I. Introduction

The daily financial press frequently run 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 tells something about economic prospects. An upwardly sloping yield curve, for example, is interpreted as a sign of strong economy ahead and a flattering or inverting yield curve as foreshadowing a 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) found that the term structure predicts future spot rates and inflation. Clearly economists and policy makers are also concerned with the link between movements in long-term and short-term interest rates and 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 United States term structure can also be used to predict growth in real GNP. The current study documents the forecasting power of the yield curve variables for predicting GDP in the Group of Seven (G-7) industrial countries.

The rest of the paper is organized as follows: Section II sets out a simple general equilibrium 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. Section III contains a brief discussion of measurement issues and data sources. Section IV then examines empirically whether the main implications of the model can be borne out by the 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. The final section offers concluding remarks.

II. The Model

The term structure of interest rates measures the relationship among the yields on default-free bonds of varying terms to maturity. Equilibrium asset pricing theories shed lights on how this relationship is determined by the underlying variables of the economy. In this paper we ask the opposite question whether we can extract information from the yield curve about future real activities.

We present a simple intertemporal equilibrium model that formalizes the link between the term structure and aggregate production processes. In the

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empirical part of the paper, we will use observed interest rate variables to predict future output growth. Our model is built on the work of Merton (1973), Lucas (1978), Brock (1982), Cox, Ingersoll and Ross (1985), and especially, Breeden (1979, 1986).

We 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 $c = \{c_t:\ t \geq 0\}$ satisfying $E[\int_0^T e^{-\rho t} u(c_t) dt] < \infty$ almost surely for all $T \geq 0$. The agent has preferences over positive stochastic consumption processes c given by the lifetime utility functional:

$$U(c) = E[\int_0^\infty e^{-\rho t} u(c(t)) dt] \tag{1}$$

where c(t) is the time t rate of consumption, E(.) is an expectation operator, ρ is the rate of time preference, and u(.) is the instantaneous utility function. For the sake of deriving an analytic characterization of the term structure, we restrict u(.) to be the logarithmic function, that is, $u(c(t)) = \log(c(t))$.

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

$$d X_t = \mu_x (X, t)\, dt + \sigma_x (X, t)\, dB_t \tag{2}$$

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:

$$Y_t = Y_0 + \int_0^t \mu_y (Y, X, s)\, ds + \int_0^t \sigma_y (Y, X, s)\, dB_s \tag{3}$$

We further impose the restrictions that both the drift and diffusion terms in (3) are homogeneous of degree one in Y, that is, $\mu_y (Y, X, s) = Y \mu_y(X, s)$, and $\sigma_y(Y, X, s) = Y \sigma_y(X, s)$. These restrictions imply that the production technology is 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, we assume that this default-free bond is the only financial security available. The value of

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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, and its dynamics can be written as

$$dP = \mu_p \, dt + \sigma_p \, dB \tag{4}$$

The consumer's total wealth at time t, W(t), in units of the physical good, is the sum of his human and nonhuman wealth. Since labor is not used in the production processes, his entire wealth consists of only the latter part, 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 intertemporal budget constraint takes the form of

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

$$= W\mu_W \, dt + W\sigma_W \, dB \tag{5}$$

An equilibrium is defined as a set of stochastic processes (P, r, a, C) such that

(i) the agent maximizes his expected lifetime utility (1) subject to the budget constraint (5);

(ii) the net supply of the default-free bond and riskless lending is zero, that is, 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 wealth of the agent is invested in the physical production processes.

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

$$\frac{1}{c} = V_w \tag{6}$$

$$W V_w (\mu_y - r) + W^2 V_{ww} a \sigma_y^2 + \frac{1}{2} W^2 Vww\, b \sigma_y \sigma_p = 0 \tag{7}$$

$$W V_w (\mu_p - r) + \frac{1}{2} W^2 V_{ww} a \sigma_y \sigma_p + W^2 V_{ww} b \sigma_p^2 = 0 \tag{8}$$

Substituting the market clearing conditions into (7), we have

$$r = \mu_y + \frac{W V_{ww}}{V_w} \sigma_y^2 \tag{9}$$

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It can be shown that given our specific assumption about utility function, the consumer's value function also takes a particularly simple form, that is, $V(W,t) = (1/\rho)\log(W)$. Therefore, from (6) we can write the 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 rate of time preference. Furthermore, since the agent's coefficient of relative risk aversion equals to one, (9) can be simplified as

$$r = \mu_y - \sigma_y^2 \tag{10}$$

Equation (10) gives a simple, closed-form formula of 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 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 the interest rate is higher if the risk associated with aggregate production is smaller, ceteris paribus. This important relationship provides the basis for forecasting economic growth via interest rate variables.

Note that due to our logarithmic utility assumption, the covariance of production process with the state variable X_t does not enter equation (10). Such a covariance term would appear for more general preference specifications, as, for example, in Breeden (1986).

For empirical implementation we employ the following discrete time approximation to equation (10):

$$r(t,T) = \mu_y(t,T) - \sigma_y^2(t,T) \tag{11}$$

The term structure implied by this production-oriented equation has some interesting shapes. It will be rising (upward sloping) if, holding the variance of production constant, the growth rate of real output in the economy is expected to be higher, and it will be falling (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 expectation about the prospects of the economy, and hence contains useful information about aggregate economic fluctuations.

Since

$$\mu_y(t,T) = E_t\left(\frac{\Delta Y_{t,T}}{Y_t}\right) \tag{12}$$

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we can rearrange (11) to obtain

$$E_t \left(\frac{\Delta Y_{t,T}}{Y_t}\right) = r(t, T) + \sigma_y^2(t, T) \tag{13}$$

Equation (13) makes it clear that investment in the risky production process receives a premium above the riskless interest rate, determined by the conditional variance of production. For the rest of this paper we assume the stochastic process of production has constant variance so that we can concentrate on the relationship between the 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 (13) the corresponding equation for the security with maturity date τ yields

$$E_t \left(\frac{\Delta Y_{\tau,T}}{Y_t}\right) = S^y_{t,\, T-\tau} \tag{14}$$

where

$$S^y_{t,\, T-\tau} = r(t, T) - r(t, \tau) \tag{15}$$

is the interest rate differential or the yield spread between the two default-free bonds with time to maturity T and τ respectively.

To remove the conditional expectation operator, rewrite (14) as

$$\frac{\Delta Y_{\tau,T}}{Y_t} = S^y_{t,\, T-\tau} + \varepsilon_t \tag{16}$$

where ε_t is the forecast error. Equation (16) is our basic model for empirical estimation in this paper.

III. Measurement Issues and Data Sources

1. Description of variables

To examine the relationship between the term structure and real activity, we focus our attention 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 comovements of the term structure and the business cycle and found that the size of yield spread is associated with the general economic conditions such as recession and recovery. For

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simplicity, we only construct a single measure of the slope of the yield curve, the difference between annualized yields on long-term and short-term government bonds. We denote this variable 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 as poor empirical performance using S^y does not necessarily constitute a strong case against the principle implication of the term structure model in section II--namely, the expected growth in real output is positively, linearly related to the slope of yield curve.

The Gross National Product (GNP) and/or the Gross Domestic Product (GDP) are the natural candidates for measurement of aggregate output. Strictly speaking the horizon over which we measure real output growth should correspond to the exact maturity structure of the government bonds we choose. What we use in the regressions are year-to-year growth rates from quarterly data, however. In other words, the dependent variables in the regression equations are

$$d\,Y_t = \log\left(\frac{Y_{t+4}}{Y_t}\right) \tag{17}$$

We believe that it is acceptable to focus on the four-quarter growth rates for testing the principle implication of our term structure model. Data over shorter horizons such as one-quarter changes likely contain more measurement error and the related evidence on stock returns (see Fama (1990b) for example) suggests that the term structure also likely has better predictive power for real activity over longer horizons spanning from one to several years.

