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THE YIELD SPREAD AS A PREDICTOR OF FUTURE REAL ACTIVITY IN AUSTRALIA

A project report submitted in partial fulfilment of the requirements of the degree of Master of Commerce (Hons).

by

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I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a university or other institute of higher learning, except where due acknowledgment is made in the text.

I also declare that the intellectual content of this project report is the product of my own work, even though I may have received assistance from others on style, presentation and language expression.

(Signed)______________________

Deok Ki Kim

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ABSTRACT

This Project Report attempts to examine, both theoretically and empirically, the yield spread as a predictor of future economic growth. It presents a theoretical model that relates the term structure of interest rates to real output growth in the context of a simple stochastic growth model. The report then empirically evaluates the yield spread between long term and short term interest rates as a predictor of real output growth in Australia using two econometric methodologies: estimation of single equation and vector autoregressive (VAR) models. We find that the yield spreads between the 10 year treasury bond rate and, respectively, the 180 day bank bill and the 13 weeks treasury bill rate are useful predictors of future real GDP growth. In particular, not only has the spread between the 10 year treasury bond rate and the 180 day bank bill rate predictive content for real GDP growth up to an horizon of 3 years, but it also outperforms other forecasting variables such as the money base, credit and the index of leading indicators in predicting GDP growth over the short to medium term. The economic rationale underlying the predictive content of yield curve is also investigated. The results of causality tests in the context of a VAR model do not support the view that the predictive power of the yield spread is due to the effect of monetary policy operating on short term rates.

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I. Introduction and Overview

It has been long recognised that financial market variables, such as stock prices and interest rates, contain a significant amount of information about the future state of the economy. Recently, there has been a growing consensus, especially in the US, that the term structure of interest rates, or more loosely interest rate spreads, contain considerable information about future economic activity.

A number of economists and financial analysts [e.g. Stock and Watson (1989), Harvey (1989)] have pointed out that whenever the yield curve inverted (i.e. whenever short rates exceeded long rates) the economy subsequently went into recession. On the other hand, an upward sloping yield curve was found to anticipate strong economic activity. These results raise the question of why the interest rate spread is such a good predictor of future real economic activity.

This project report aims to examine the yield spread variables between the long term and short term interest rates as a predictor of real economic growth in Australia. In particular, it attempts to provide an economic rationale underlying the predictive power of yield spreads. The organisation of this investigation is as follows.

A brief survey of the literature on the term structure, both theoretical and empirical, is provided in this chapter. Then in Chapter 2, a theoretical relation linking the slope of yield curve to the expected growth in real output is derived in the framework of a stochastic growth model. This theoretical relation provides a framework for the empirical analysis of Chapter 3, which is divided into four sections. After discussing the data in the first section, we examine the predictive power of the yield spread for real economic growth using a single equation regression methodology. In section 3, we use a vector autoregression (VAR) methodology to evaluate the predictive power of the yield spread relative to other forecasting variables.

In Chapter 3, we also attempt to determine what the data suggests is the reason for the predictive power of the yield spread. The proposition that we test is whether the predictive power of yield spread stems from the effect of monetary policy on the short term interest rate. Finally in section 4, we investigate the causality between the short and long end of the yield spread. Chapter 4 presents the conclusions of the report and provides policy implications.

Survey of Literature

The formal link between asset markets and real activity was first noted by Fisher (1907). Since the development of the intertemporal capital asset pricing model (ICAPM) by Merton in 1973, asset pricing models and, in particular, models of the term structure, have been developed in a general equilibrium framework assuming rational expectations. [See Lucas (1978), Brock (1982), Cox, Ingersoll and Ross (1985a, 1985b) and Breedon (1979, 1986)]. The equilibrium asset pricing theories have suggested a relation between the asset returns and expected consumption paths.

While many researchers looked at the term structure and consumption in the continuous time framework, the discrete time version of these theories has also been well developed. [See Harvey (1988), Fisher and Richardson (1990), for example]. However, the relation between term structure of interest rates and output growth has not received as much theoretical consideration. Very recently, Hu (1993) derives a theoretical link between the yield spread and real output growth by extending the continuous time stochastic version of the equilibrium asset pricing model.

The growth of the equilibrium approach, however, has not been confined to asset pricing theories. In macroeconomics, the dynamic equilibrium approach has been applied to business cycle analysis most notably by Lucas (1975, 1977, 1980) and Kydland and Prescott (1982). [See also Long and Plosser (1983), King, Plosser and Rebelo (1988) and Campbell (1994)].

