the time to maturity. Its dynamics can be written as

$$dP = \mu_p\, dt + \sigma_p\, dB. \tag{5}$$

The consumer's total wealth at time t, $W(t)$, in units of the physical good, is the sum of his or her human and nonhuman wealth. Since labor

is not used in the production processes, the consumer's entire wealth consists of the nonhuman part only, which is to be allocated among investments in the production processes, default-free bonds, and riskless borrowing and lending. Suppose that the consumer invests an amount of wealth, aW, in the production process and an amount of wealth, bW, in the default-free bond. Then, his or her intertemporal budget constraint takes the form

$$dW = [aW(\mu_y - r) + bW(\mu_p - r) + rW - c]dt + aW\sigma_y dB + bW\sigma_p dB. \qquad (6)$$

An equilibrium is defined as a set of stochastic processes (P, r, a, C) such that (i) the agent maximizes his or her expected lifetime utility, equation (2), subject to budget constraint (6) and (ii) the net supply of the default-free bond and riskless lending is zero: $b = 0$.

The market-clearing condition (ii) is intuitive since there is only one agent in this economy. This condition implies that $a = 1$—that is, all the agent's wealth is invested in the physical production processes.

Denote the consumer's value function as $V(W, X, t)$. Applying Bellman's principle to this continuous-time stochastic control problem leads to the following first-order conditions:

$$\frac{1}{c} = V_w, \qquad (7)$$

$$WV_w(\mu_y - r) + W^2 V_{ww} a\sigma_y^2 + \frac{1}{2} W^2 V_{ww} b\sigma_y\sigma_p = 0, \qquad (8)$$

$$WV_w(\mu_p - r) + \frac{1}{2} W^2 V_{ww} a\sigma_y \sigma_p + W^2 V_{ww} b\sigma_p^2 = 0, \qquad (9)$$

where V_w and V_{ww} denote the first-order and second-order partial derivatives of V with respect to W. Substituting the market-clearing conditions into equation (8) gives

$$r = \mu_y + \frac{WV_{ww}}{V_w} \sigma_y^2. \qquad (10)$$

It can be shown that given the specific assumption about the utility function, the consumer's value function also takes a simple form: $V(W,t) = (1/\rho) \log(W)$. Therefore, from equation (7) one can write optimal consumption as

$$c = \rho W = \rho Y.$$

This consumption function implies that the agent consumes a fixed proportion of output, with the proportionality factor being his or her rate of

time preference. Furthermore, since the agent's coefficient of relative risk aversion equals one, equation (10) can be simplified as

$$r = \mu_y - \sigma_y^2. \tag{11}$$

Equation (11) gives a simple, closed-form formula for the equilibrium interest rate. It explicitly links the interest rate to the economy's production processes. Since real output is postulated to follow the Ito process, and the agent has logarithmic preference, the path of the riskless interest rate is completely determined by the first two moments of the production technology. The equilibrium interest rate is higher if the expected growth rate of real output is higher, and is also higher if the risk associated with aggregate production is smaller, all other things equal. This important relationship provides the basis for forecasting economic growth through interest rate variables.

Note that because of the logarithmic utility assumption, the covariance of the production process with the state variable X_t does not enter equation (11). Such a covariance term would appear for more general preference specifications, as, for example, in Breeden (1986).

For empirical implementation, the following discrete-time approximation to equation (11) is used:

$$r(t, T) = \mu_y(t, T) - \sigma_y^2(t, T). \tag{12}$$

The term structure implied by this production-oriented equation has some interesting shapes. It will be upwardsloping if, holding the variance of production constant, the growth rate of real output in the economy is expected to be higher. It will be downward sloping if the economy is expected to enter a phase of recession. Therefore, the term structure, or the yield differential between long-term and short-term interest rates, embodies the market's expectations about the prospects of the economy, and hence contains useful information about aggregate economic fluctuations.

Since

$$\mu_y(t, T) = E_t\left(\frac{\Delta Y_{t,T}}{Y_t}\right), \tag{13}$$

equation (12) can be rearranged to obtain

$$E_t\left(\frac{\Delta Y_{t,t}}{Y_t}\right) = r(t, T) + \sigma_y^2(t, T). \tag{14}$$

Equation (14) makes it clear that investment in the risky production process receives a premium over the riskless interest rate, determined by the conditional variance of production. In the rest of this paper, it

is assumed that the stochastic process of production has constant variance so that one can concentrate on the relationship between expected economic growth and the term structure of interest rates.

Consider two default-free bonds with maturity dates at T and τ, respectively. Subtracting from equation (14) the corresponding equation for the bond with maturity τ yields

$$E_t\left(\frac{\Delta Y_{\tau,T}}{Y_t}\right) = S^y_{t,T-\tau}, \tag{15}$$

where

$$S^y_{t,T-\tau} = r(t,T) - r(t,\tau) \tag{16}$$

is the interest rate differential, or yield spread, between the two default-free bonds.

To remove the conditional expectations operator, rewrite equation (15) as

$$\frac{\Delta Y_{\tau,T}}{Y_t} = S^y_{t,T-\tau} + \epsilon_t, \tag{17}$$

where ϵ_t is the forecast error. Equation (17) is the basic model for empirical estimation in this paper.

II. Measurement Issues and Data Sources

To examine the relationship between the term structure and real activity, this paper focuses on the yield spread between default-free bonds with different maturities. This spread measures the slope of the yield curve. Economists' interest in this particular variable dates back to Kessel (1965), who first documented the co-movements of the term structure and the business cycle and found that the size of the yield spread is associated with general economic conditions, such as recession and recovery. For simplicity, only a single measure of the slope of the yield curve is constructed: the difference between annualized yields on long-term versus short-term government bonds. This variable is denoted as S^y. A wider spectrum of bond maturities would presumably provide finer information on the forecasting power of the term structure for economic growth. Thus, the regression results below should be carefully interpreted, because poor empirical performance using S^y does not necessarily constitute a strong case against the principle implication of the term structure model in the preceding section—namely, that expected growth

in real output is positively and linearly related to the slope of the yield curve.

The gross national product and the gross domestic product are the natural candidates for measuring aggregate output. Strictly speaking, the horizon over which one measures real output growth should correspond to the exact maturity structure of the government bonds chosen. What the regressions use, however, are year-to-year growth rates taken from quarterly data. In other words, the dependent variable in the regression equations is

$$dY_t = \log\left(\frac{Y_{t+4}}{Y_t}\right). \tag{18}$$

It is acceptable to focus on the four-quarter growth rates when testing the term structure model, because data over shorter horizons, such as one-quarter changes, likely contain more measurement error. The related evidence on stock returns (see Fama (1990b), for example) suggests that term structure may also have better predictive power for real activity over horizons spanning from one to several years.