2. The data

We apply the basic model of term structure to the "Group of Seven" (G-7)--Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States. We work 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, we use real GNP or real GDP whichever is contained in the International Financial Statistics. This quarterly series is seasonally adjusted at annual rates. In those cases in which both nominal GNP and nominal GDP are available for a country, we compared the two real series under the assumption of a common deflator and found only minor difference between the two series. Therefore we simply picked the longest series as our measure of real output.

The quarterly long-term government bond yield and quarterly treasury bill rate are taken from International Financial Statistics's interest rates data. These are period-average annualized rates. The long-term government

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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 rate series is not available for a country, we use a typical short-term interest rate as a proxy for the T-bill rate. This series is published in OECD's Financial Statistics. The stock price index and consumer price index are taken from IMF's International Financial Statistics. Quarterly data are period averages.

Table 1 reports summary statistics for three time series: real GDP growth, yield spread and stock market price changes. The standard deviation of the yield spread is typically within one half the mean GDP growth rates. The stock market price changes are much more volatile than either GDP growth or the yield spread. They exhibit fairly similar autocorrelation patterns. The time series data are also plotted in Figure 1. The series are aligned so that if the GDP growth and financial time series coincided, then the financial variables would be a prefect forecast of GDP growth. The 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 the stock prices. Since stock prices exhibit far more variability than real GDP, stock price changes are likely very noisy predictors of GDP growth.

IV. Empirical Evidence

Table 2 documents the within-sample forecasting power of the term structure over the whole period for each country. Due to the use of overlapping data in regressions for annual growth, the OLS standard errors are inconsistent although the OLS estimates of the slope coefficients are still consistent. We use the Hansen (1982) and Newey and West (1987) method of adjustment 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 that the yield spread alone explains more than half of the GDP variation in Canada. The explanatory power of yield spread is not limited to the full sample period. The sub-sample results in Table 3 offer further evidence that the yield curve contains a great deal of information about real output growth. It appears that the relatively small R^2 for the United Kingdom stems from the latter half of the sample we examined. Table 4 presents some evidence that the yield spread also helps predict the GDP growth residual, obtained by regressing GDP growth on all its possible lags.

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

	Sample Period	No. Obs.	Mean	Std. Dev.	Autocorrelation $\rho1$	$\rho2$	$\rho3$	$\rho4$	$\rho8$	$\rho12$
Canada										
GDP growth	57:1-91:4	140	0.03825	0.02566	0.81	0.59	0.36	0.11	0.08	0.07
Yield spread	57:1-91:4	140	0.00942	0.01474	0.85	0.67	0.51	0.40	0.07	-0.04
Stock price changes	57:1-91:4	140	0.00349	0.16708	0.79	0.45	0.07	-0.22	-0.07	-0.05
France										
GDP growth	71:1-91:3	83	0.02715	0.01946	0.86	0.69	0.48	0.29	0.11	0.11
Yield spread	71:1-91:3	83	0.00683	0.01258	0.75	0.42	0.20	-0.02	-0.25	-0.01
Stock price changes	71:1-91:3	83	0.00714	0.23665	0.77	0.53	0.25	-0.08	-0.03	0.01
Germany										
GDP growth	61:1-91:4	124	0.03046	0.02381	0.78	0.56	0.38	0.16	-0.12	0.01
Yield spread	61:1-91:4	124	0.01913	0.01595	0.84	0.67	0.48	0.28	-0.07	0.09
Stock price changes	61:1-91:4	124	-0.00961	0.18663	0.80	0.51	0.25	-0.02	-0.25	0.13
Italy										
GDP growth	72:1-91:4	80	0.03021	0.02851	0.79	0.48	0.12	-0.17	-0.15	0.16
Yield spread	72:1-91:4	80	-0.00356	0.01902	0.78	0.44	0.14	-0.05	0.12	0.09
Stock price changes	72:1-91:4	80	-0.04972	0.33407	0.88	0.67	0.41	0.16	-0.01	0.04
Japan										
GDP growth	67:4-91:4	97	0.04472	0.03678	0.83	0.73	0.58	0.40	0.07	0.11
Yield spread	67:4-91:4	97	0.00234	0.01430	0.85	0.64	0.18	-0.01	-0.32	-0.29
Stock price changes	67:4-91:4	97	0.06262	0.20236	0.86	0.63	0.38	0.11	-0.17	0.11
United Kingdom										
GDP growth	59:1-91:4	132	0.02413	0.02432	0.65	0.44	0.24	0.03	-0.13	-0.02
Yield spread	59:1-91:4	132	0.01188	0.02063	0.90	0.79	0.68	0.58	0.27	0.29
Stock price changes	59:1-91:4	132	0.02076	0.21898	0.81	0.54	0.25	-0.02	-0.11	-0.12
United States										
GDP growth	58:1-91:4	136	0.02828	0.03302	0.85	0.62	0.35	0.11	-0.09	-0.06
Yield spread	58:1-91:4	136	0.01231	0.01155	0.85	0.68	0.55	0.43	0.01	-0.12
Stock price changes	58:1-91:4	136	0.01939	0.15618	0.80	0.47	0.11	-0.17	-0.08	0.09

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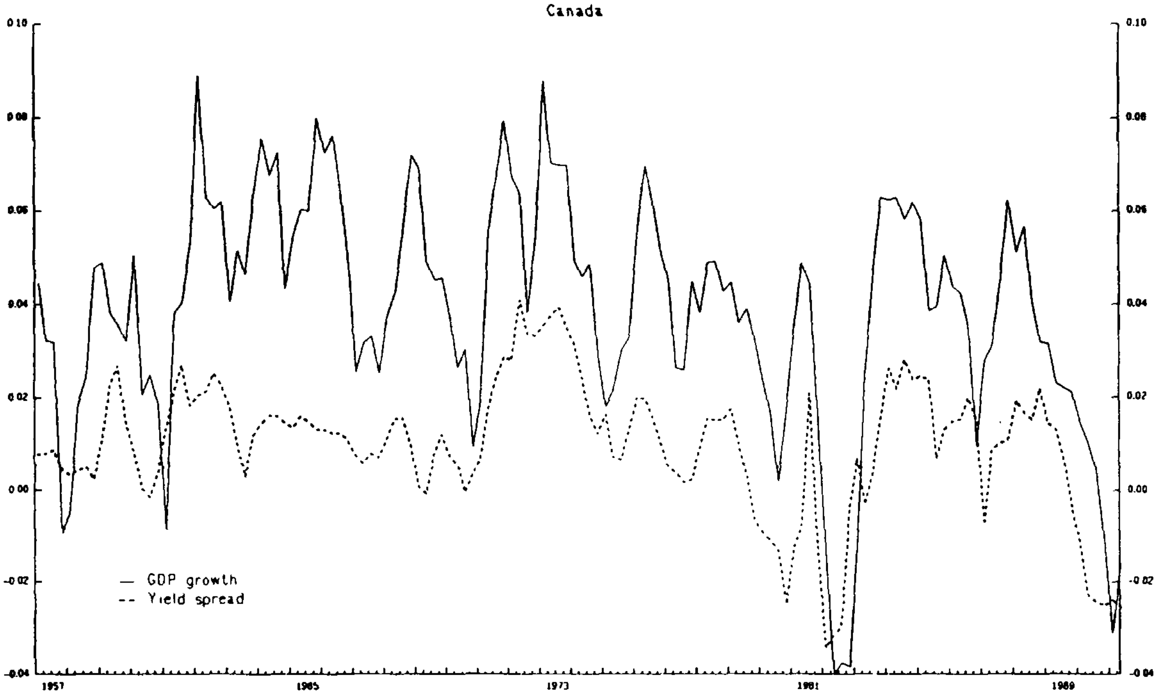
Figure 1. Time Series Plots