The emergence of the equilibrium approach to studying economic growth and business cycle fluctuations has opened the theoretical possibility for relating the real term structure to consumption growth. [See Kydland and Prescott (1988), Campbell (1994)]

Recently, Salyer (1994) derives parametric relations between the term structure of interest rates and production in the framework of a simple equilibrium stochastic growth model. This project report also takes a similar approach, utilising a discrete time stochastic growth model, so as to show the link between the real (and also nominal) term structure of interest rates and expected growth in real output. This will be presented in detail in Chapter 2.

A number of studies have examined the empirical relation between movements in the yield spread and real output. Stock and Watson (1989) examined the predictive power of two interest rate spreads: the difference between the six month commercial paper rate and the Treasury bill rate with the same maturity (also referred to as the paper-bill spread), and the difference between the ten year and one year Treasury bond rates. They found that the paper-bill spread is an exceptionally good predictor of future real activity. This finding has been confirmed by Bernanke (1990) and further by Friedman and Kuttner (1992). But a very recent study by Emery (1996) refutes their claim by arguing that the predictive power of the paper bill spread is largely due to two outliers in the sample period under investigation.

Other spread variables have also been investigated. Bernanke and Blinder (1992) claim that the spread between the federal funds rate and a long term rate is an "extremely" good predictor of US economic growth.

There are numerous studies that have examined the predictive power of the spread between long term and short term riskless interest rates. They include the early studies by Harvey (1988, 1989), Chen (1991), Estrella and Hardouvelis (1991), and recently Hu (1993) and Plosser and Rouwenhorst (1994). They all have shown that the term structure of the US and/or other industrialised nations[1] can be used to predict real economic growth.

In the Australian context, Lowe (1992) and Alles (1995) examined the spread between short term and long term interest rates as a predictor of real activity. Lowe finds that the spread between the nominal interest rate on 180 day bank bills and 10 year government bonds predicts the rate of change in real activity

[1] See Table 1 for these countries.

for forecast horizons of one to two years. Alles also presents evidence that the Australian term structure is a good predictor of cumulative growth in real GDP. Both Alles and Lowe find that the yield spread contains no predictive information for future growth in output prior to the third quarter of 1982 and that the yield spread is less effective in predicting quarterly, as opposed to annual, growth rates of output. This project report also examines the robustness of their findings.

Many arguments are given as to why movements in the yield spread are related to future growth of real output or domestic demand. There are two main but different views concerning the economic rationale for the predictive power of the spread between short term and long-term rates.

The first attributes the predictive power to the effectiveness of monetary policy through short-run price stickiness. Typically, the monetary authority's actions to influence interest rates occur at the short end of the term structure. According to this view, a tight monetary policy causes short term rates to increase relative to long term rates which will lead to a flat or negative slope of the yield curve. Higher short term rates will deter consumption and investment, which will eventually dampen economic activity. Consequently, a flat or inverted yield curve is associated with a future downturn in economic activity.

In fact, a number of economists share the view that a good way to judge the stance of monetary policy is to look at the slope of the yield curve. Studies that interpret the predictive power of the yield curve as a result of the transmission mechanism of monetary policy include Bernanke (1990), Bernanke and Blinder (1992) and Lowe (1992), among others. For example, Lowe asserts that the predictive power of the spread is mainly due to the liquidity effect, the negative response of the interest rate to a contemporaneous rise in the money supply. The argument is that movements in short term interest rates as a consequence of monetary policy actions underlie the predictive power of the yield spread for future real activity because real activity responds to movements in short term interest rates with a lag.

The other view is that the predictive power of the yield spread is a consequence of economic agents' expectations about the future state of the economy and intertemporal utility maximising behaviour. Harvey (1988, 1989), Hu (1993) and Plosser and Rouwenhorst (1994) are representative examples of this point of view. This study is more in line with this view, although we consider the influence of monetary policy on the yield spread.

Table 1 provides a summary of previous studies on the predictive power of the term structure of interest rates. The table includes the theoretical perspective and empirical methods used and the conclusions reached.

This study may be considered as an extension of previous Australian studies. While the former Australian studies use exclusively single equation OLS econometric methods this study uses both single and multiple equations (Vector Autoregression) methods to analyse the predictive power of the term structure. Although some US studies employ VAR models [See Bernanke and Blinder (1992), Friedman and Kuttner (1992)], there are no Australian studies which examine the predictive power of yield spread in the VAR framework. This study does just that. Using this methodology we can investigate the direction of causality between short and long term rates as well as the dynamic interactions among the yield spread, other financial variables and real activity.