The basic model of interest rate term structure is applied to the G-7 countries—Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States. The paper works with quarterly data. Most of the series used in this study are taken from the International Monetary Fund's *International Financial Statistics*.

For aggregate real output series, the study uses real GNP or real GDP, whichever is contained in the *International Financial Statistics*. The quarterly series are seasonally adjusted at annual rates. In those cases in which both nominal GNP and nominal GDP are available for a country, the two real series have been compared under the assumption of a common deflator. Because only a minor difference between the two series exists, the longest series is picked as the measure of real output.

The quarterly long-term government bond yield and quarterly treasury bill (T-bill) rate are taken from *International Financial Statistics*'s interest rate data. They are period-average annualized rates. The long-term government bonds usually have at least five years to maturity, while the short-term rate used here is the three-month T-bill rate. If the treasury bill series is not available for a country, a typical short-term interest rate is then used as a proxy for the T-bill rate. This series is published in Organisation for Economic Cooperation and Development's (OECD) *Financial Statistics*. The stock price index and consumer price index are taken from *International Financial Statistics*. Quarterly data are period averages.

Table 1 reports summary statistics for three time series: real GDP

Table 1. *Summary Statistics for Real GDP Growth, Yield Spread, and Real Stock Price Changes Based on Quarterly Data*

	Sample period	Number of observations	Mean	Standard deviation	Autocorrelation ρ1	ρ2	ρ3	ρ4	ρ8	ρ12
Canada										
GDP growth	1957:1–1991:4	140	0.03825	0.02566	0.81	0.59	0.36	0.11	0.08	0.07
Yield spread	1957:1–1991:4	140	0.00942	0.01474	0.85	0.67	0.51	0.40	0.07	−0.04
Stock price changes	1957:1–1991:4	140	0.00349	0.16708	0.79	0.45	0.07	−0.22	−0.07	−0.05
France										
GDP growth	1971:1–1991:3	83	0.02715	0.01946	0.86	0.69	0.48	0.29	0.11	0.11
Yield spread	1971:1–1991:3	83	0.00683	0.01258	0.75	0.42	0.20	−0.02	−0.25	−0.01
Stock price changes	1971:1–1991:3	83	0.00714	0.23665	0.77	0.53	0.25	−0.08	−0.03	0.01
Germany										
GDP growth	1961:1–1991:4	124	0.03046	0.02381	0.78	0.56	0.38	0.16	−0.12	0.01
Yield spread	1961:1–1991:4	124	0.01913	0.01595	0.84	0.67	0.48	0.28	−0.07	0.09
Stock price changes	1961:1–1991:4	124	−0.00961	0.18663	0.80	0.51	0.25	−0.02	−0.25	0.13
Italy										
GDP growth	1972:1–1991:4	80	0.03021	0.02851	0.79	0.48	0.12	−0.17	−0.15	0.16
Yield spread	1972:1–1991:4	80	−0.00356	0.01902	0.78	0.44	0.14	−0.05	0.12	0.09
Stock price changes	1972:1–1991:4	80	−0.04972	0.33407	0.88	0.67	0.41	0.16	−0.01	0.04
Japan										
GDP growth	1967:4–1991:4	97	0.04472	0.03678	0.83	0.73	0.58	0.40	0.07	0.11
Yield spread	1967:4–1991:4	97	0.00234	0.01430	0.85	0.64	0.18	−0.01	−0.32	−0.29
Stock price changes	1967:4–1991:4	97	0.06262	0.20236	0.86	0.63	0.38	0.11	−0.17	0.11
United Kingdom										
GDP growth	1959:1–1991:4	132	0.02413	0.02432	0.65	0.44	0.24	0.03	−0.13	−0.02
Yield spread	1959:1–1991:4	132	0.01188	0.02063	0.90	0.79	0.68	0.58	0.27	0.29
Stock price changes	1959:1–1991:4	132	0.02076	0.21898	0.81	0.54	0.25	−0.02	−0.11	−0.12
United States										
GDP growth	1958:1–1991:4	136	0.02828	0.03302	0.85	0.62	0.35	0.11	−0.09	−0.06
Yield spread	1958:1–1991:4	136	0.01231	0.01155	0.85	0.68	0.55	0.43	0.01	−0.12
Stock price changes	1958:1–1991:4	136	0.01939	0.15618	0.80	0.47	0.11	−0.17	−0.08	0.09

growth, yield spreads, and stock market price changes. The standard deviations of the yield spreads are typically within one-half of the mean GDP growth rates. The stock market price changes are much more volatile than either GDP growth or the yield spreads. They exhibit fairly similar patterns of autocorrelation.

The time series data are plotted in Figure 1. The series are aligned so that if the GDP growth and financial time series coincide, then the financial variables are a perfect forecast of GDP growth. The individual figures suggest that the yield spread leads real output. This pattern is especially evident for Canada, France, and Germany. It seems that the yield spread tracks real GDP growth more closely than do stock prices. Since stock prices exhibit far more variability than real GDP, stock price changes are likely to be very noisy predictors of GDP growth.