GDP Growth and Lagged Yield Spread
Canada



GDP Growth and Lagged Stock Price Changes
Canada

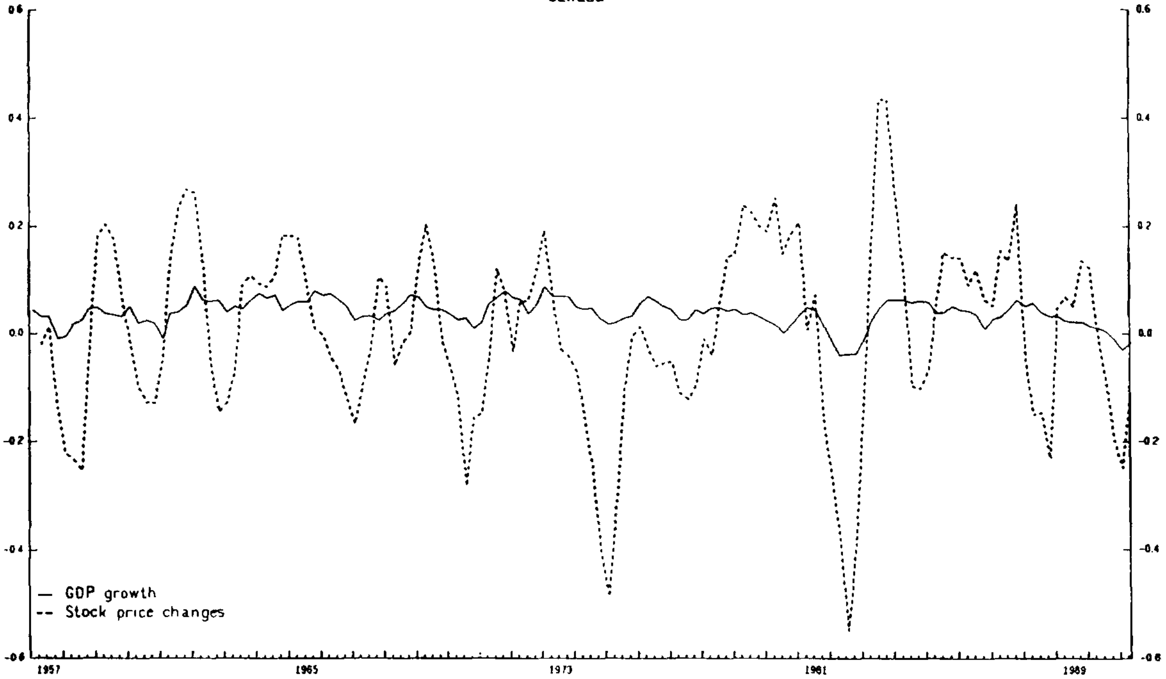


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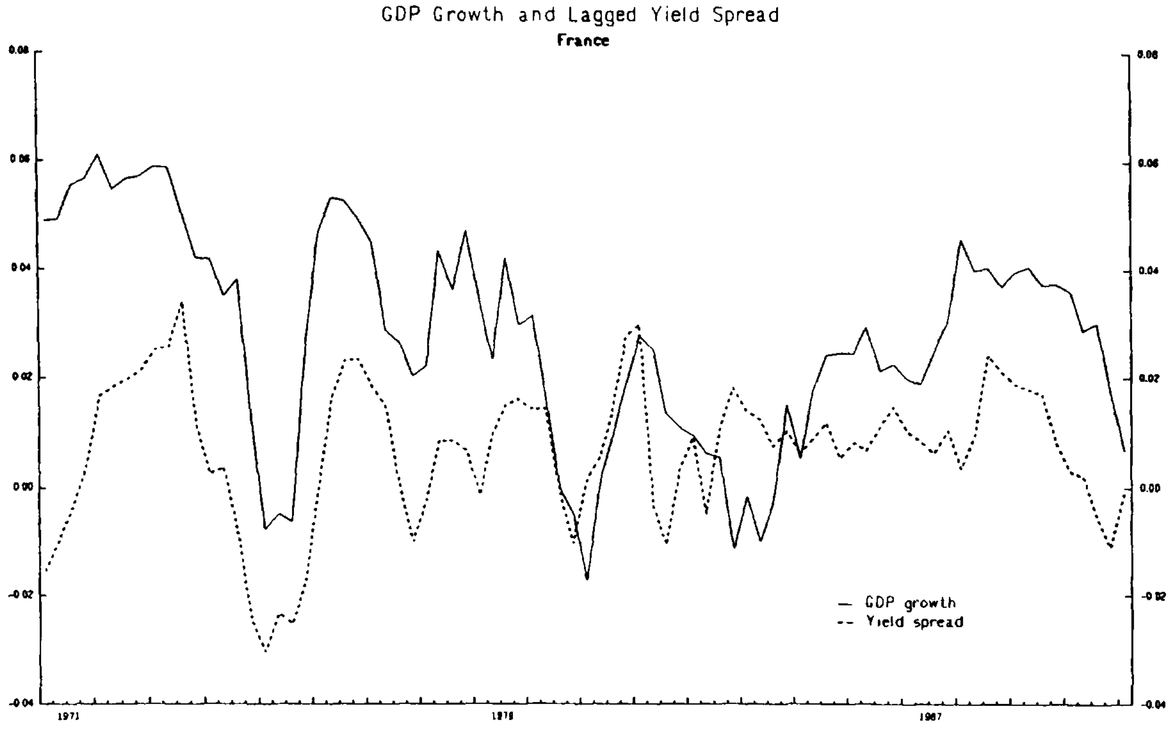
Figure 1 (continued). Time Series Plots