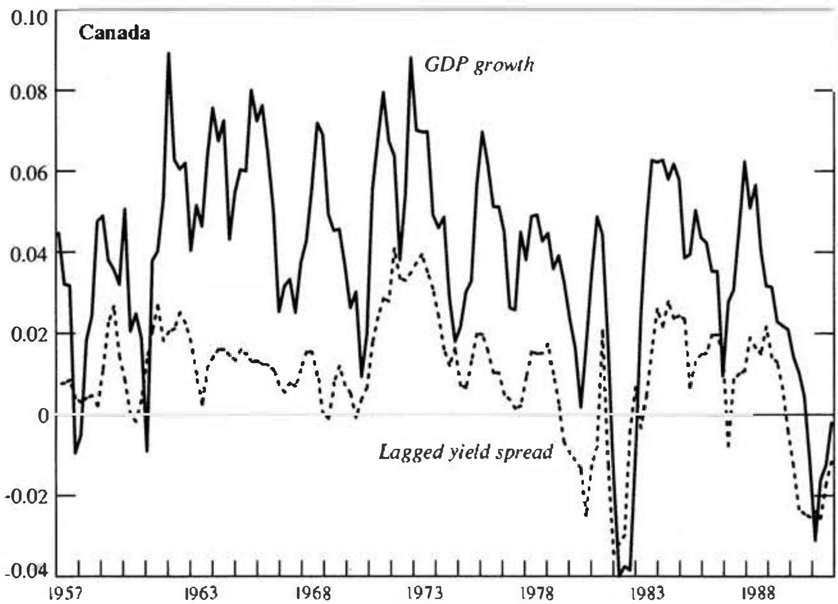
III. Empirical Evidence

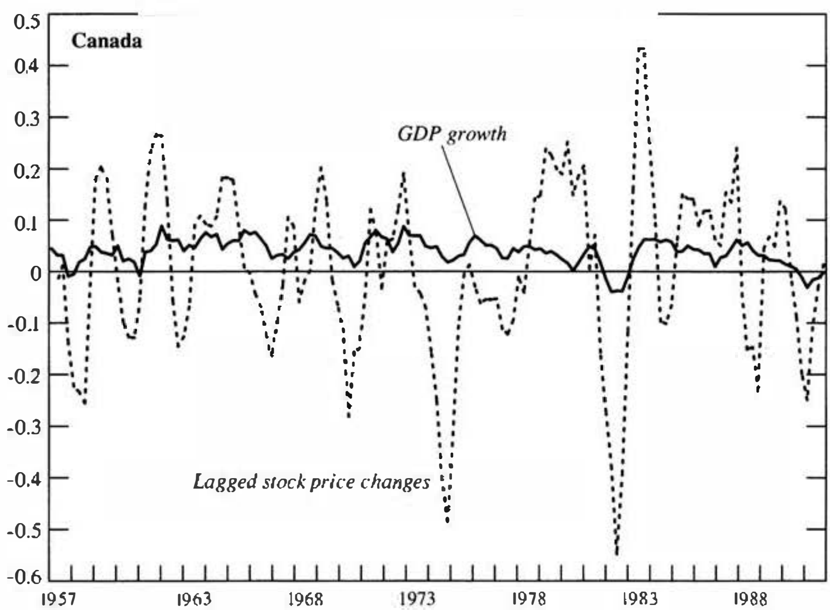
Table 2 documents the within-sample forecasting power of the term structure over the whole period for each country. Because of the overlapping data in the regressions for annual growth, the ordinary least squares (OLS) standard errors are inconsistent, although the OLS estimates of the slope coefficients are not. The Hansen (1982) and Newey and West (1987) method is used to correct for autocorrelation and conditional heteroskedasticity.

The estimated slope coefficients are significantly positive for all countries, suggesting that the slope of the yield curve is positively related to the expected growth rate in real output. A simple measure of the term structure—the yield spread between long-term and short-term government bonds—can explain a large fraction of the variation in real output. It is especially striking to note, for example, that the yield spread alone explains more than half of the GDP variation in Canada. The explanatory power of the yield spread is not limited to the full sample period. The subsample results in Table 3 offer further evidence that the yield curve contains a great deal of information about real output growth. It appears, for example, that the relatively small R^2 for the United Kingdom stems from the latter half of the sample. Table 4 presents evidence that the yield spread also helps predict the GDP growth residual, obtained by regressing GDP growth on all its possible lags.

To evaluate the forecasting performance of the term structure, consider an alternative model based on the changes in stock prices. Studies of the business cycle have paid a great deal of attention to the stock market. In the 1920s, the Harvard "ABC" system pioneered the use of

Figure 1. *GDP Growth, Lagged Yield Spread, and Lagged Stock Price Changes: G-7 Countries*





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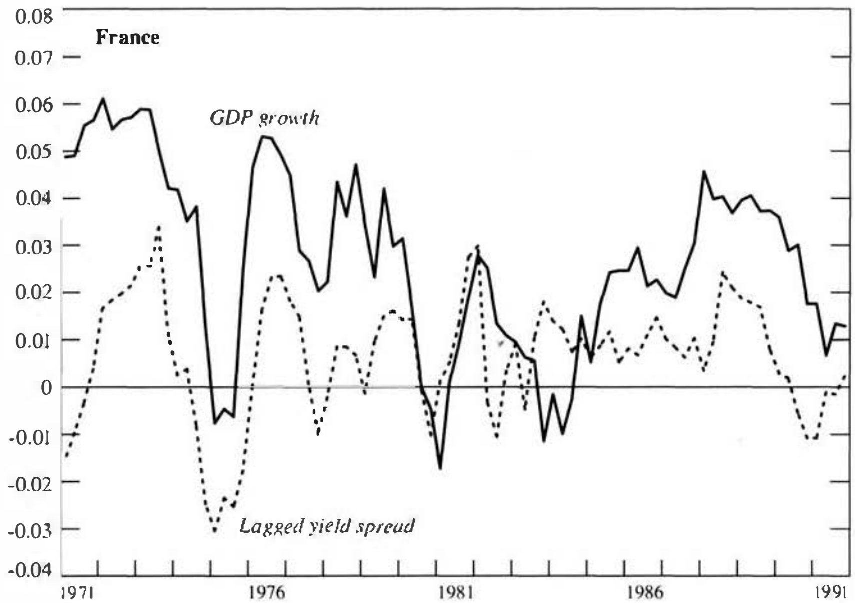

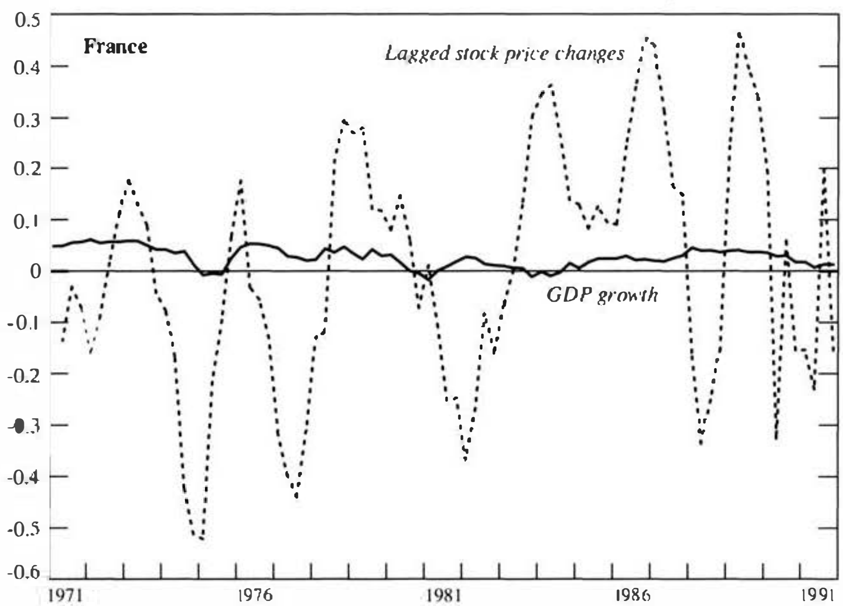

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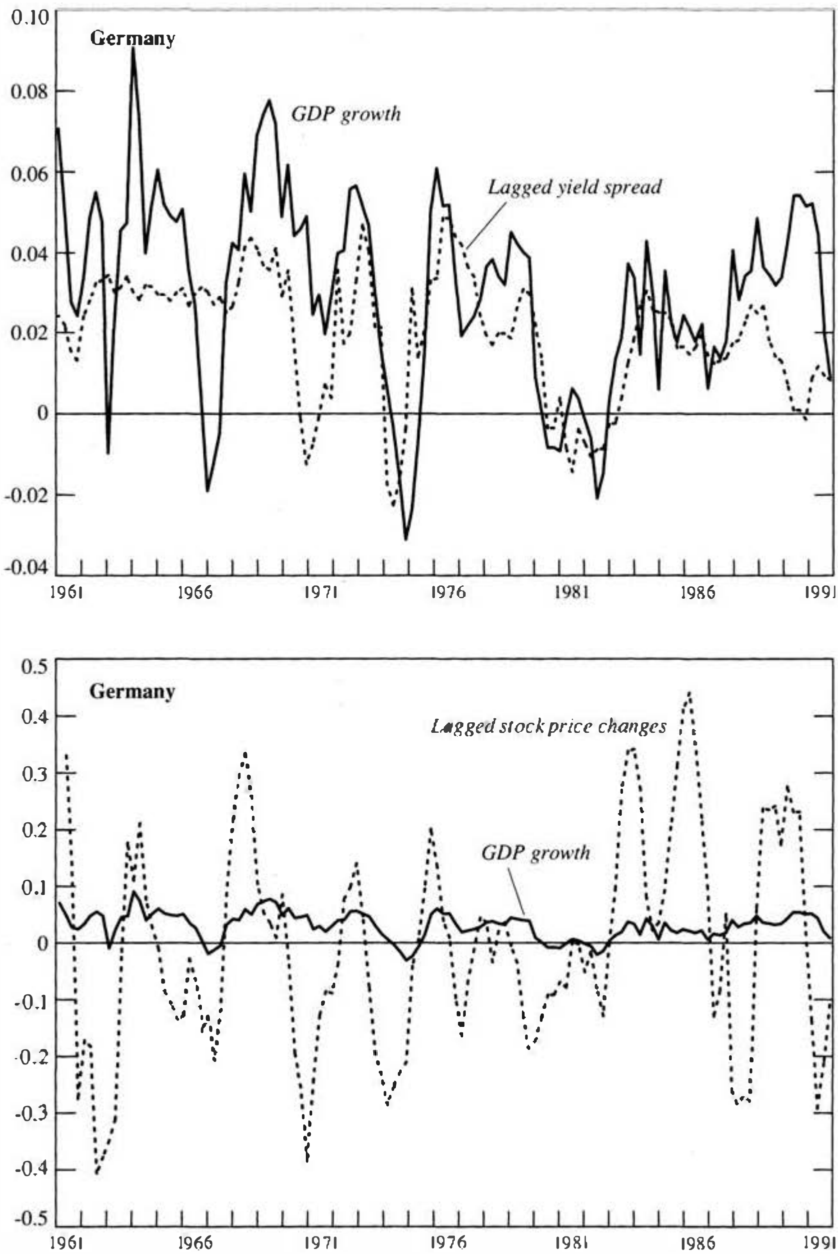

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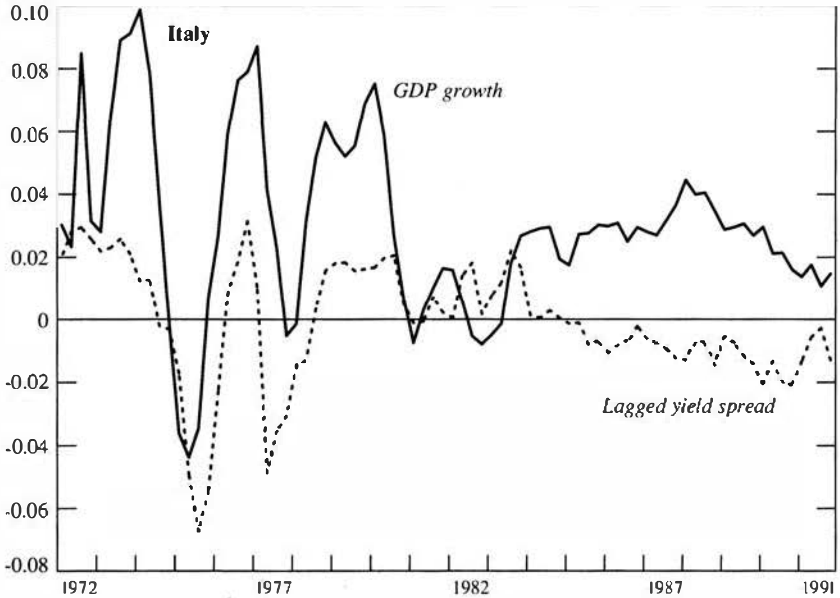