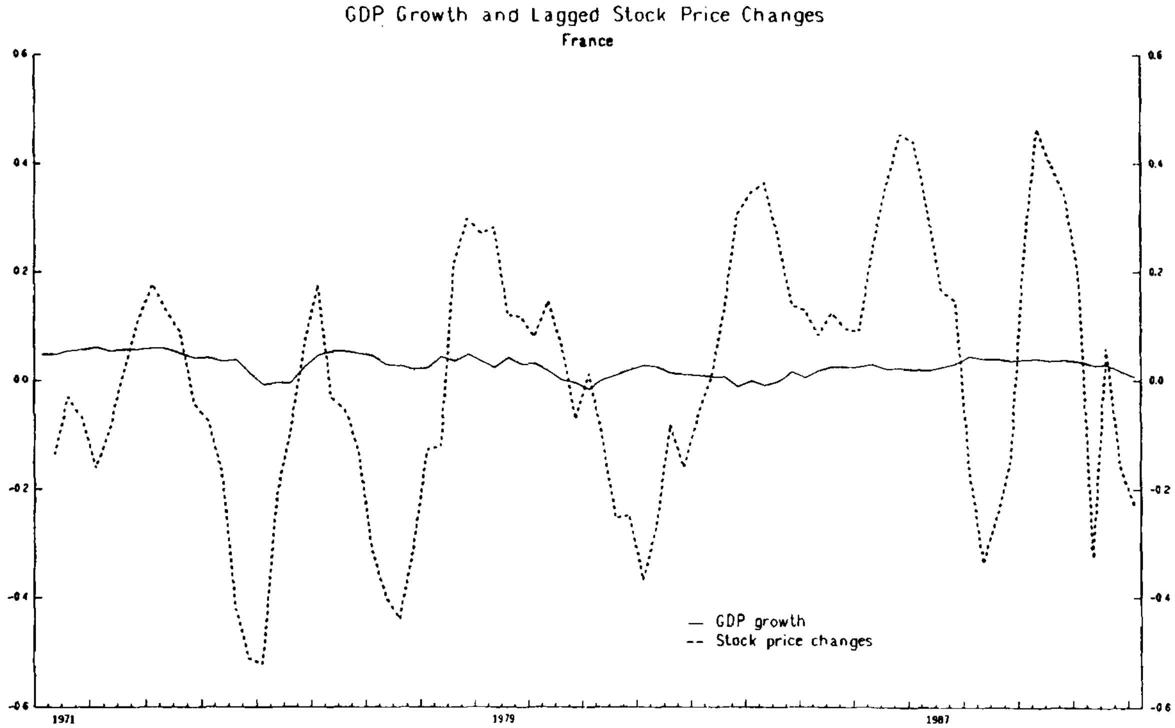


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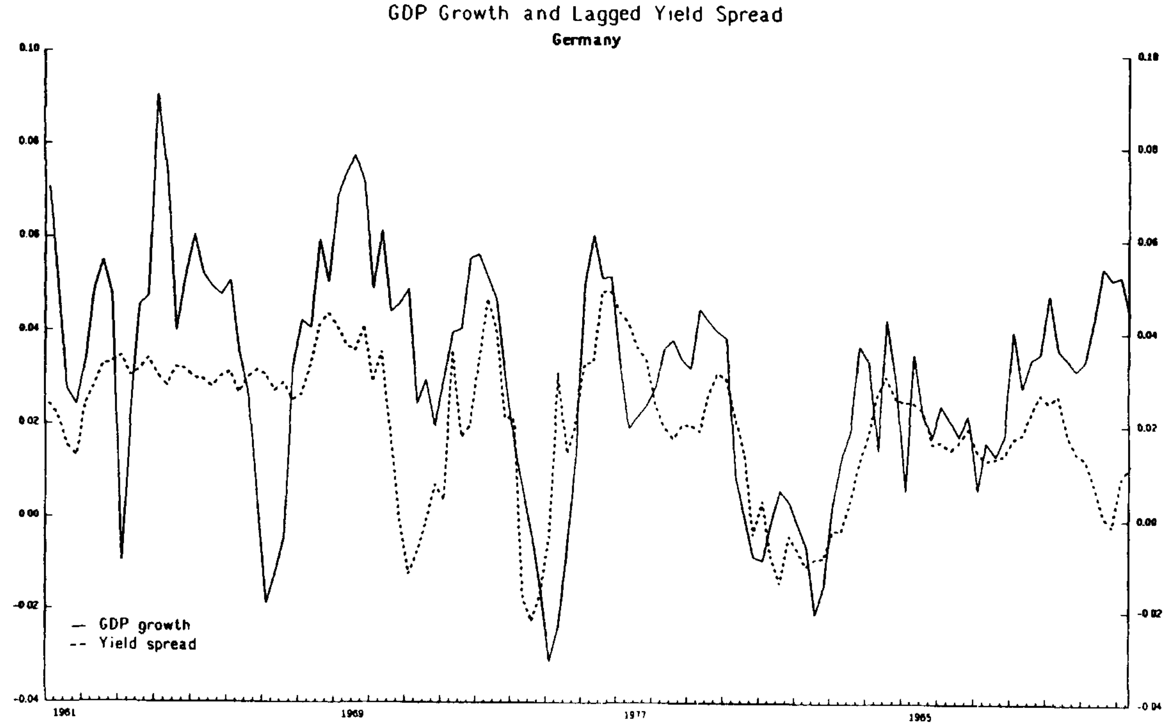
Figure 1 (continued). Time Series Plots



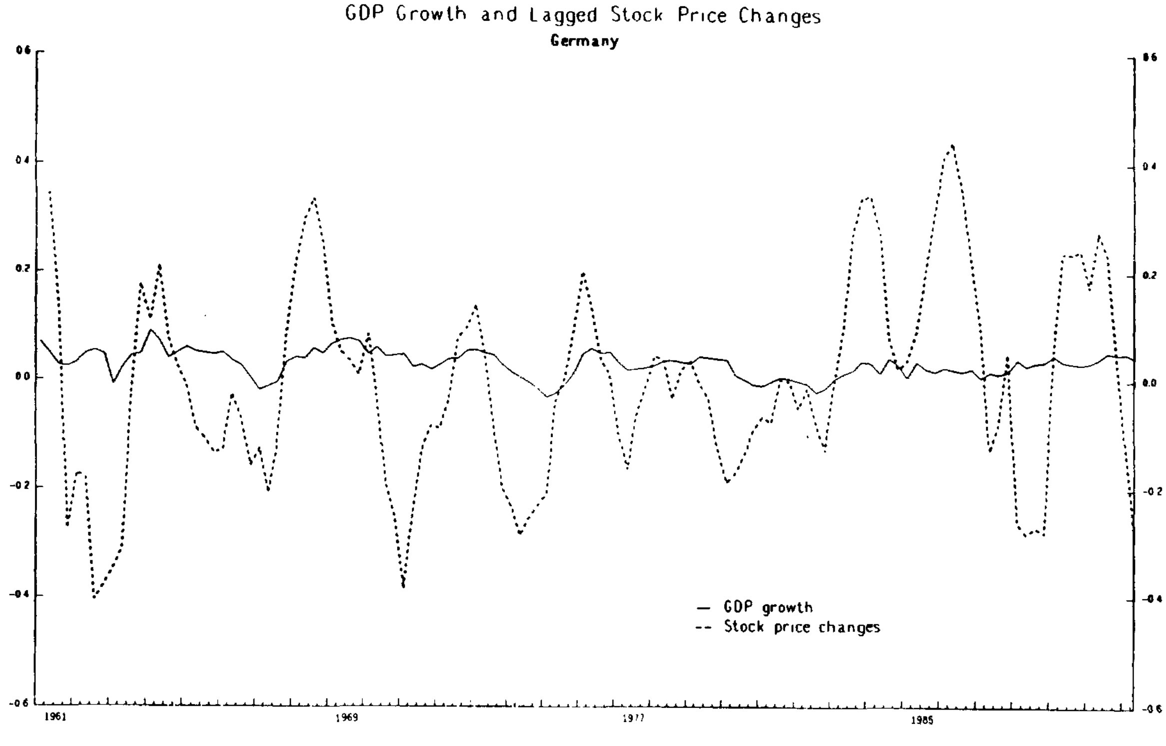


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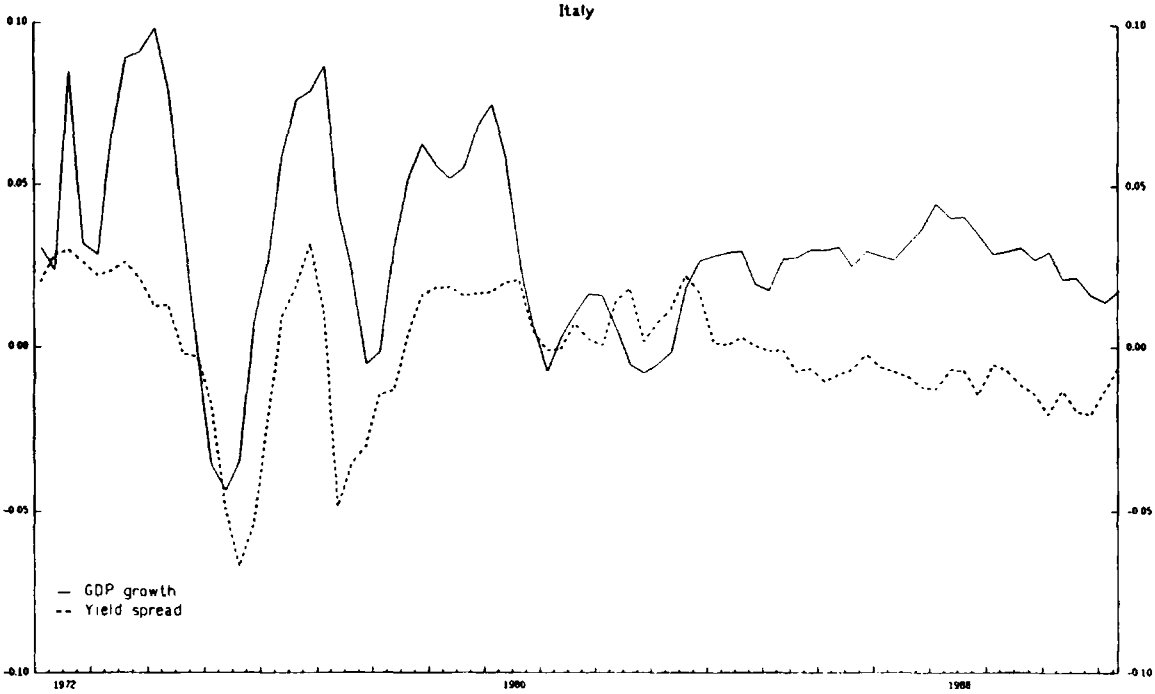
Figure 1 (continued). Time Series Plots