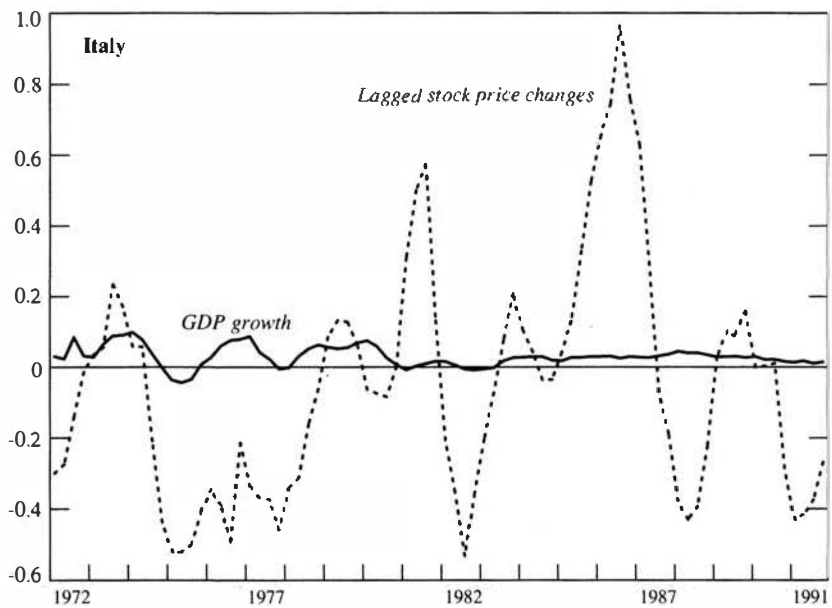

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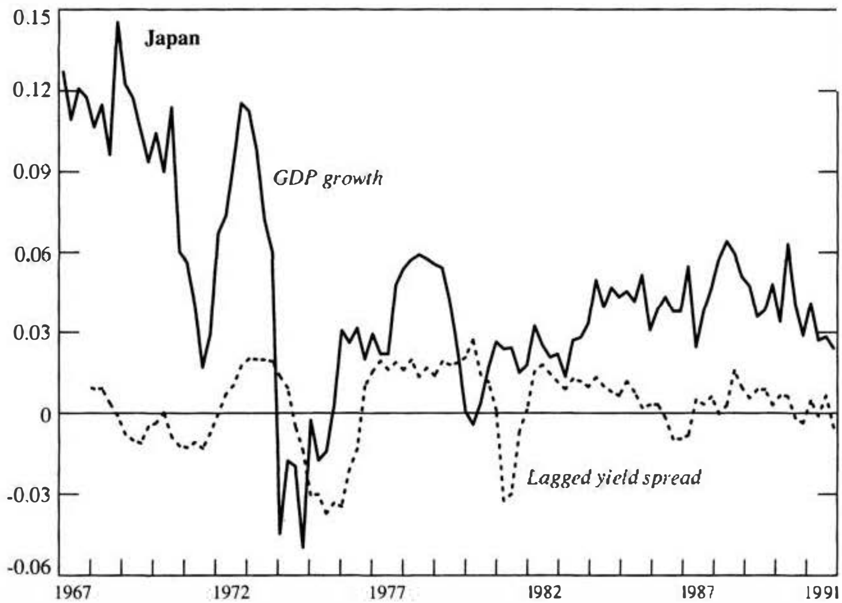

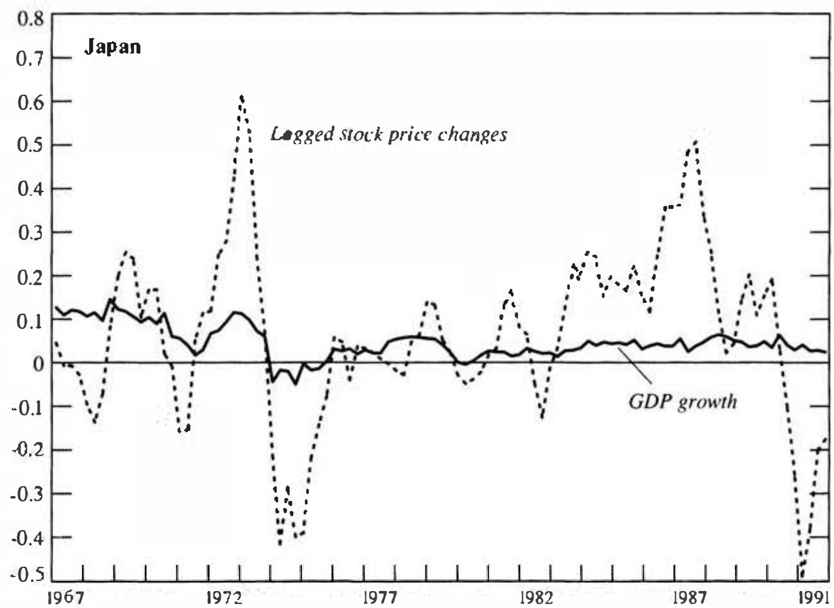

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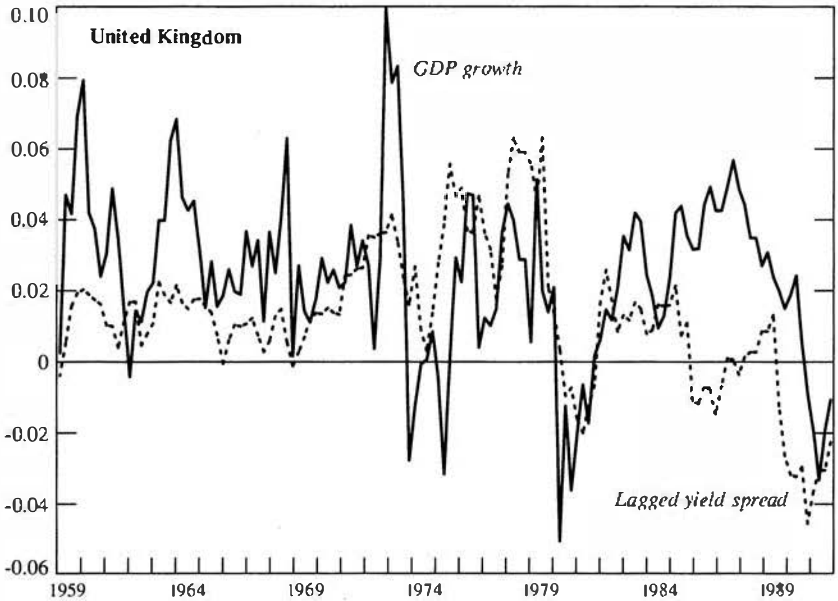