GDP Growth and Lagged Yield Spread
Italy



GDP Growth and Lagged Stock Price Changes
Italy

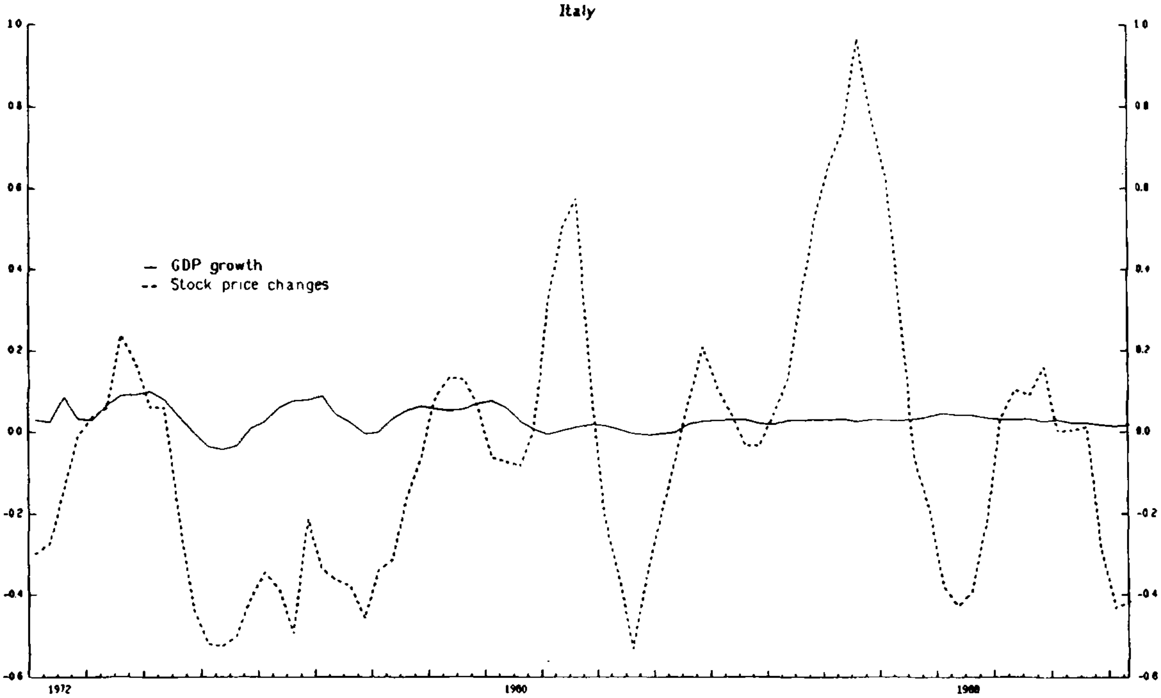


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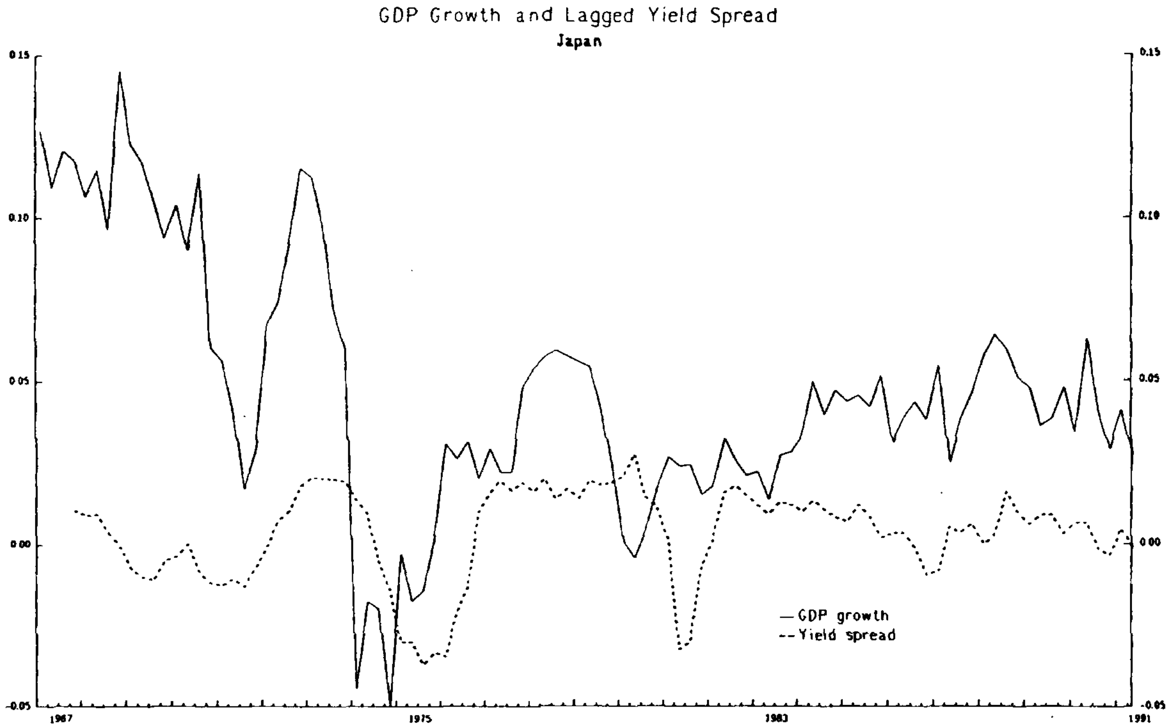
Figure 1 (continued). Time Series Plots



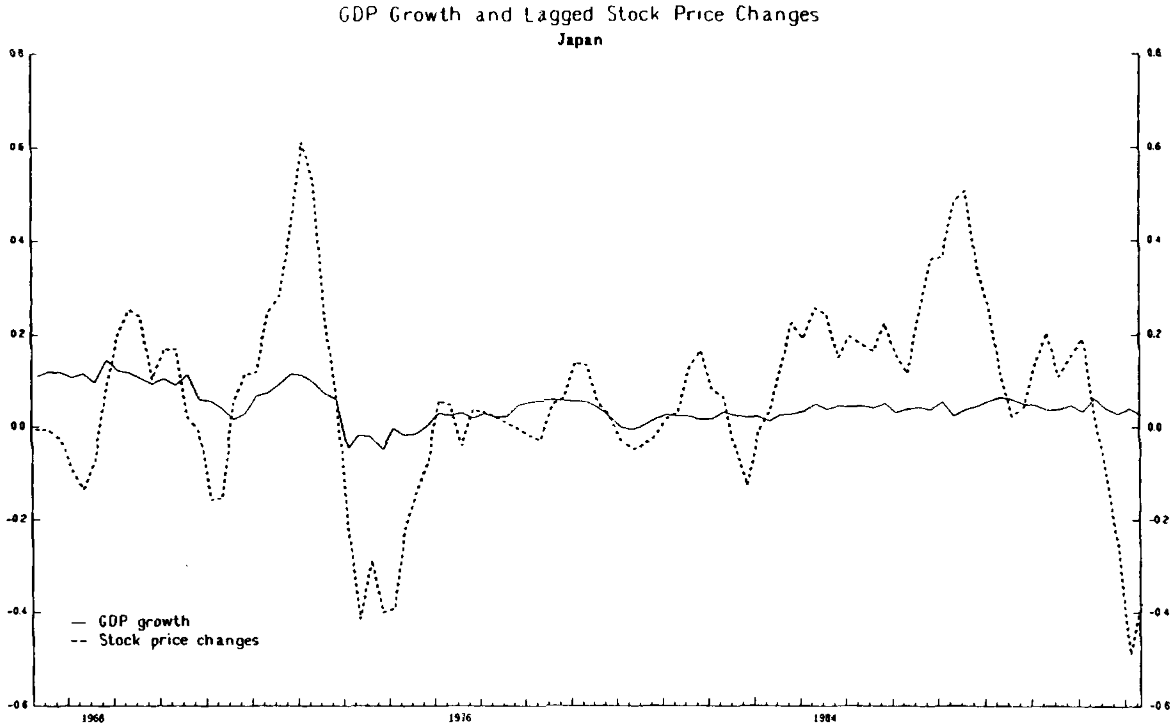


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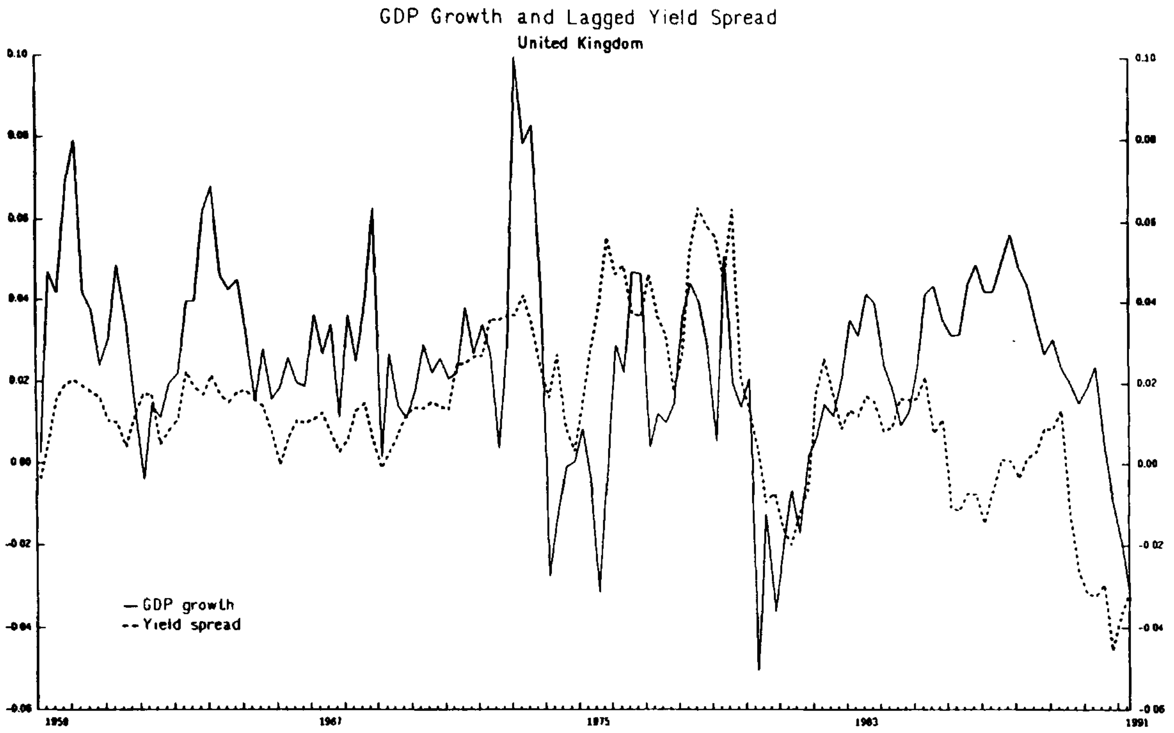
Figure 1 (continued). Time Series Plots



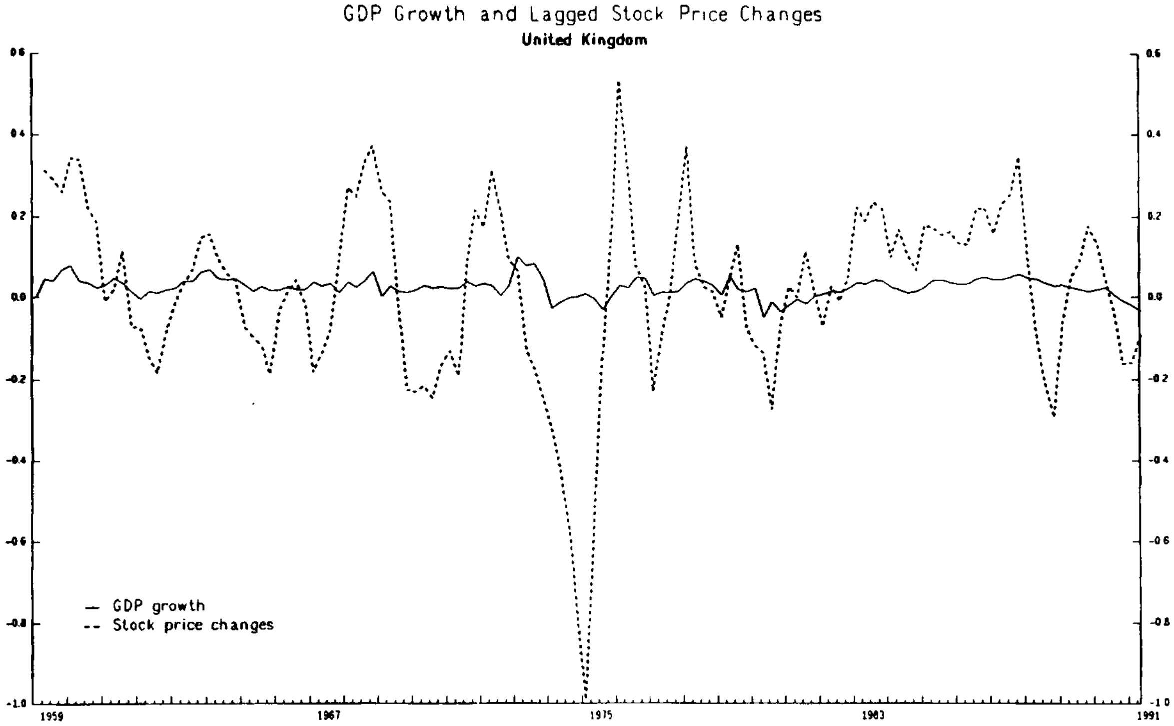


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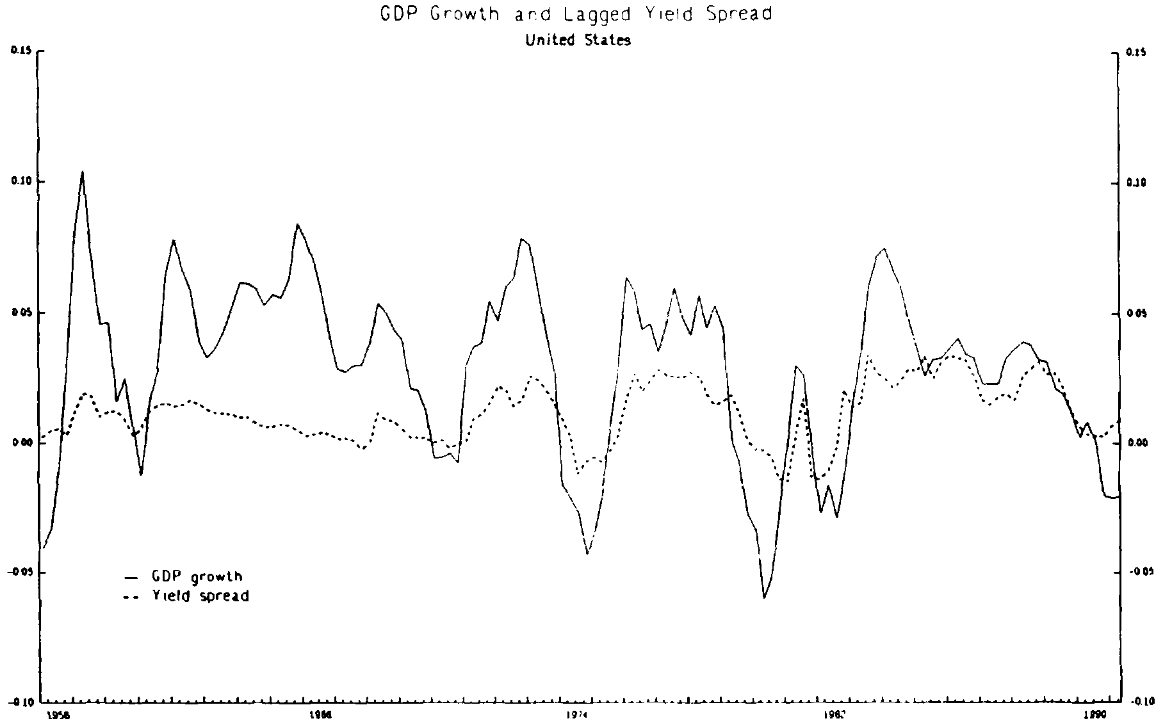
Figure 1 (concluded). Time Series Plots