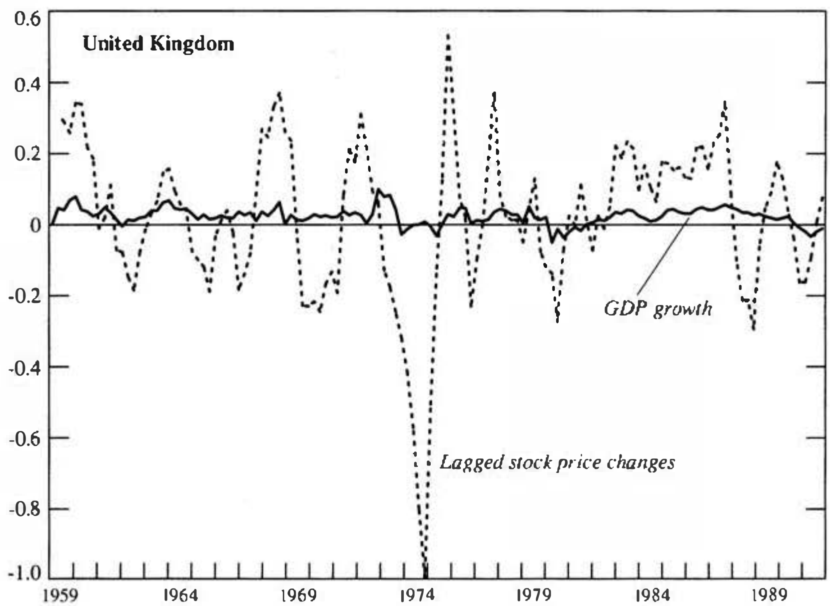

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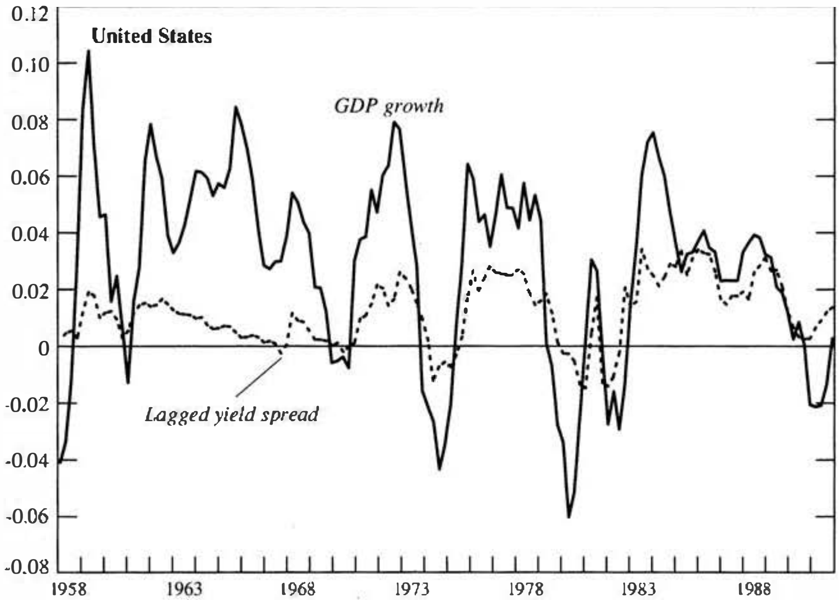

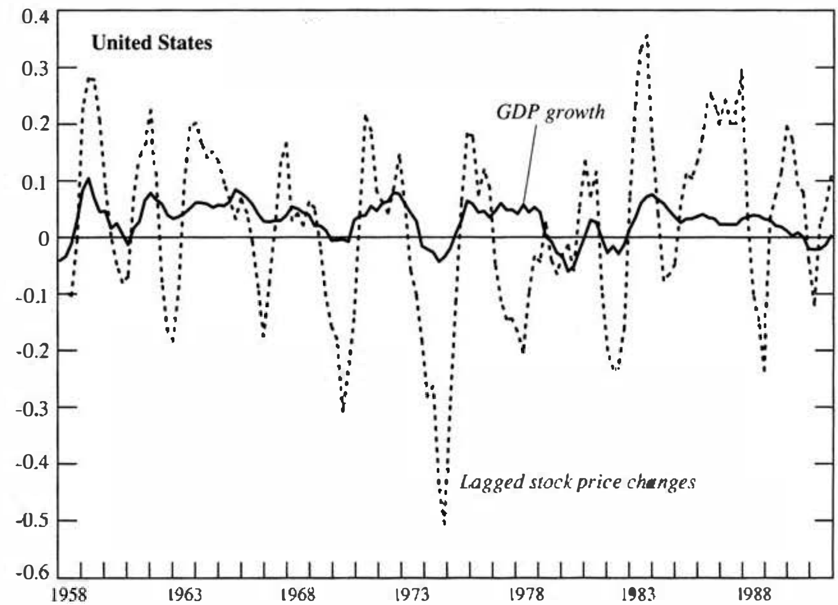

Table 2. *Forecasting Real Output Growth from the Yield Curve*

Country	Sample period	Number of observations	Coefficient on yield spread (β)	$\chi^2(2)$	$\chi^2(1)$	$\bar{R}^2$
Canada	1957:1–1991:4	140	1.2659 (8.6548)	11.2909 (0.0083)	0.1169 (0.7748)	0.523
France	1971:2–1991:3	83	0.62203 (3.0140)	32.2443 —	0.9762 (0.3510)	0.159
Germany	1961:2–1991:4	123	0.8067 (4.0584)	3.3542 (0.0679)	0.8455 (0.4309)	0.270
Italy	1972:1–1991:4	80	0.7992 (4.4916)	65.0060 —	0.9027 (0.3991)	0.287
Japan	1967:4–1991:4	97	0.7424	46.9170 —	1.2464 (0.2260)	0.168
United Kingdom	1959:1–1991:4	132	0.6595	16.0044 —	1.8736 (0.1752)	0.083
United States	1958:1–1992:1	137	1.5702 (4.4576)	23.1909 —	0.2367 (0.6266)	0.296

Note: The regression equation is $dY_t = \alpha + \beta S^y_{t-1} + \epsilon_t$, where $dY_t = \log(Y_{t+4}/Y_t)$ is the annual growth rate in real GNP or GDP, and S^y is the yield spread between long-term and short-term government bonds.

The table presents (i) the slope coefficient β; (ii) the t-ratios (in parenthesis), computed from standard errors after a Hansen (1982) and Newey and West (1987) correction for autocorrelation and conditional heteroskedasticity; and (iii) regression R^2, adjusted for degrees of freedom.

Also, $\chi^2(2)$ is the joint test for $\alpha = 0$ and $\beta = 1$, and $\chi^2(1)$ is the test for $\beta = 1$ only. The corresponding p-values are in the parenthesis. A dash stands for zero p-value.

Table 3. *Forecasting Real Output Growth from the Yield Curve: Subsample Results*

Country	Sample period	Number of observations	Coefficient on yield spread (β)	$\bar{R}^2$
Canada	1957:1–1974:4	72	1.0498 (4.2984)	0.250
	1975:1–1991:4	68	1.2769 (7.4700)	0.613
France	1971:1–1981:4	44	0.7767 (4.1944)	0.297
	1982:1–1991:3	39	0.6316 (2.9468)	0.185
Germany	1961:1–1974:4	56	0.6869 (2.7733)	0.184
	1975:1–1991:4	68	0.7561 (3.5066)	0.265
Italy	1972:1–1981:4	40	0.9832 (7.1228)	0.429
	1982:1–1991:4	40	0.5959 (2.911)	0.429
Japan	1967:4–1981:4	57	0.5662 (2.218)	0.210
	1982:1–1991:4	40	0.4342 (3.125)	0.114
United Kingdom	1959:1–1974:4	64	0.9561 (3.1619)	0.148
	1975:1–1991:4	68	0.2460 (1.4185)	0.059
United States	1958:1–1981:4	96	1.2004 (4.9555)	0.377
	1982:1–1991:4	40	1.0757 (6.4756)	0.582

Note: The regression equation is $dY_t = \alpha + \beta S^y_{t-1} + \epsilon_t$, where $dY_t = \log(Y_{t+4}/Y_t)$ is the annual growth rate in real GNP or GDP, and S^y is the yield spread between long-term and short-term government bonds.