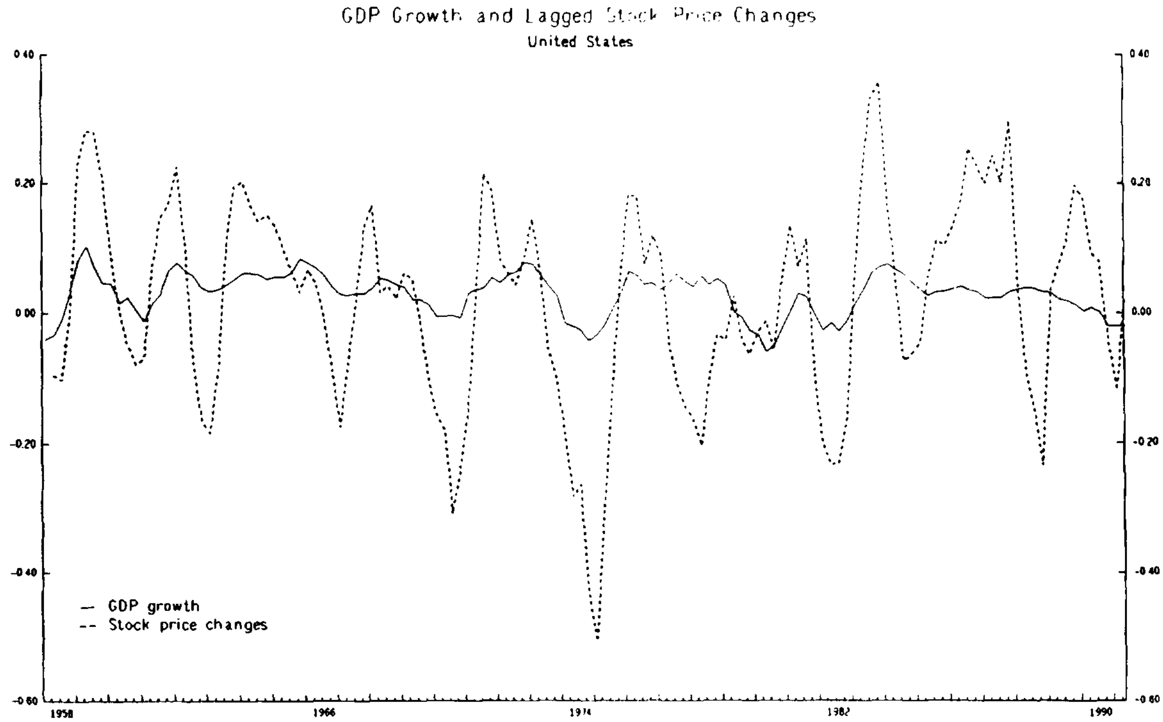


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Table 2. Forecasting Real Output Growth from the Yield Curve

$$d\,Y_t = \alpha + \beta\, S^y_{t-1} + \epsilon_t$$

where $dY_t = \log(Y_{t+4}/Y_t)$ is the annual growth rate in real GNP/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.

Country	Sample Period	No. Obs.	β	$\chi^2(2)$	$\chi^2(1)$	$\bar{R}^2$
Canada	57:1 - 91:4	140	1.2659	11.2909	0.1169	0.523
			(8.6548)	(0.0083)	(0.7748)	
France	71:2 - 91:3	83	0.62203	32.2443	0.9762	0.159
			(3.0140)	(--)	(0.3510)	
Germany	61:2 - 91-4	123	0.8067	3.3542	0.8455	0.270
			(4.0584)	(0.0679)	(0.4309)	
Italy	72:1 - 91:4	80	0.7992	65.0060	0.9027	0.287
			(4.4916)	(--)	(0.3991)	
Japan	67:4 - 91:4	97	0.7424	46.9170	1.2464	0.168
				(--)	(0.2260)	
United Kingdom	59:1 - 91:4	132	0.6595	16.0044	1.8736	0.083
				(--)	(0.1752)	
United States	58:1 - 92:1	137	1.5702	23.1909	0.2367	0.296
			(4.4576)	(--)	(0.6266)	

Note: $\chi^2(2)$ is the joint test for $\alpha=0$ and $\beta=1$, and $\chi^2(1)$ is the test for $\beta=1$ only. The correpsonding p-values are in the parenthesis. The notation (--) stands for zero p-value.

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Table 3. Forecasting Real Output Growth from the Yield Curve: Sub-sample Results

$$d Y_t = \alpha + \beta S^{y}_{t-1} + \epsilon_t$$

where $dY_t = \log(Y_{t+4}/Y_t)$ is the annual growth rate in real GNP/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.

Country	Sample Period	No. Obs.	β	$\bar{R}^2$
Canada	57:1 - 74:4	72	1.0498 (4.2984)	0.250
	75:1 - 91:4	68	1.2769 (7.4700)	0.613
France	71:1 - 81:4	44	0.7767 (4.1944)	0.297
	82:1 - 91:3	39	0.6316 (2.9468)	0.185
Germany	61:1 - 74:4	56	0.6869 (2.7733)	0.184
	75:1 - 91:4	68	0.7561 (3.5066)	0.265
Italy	72:1 - 81:4	40	0.9832 (7.1228)	0.429
	82:1 - 91:4	40	0.5959 (2.911)	0.429
Japan	67:4 - 81:4	57	0.5662 (2.218)	0.210
	82:1 - 91:4	40	0.4342 (3.125)	0.114
United Kingdom	59:1 - 74:4	64	0.9561 (3.1619)	0.148
	75:1 - 91:4	68	0.2460 (1.4185)	0.059
United States	58:1 - 81:4	96	1.2004 (4.9555)	0.377
	82:1 - 91:4	40	1.0757 (6.4756)	0.582

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

$$Res_t = \alpha + \beta S_{t-1}^{y} + \epsilon_t$$

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.

Country	Sample Period	No. Obs.	β	$\bar{R}^2$
Canada	57:1 - 914	140	0.2699* (3.8715)	0.095
France	72:3 - 91:3	77	0.1776* (2.0966)	0.061
Germany	62:3 - 91:4	118	0.2222* (3.3349)	0.022
Italy	72:1 - 91:4	80	0.1276 (1.5436)	0.022
Japan	67:4 - 91:4	97	0.1472 (1.1063)	0.005
United Kingdom	59:1 - 91:4	97	0.1472 (1.1063)	0.005
United States	59:3 - 91:4	130	0.3221* (3.3936)	0.085

Note: The sign * indicates that the coefficient is significantly different from zero at the 5 percent level in a two tailed test.