The table presents (i) the slope coefficient β; (ii) the *t*-ratios (in parenthesis), computed from standard errors robust to conditional heteroskedasticity; and (iii) regression R^2, adjusted for degrees of freedom.

the stock market price as a main component of its "A" curve for tracking the business cycle. Today the Standard & Poor's 500 stock price index is included in the U.S. Department of Commerce's index of leading economic indicators. The OECD regularly publishes a national share price index along with a list of other economic variables in its main economic indicators. The view that stock prices contain information about future economic fluctuations is highly popular among academics and practi-

Table 4. *Predicting the Residual of GDP Growth from the Yield Curve*

Count y	Sample period	Number of observations	Coefficient on yield spread (β)	$\bar{R}^2$
Canada	1957:1–1991:4	140	0.2699* (3.8715)	0.095
France	1972:3–1991:3	77	0.1776* (2.0966)	0.061
Germany	1962:3–1991:4	118	0.2222* (3.3349)	0.022
Italy	1972:1–1991:4	80	0.1276 (1.5436)	0.022
Japan	1967:4–1991:4	97	0.1472 (1.1063)	0.005
United Kingdom	1959:1–1991:4	97	0.1472 (1.1063)	0.005
United States	1959:3-1991:4	130	0.3221* (3.3936)	0.085

Note: The regression equation is $Res_t = \alpha + \beta S^y_{t-1} + \epsilon_t$, where Res_t is the residual obtained by regressing GDP growth on all its possible lags, and S^y is the yield spread between long-term and short-term government bonds.

The table presents (i) the slope coefficient β; (ii) the t-ratios (in parenthesis), computed from standard errors robust to conditional heteroskedasticity; and (iii) regression R^2, adjusted for degrees of freedom.

Also, the sign * indicates that the coefficient is significantly different from zero at the 5 percent level in a two-tailed test.

tioners. Fama (1981, 1990b), Barro (1989), Harvey (1989), and Chen (1991) have found evidence from the U.S. data that stock returns lead changes in real activity.

Since stock prices are the discounted present values of future dividend streams, and corporate dividends and earnings are correlated with GDP, stock prices should contain information about GDP growth. However, because the stock market price is far more volatile than output, as can be seen by Figure 1, it is likely to be a very poor predictor of GDP growth. Table 5 gives regression results for the stock price model using international data. For France, Germany, and Italy, stock prices have little power for predicting real output but do have forecasting power for the other G-7 countries. Comparing Table 5 with Tables 2 and 3, however, shows that the forecasting model based on stock prices underperforms the term structure model for all but two countries within the sample. Most of the yield curve regressions in Table 2 have larger R^2's than the stock price equations in Table 5. The yield spread, for example, is able to explain 27 percent of the variance in real GDP in Germany, while stock price changes explain only about 5 percent of Germany's output varia-

tion. The lagged stock price changes, however, have more explanatory power for GDP growth in Japan and the United Kingdom than the term structure model does. On balance, it seems that the yield spread variable has more within-sample forecasting power for real GDP growth than stock prices. Therefore, while Fischer and Merton (1984) claim that the stock market price is the single best predictor of the business cycle, the evidence documented here suggests that the bond market more likely outperforms the stock market in predicting future real activity.

Table 6 reports results from multiple regressions. In addition to the yield spread, other information variables, such as stock prices, lagged output growth, and inflation, are added to the regression equation. For most countries, the yield spread has marginal forecasting power over stock prices, lagged output growth, and inflation. Indeed, stock price changes have almost no forecasting power for France, Germany, and Italy, while the yield spread has a strong ability to predict real output growth for all the countries except Japan. It appears that the yield curve and current output growth are the most powerful predictors of future output growth.

To evaluate the forecasting performance of the yield spread, a univariate time series forecasting model is also considered as a third benchmark model. Autoregressive moving-average (ARMA) models for real GDP growth, with up to two autoregressive and two moving-average parameters, are estimated for each country. A "best" ARMA representation is chosen as the univariate time series forecasting model, using Akaike's information criterion.

Table 7 provides out-of-sample forecasting evaluation. The out-of-sample forecasting performance of the yield spread is compared with that of a stock price–based model and a univariate time series forecasting model. The stock price model is that described in Table 5. The forecasting period is from 1982:1 to 1991:4, with a total of 40 forecasts. All three models are initially estimated up to 1981:4 for each country and used to forecast real GDP growth for 1982:1. The models are then reestimated with data up to 1982:1, and new forecasts are generated. This procedure is repeated up to 1991:4.

Table 7 reports two evaluation statistics: the mean absolute error (MAE) and the root mean squared error (RMSE). The results suggest that the yield spread model compares favorably with the alternative forecasting models. The yield spread model outperforms both the stock price model and the ARMA model for Canada, Italy, and Japan. It outperforms the stock price model for France and Germany. For the United States, it appears that the two financial variables have about equal forecasting performance, but none of them can do better than the AR(1)

Table 5. *Forecasting Real Output Growth from Stock Prices*

Country	Sample period	Number of observations	Coefficient on stock prices (β)	$\bar{R}^2$
Full sample results				
Canada	1957:2–1991:4	139	0.071 (2.987)	0.206
France	1971:2–1991:3	82	−0.001 (0.040)	−0.012
Germany	1961:2–1991:4	123	0.029 (1.697)	0.047
Italy	1972:1–1991:4	80	0.015 (1.259)	0.019
Japan	1967:4–1991:4	97	0.084 (2.443)	0.204
United Kingdom	1959:2–1991:4	131	0.045 (5.603)	0.156
United States	1958:2–1992:1	135	0.111 (4.887)	0.286
Subsample results				
Canada	1957:1–1974:4	71	0.072 (3.992)	0.214
	1975:1–1991:4	68	0.071 (2.573)	0.250
France	1971:1–1981:4	44	0.030 (2.002)	0.062
	1982:1–1991:3	39	−0.010 (0.634)	0.003
Germany	1961:1–1974:4	56	0.062 (3.125)	0.215
	1975:1–1991:4	68	0.022 (1.263)	0.022
Italy	1972:1–1981:4	40	0.038 (0.746)	0.057
	1982:1–1991:4	40	0.011 (1.139)	0.084
Japan	1967:4–1981:4	57	0.151 (5.225)	0.388
	1982:1–1991:4	40	0.016 (2.697)	0.048
United Kingdom	1959:1–1974:4	64	0.045 (5.305)	0.187
	1975:1–1991:4	68	0.050 (2.721)	0.178
United States	1958:1–1981:4	96	0.141 (6.678)	0.383
	1982:1–1991:4	40	0.080 (1.980)	0.195

Note: The regression equation is $dY_t = \alpha + dS^p_{t-1} + \epsilon_t$, where $dY_t = \log(Y_{t+4}/Y_t)$ is the annual growth rate in real GNP or GDP, S^p_t is the national stock price index deflated by the consumer price index, and $dS^p_t = \log(S^p_{t+4}/S^p_t)$ is the annual change in real stock prices.

The table presents (i) the slope coefficient β; (ii) the *t*-ratios (in parenthesis), computed from standard errors after a Hansen (1982) and Newey and West (1987) correction for autocorrelation and conditional heteroskedasticity; and (iii) regression R^2, adjusted for degrees of freedom.

Table 6. *Regressions with Multiple Information Variables*

			Coefficients on				
Country	Sample period	Number of observations	Yield curve (c_1)	Stock prices (c_2)	Lagged output (c_3)	Inflation (c_4)	$\bar{R}^2$
Canada	1958:2–1991:4	135	0.506*	0.031	0.554	−0.023	0.76
			(7.40)	(5.35)	(13.77)	(−0.54)	
France	1971:2–1991:3	82	0.220*	0.003	0.852	−0.036	0.77
			(2.47)	(0.06)	(23.12)	(−0.86)	
Germany	1961:2–1991:4	123	0.237*	0.015	0.694	−0.039	0.67
			(2.32)	(1.79)	(12.60)	(0.51)	
Italy	1972:1–1991:4	80	0.323*	0.001	0.683	−0.094	0.69
			(3.14)	(0.03)	(10.00)	(−2.68)	
Japan	1968:1–1991:4	96	0.041	0.018	0.792	−0.021	0.74
			(0.26)	(2.12)	(9.69)	(−0.28)	
United Kingdom	1959:2–1991:4	131	0.288*	0.021	0.416	−0.135	0.55
			(3.85)	(2.75)	(7.73)	(−4.37)	
United States	1958:2–1992:1	135	0.342*	0.033	0.732	−0.089	0.81
			(2.29)	(2.80)	(12.43)	(−1.27)	

Note: The regression equation is $dY_t = c_0 + c_1 S^y_{t-1} + c_2 dS^p_{t-1} + c_3 dY_{t-1} + c_4 \pi_{t-1} + \varepsilon_t$, where $dY_t = \log(Y_{t+4}/Y_t)$ is the annual growth rate in real GNP or GDP, S^p_t is the national stock price index deflated by the consumer price index, $dS^p_t = \log(S^p_{t+4}/S^p_t)$ is the annual change in real stock prices, and π_t is the consumer price inflation rate.

This table presents (i) the slope coefficients; (ii) the t-ratios (in parenthesis), computed from standard errors after a Hansen (1982) and Newey and West (1987) correction for autocorrelation and conditional heteroskedasticity; and (iii) regression R^2, adjusted for degrees of freedom.

Also, the * indicates that the coefficient is significantly different from zero at the 5 percent level in a two-tailed test.

Table 7. *Out-of-Sample Forecasting Performance of the Yield Curve Versus Alternative Forecasting Models: 1982:1–1991:4*

Country	Model	Mean absolute error	Root mean squared error
Canada	Yield spread	0.0156	0.0217
	Stock price changes	0.0258	0.0324
	AR(1)	0.0326	0.0365
France	Yield spread	0.0154	0.0201
	Stock price changes	0.0191	0.0234
	ARMA(1,2)	0.0120	0.0150
Germany	Yield spread	0.0117	0.0155
	Stock price changes	0.0235	0.0268
	ARMA(2,2)	0.0128	0.0152
Italy	Yield spread	0.0143	0.0209
	Stock price changes	0.0222	0.0250
	AR(1)	0.0229	0.0246
Japan	Yield spread	0.0156	0.0187
	Stock price changes	0.0311	0.0369
	ARMA(1,2)	0.0356	0.0384
United Kingdom	Yield spread	0.0173	0.0204
	Stock price changes	0.0144	0.0186
	ARMA(1,2)	0.0287	0.0317
United States	Yield spread	0.0291	0.0309
	Stock price changes	0.0286	0.0317
	AR(1)	0.0206	0.0272

Note: Parameters of each model are reestimated at each point in the time series during 1981:4–1991:3. These parameters are used to forecast real GDP growth for the 1982:1–1991:4 period. AR(·) and ARMA(·) denote autoregressive (AR) moving-average (MA) time series models.

model. The United Kingdom is the only case where the forecasts from the yield spread model are inferior to those from the stock price model. Nevertheless, the yield spread model still outperforms the univariate time series forecasting model for the United Kingdom.

In summary, the empirical evidence seems to support the main implications of the simple model developed in the initial sections of this paper. It appears that the slope of the yield curve is positively related to the expected growth rates of real GDP in the G-7 countries. The term structure contains information about the real sector of the economy and can therefore be used to forecast future economic activity. The yield spread tends to have more within-sample forecasting power than stock prices, and its out-of-sample forecasting performance compares favorably with that of alternative forecasting models. The forecasting ability of the yield curve is quite impressive considering the cost and performance of many large-scale macroeconometric forecasting models that are also used to predict real output. In the case of the United States, for

example, Harvey (1989) found that forecasts based on the yield curve compare favorably with forecasts from seven leading econometric models, including the Data Resources Incorporated (DRI) model and the Wharton Econometric Forecasting Associates (Wharton) model.

IV. Conclusions

There is a popular belief that the term structure of interest rates contains information about fluctuations in real output. Many equilibrium asset pricing models attempt to explain how underlying variables in the economy determine the term structure. The question asked in this paper is, if the term structure bears any relation at all to changes in economy-wide variables, such as real GDP growth, can this relationship be used to forecast aggregate fluctuations via some easily measured term structure variables? This paper made an attempt to formalize the link between the yield curve and real activity. A simple, closed-form formula of the term structure is derived, expressed in terms of the parameters of the stochastic production processes. It is shown that the term structure of interest rates embodies the market's expectations about changes in the macroeconomic fundamental—the growth in real aggregate output. Applying the model to the G-7 industrial countries, the paper found evidence supporting the model's main implication—that the slope of the yield curve is positively related to the expected growth in real output. The empirical results suggest that the yield spread between long-term and short-term government bonds serves as a good predictor of future economic growth. This easily measured variable has more forecasting power than changes in stock prices, and it retains marginal forecasting power when other commonly used variables, such as lagged GDP growth, stock price changes, and inflation, are added to the regressions. The out-of-sample forecasting performance of the yield spread also compares favorably with those of the stock price model and the univariate time series forecasting model. It seems that even a crude measure of the slope of the yield curve, such as the yield spread used in this study, can provide useful information about the business cycle to both private investors and policymakers. Policy authorities might well consider adding some measure of the term structure to their list of leading economic indicators.

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