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To evaluate the forecasting performance of the term structure, we consider an alternative model based on the stock prices. Studies of business cycle have paid a great deal of attention to the stock market. In 1920's the Harvard "ABC" system pioneered in using the stock market price as a main component of its leading "A" curve for tracking the business cycle. Today the Standard & Poor's 500 stock price index is included in the United States Commerce Department's index of leading indicators. The OECD regularly publishes 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 practitioners. Fama (1981, 1990b), Barro (1989), Harvey (1989) and Chen (1991) have found evidence from the United States data that stock returns lead changes in real activity.

Since stock prices are the discounted present value of future dividend stream, and corporate dividends and earnings are correlated with GDP, stock prices should contain information about GDP growth. However, since the stock market price is far more volatile than output, it is likely a poor predictor of GDP growth. Table 5 gives single regression results for the stock price model using international data. For France, Germany and Italy, stock prices have little power for predicting real output, although stock prices have forecasting power for all other countries. Comparing Table 5 with Table 2 and Table 3, however, shows that the forecasting model based on stock prices under-performs the term structure based model within the sample for all but two countries. Most regressions in Table 2 have greater R^2 than the corresponding equations in Table 5. The yield spread, for example, is able to explain 27 percent of the variance in real GDP in Germany, while the stock price changes explain only about 5 percent of the variation in German GDP growth. The lagged stock price changes however have somewhat larger explanatory power for GDP growth in Japan and the United Kingdom than the corresponding term structure model. On balance it seems that the yield spread variable has more within-sample forecasting power for real GDP growth than stock prices. Fischer and Merton (1984) claim that the stock market price is the single best predictor of 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, the lagged output growth, and inflation are added to the regression equation. For most countries, the yield spread has marginal forecasting power over stock prices, the lagged output growth and inflation. The stock price changes have almost no forecasting power for France, Germany and Italy while the yield spread has strong ability in predicting real output growth for all the countries except Japan. It appears that the yield curve and the current output growth are the most powerful predictors of future output growth.

To evaluate the forecasting performance of the yield spread we also consider a univariate time series forecasting model as a third benchmark

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Table 5. Forecasting Real Output Growth from Stock Prices

Panel (a)	Full Sample Results

$$d\,Y_t = \alpha + dS_{t-1}^{p} + \epsilon_t$$

where $dY_t = \log(Y_{t+4}/Y_t)$ is the annual growth rate in real GNP/GDP, and S_t^p is the national stock price index deflated by the consumer price index, and

$$d\,S_t^p = \log(S_{t+4}^p/S_t^p$$

is the annual change in real stock prices.

The Panel 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.

Country	Sample Period 1/	Number of Observations	β	$\bar{R}^2$
Canada	57:2 - 91:4	139	0.071 (2.987)	0.206
France	71:2 - 91:3	82	-0.001 (0.040)	-0.012
Germany	61:2 - 91:4	123	0.029 (1.697)	0.047
Italy	72:1 - 91:4	80	0.015 (1.259)	0.019
Japan	67:4 - 91:4	97	0.084 (2.443)	0.204
United Kingdom	59:2 - 91:4	131	0.045 (5.603)	0.156
United States	58:2 - 92:1	135	0.111 (4.887)	0.286

1/ Quarterly data.

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Table 5 (Concluded). Forecasting Real Output Growth from Stock Prices

Panel (b)		Sub-Sample Results		
Country	Sample Period	Number of Observations	β	$\bar{R}^2$
Canada	57:1 - 74:4	71	0.072 (3.992)	0.214
	75:1 - 91:4	68	0.071 (2.573)	0.250
France	71:1 - 81:4	44	0.030 (2.002)	0.062
	82:1 - 91:3	39	-0.010 (0.634)	0.003
Germany	61:1 - 74:4	56	0.062 (3.125)	0.215
	75:1 - 91:4	68	0.022 (1.263)	0.022
Italy	72:1 - 81:4	40	0.038 (0.746)	0.057
	82:1 - 91:4	40	0.011 (1.139)	0.084
Japan	67:4 - 81:4	57	0.151 (5.225)	0.388
	82:1 - 91:4	40	0.016 (2.697)	0.048
United Kingdom	59:1 - 74:4	64	0.045 (5.305)	0.187
	75:1 - 91:4	68	0.050 (2.721)	0.178
United States	58:1 - 81:4	96	0.141 (6.678)	0.383
	82:1 - 91:4	40	0.080 (1.980)	0.195

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Table 6. Regressions with Multiple Information Variables

$$d\,Y_t = c_0 + c_1\,S^{y}_{t-1} + c_2\,d\,S^{p}_{t-1} + c_3\,d\,Y_{t-1} + c_4\,\pi_{t-1} + \epsilon_t$$

where $dY_t = \log(Y_{t+4}/Y_t)$ is the annual growth rate in real GNP/GDP, S^p_t is the national stock price index deflated by the consumer price index,

$$d\,S^p_t = \log(S^p_{t+4}/S^p_t)$$

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.

Country	Sample Period	No. Obs.	c_1	c_2	c_3	c_4	$\bar{R}^2$
Canada	58:2-91:4	135	0.506*	0.031	.554	-0.023	0.76
			(7.40)	(5.35)	(13.77)	(-0.54)	
France	71:2-91:3	82	0.220*	0.003	0.852	-0.036	0.77
			(2.47)	(0.06)	(23.12)	(-0.86)	
Germany	61:2-91:4	123	0.237*	0.015	0.694	-0.039	0.67
			(2.32)	(1.79)	(12.60)	(0.51)	
Italy	72:1-91:4	80	0.323*	0.001	0.683	-0.094	0.69
			(3.14)	(0.03)	(10.00)	(-2.68)	
Japan	68:1-91:4	96	0.041	0.018	0.792	-0.021	0.74
			(0.26)	(2.12)	(9.69)	(-0.28)	
United Kingdom	59:2-91:4	131	0.288*	0.021	0.416	-0.135	0.55
			(3.85)	(2.75)	(7.73)	(-4.37)	
United States	58:2-92:1	135	0.342*	0.033	0.732	-0.089	0.81
			(2.29)	(2.80)	(12.43)	(-1.27)	

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

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model. ARMA models for real GDP growth with up to two autoregressive and two moving average parameter are estimated for each country and 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-based model is that described in Table 5. The forecasting period evaluated is from 1982 Q1 to 1991 Q4, with a total of 40 forecasts. All three models are initially estimated up to 1981 Q4 for each country, and used to forecast real GDP growth for 1982 Q1. The models are re-estimated with data up to 1982 Q1 and forecasts are calculated. This procedure is repeated up to 1991 Q4.

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-based model and the ARMA model for Canada, Italy and Japan. It outperforms the stock price-based 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) model. The United Kingdom is the only case where the forecasts from the yield spread model are inferior to those from the stock price-based 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 section II. 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 for forecasting 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 the 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 in predicting real output. 1/

1/ 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, Inc. (DRI) model and the Wharton Econometric Forecasting Associates, Inc. (Wharton) model.

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Table 7. Out-of-Sample Forecasting Performance of the Yield Curve vs. Alternative Forecasting Models: 1982:Q1-1991:Q4

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 re-estimated at each point in the time series during 1981:Q4-1991:Q3. These parameters are used to forecast the real GDP growth for the 1982:Q1-1991:Q4 period.

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V. 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 the term structure is determined by the underlying variables in the economy. The question asked in this paper is this: if the term structure bears any relations at all with changes in the economy-wide variables such as real GDP growth, can this relationship be exploited for forecasting 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. We derived a simple, closed-form formula of the term structure, expressed in terms of the parameters of the stochastic production processes. It is shown that the term structure of interest rates embodies market's expectation about changes in the macroeconomic fundamental--the growth in real aggregate output of the economy. Applying the model to the G-7 industrial countries, we 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 the future economic growth. This easily measured variable has more forecasting power than stock price changes 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 that of the stock price-based 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 policy makers. It may well be worthwhile for policy authorities to consider adding some measure of the term structure to the list of leading indicators.

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