Table 1 : Summary and Comparisons of Empirical Research on the Term structure and Real Economic growth

Studies	Harvey (1989)	B & B (1990)	E & H (1991)	Lowe (1992)	Hu (1993)	P & R (1994)
Country	US	US	US	AUS	G-7	US, GER, CAN,UK
Short-term Yields	3-month T-bill	Federal funds rate	3-month T-bill	180 day bank-bill	3-month Govt-bonds	3-month T-bill
Long-term Yields	5,10 year T-bonds	Any open market rates	10 year T-bond	10 year T-bond	10 year T-bonds	10 year T-bond
Forecasted Variable(s)	GNP annual growth	IP,EMP, CONS	GNP annual and quarterly growth	IP, GDP annual growth	GDP annual growth	IP, GNP annual and quarterly growth
Competing predictors	Stock return (S & P 500)	M1, M2, T-bill, T-bonds	Federal funds IDLI annual %	IDLI annual %	Stock returns GDP ARIMA	k-year bonds(k=1 - 5) money growth
F - H	1 year	N/A	4-8 quarters	1-2 years	1 year	1-3 years
Econometric method	Single eqn N-W	Unrestricted VAR	Single eqn N-W	Single eqn N-W	Single eqn N-W	Single eqn N-W
Sample period	53:2-89:2 76:1-85:1 (Q)	59:7 - 89:12 (Q)	55:2-88:4 (Q)	72:3 / 82:3 - 91:2 (M, Q)	57:1-92:1 (Q)	57:1 / 75:1 - 91:3 (Q)
The predictive power is due to	Expectation, Intertemporal substitution	M.P. highly effective	Yield curve content indep.of M.P.	Short-end effective. M.P. effective	Agent's Expectations	Market expectations RBC theory prediction.

Note: B & B = Bernanke and Blinder, E & H = Estrella and Hardouvelis, P & R = Plosser and Rouwenhorst, IP = Industrial production, EMP = Employed persons, CONS = Consumption, IDLI = Index of leading indicators, F - H = forecasting horizon, M.P. = Monetary Policy, N-W = Newey-West correction, VAR = vector autoregression, Q = Quarterly data, M = Monthly data, eqn. = equation.

II. Theoretical Considerations

In this chapter, the link between the term structure of interest rates and real output is analytically derived within a stochastic growth model.

The use of dynamic equilibrium models in the business cycle literature was initiated by Lucas (1972, 1975, 1980) and Barro (1976, 1981) and then substantially developed and elaborated by Kydland and Prescott (1982), King, Plosser and Rebelo (1988), Campbell (1994), to name a few.

Interest rates are a crucial variable in dynamic equilibrium business cycle models, and as a consequence a natural extension is to consider the term structure within such a framework. The relationship between the term structure and real economic growth has been studied in the context of an equilibrium business cycle model by Salyer (1994) and Plosser and Rouwenhorst (1994) among others.

This study attempts to analytically consider the link between the term structure of interest rates and real output growth in the context of stochastic growth model. Note that the model considered here is a variant of the Brock-Mirman[2] social planner's economy.

[2] See Brock and Mirman (1972)

Term structure of interest rates and economic growth in dynamic competitive equilibrium.

We consider a simple intertemporal general equilibrium model as follows.

Preferences

Consider a representative agent maximising life time utility

$$E_0[\sum_{t=0}^{\infty} \beta^t \ln C_t] \qquad (1)$$

Note that for log utility the coefficient of relative risk aversion is unity.

Production/Technology

Consider the production function

$$Y_t = A_t K_t^{\alpha} \qquad (2)$$

where A and K denote technology and capital respectively.

This specification[3] exhibits decreasing returns to scale with fixed labour, $N_t = 1$, so that capital is the only input.

We also assume that A_t is lognormally[4] distributed with mean 0 and constant variance.

Capital accumulation

The evolution of the capital stock is

$$K_{t+1} = (1-\delta)K_t + I_t \qquad (3)$$

[3] This is a concave production function. For the use of this type of specification; see Balvers et al. (1990) and Salyer (1994).

[4] For a lognormal random variable X_{t+1} : $\log(E_t X_{t+1}) = E_t \log X_{t+1} + 1/2 \mathrm{var}_t(\log X_{t+1})$

The gross investment I_t is a decision variable at time t. This may be interpreted as a gestation lag of one period before investment becomes available as an input to production next period.

To derive closed form solution, capital is assumed to depreciate fully each period, i.e. $\delta = 1$.

$$K_{t+1} = I_t \qquad (3')$$

Efficiency condition for capital use

The gross rate of return on a one period investment in capital is equal to the marginal product of capital under complete depreciation (which, in equilibrium, is equal to $1+r_{1t}$). That is,

$$1+r_{1t} = [\alpha A_{t+1} K_{t+1}^{\alpha-1}] \qquad (4)$$

It is important to distinguish β from $1/R_{t+1}$, where R_{t+1} is the gross rate of return. Note that β discounts utility units while $1/R_{t+1}$ discounts consumption (real net cash flows).

Resource constraint

Since labour is assumed to be fixed, all we require is that

$$C_t + I_t \leq Y_t$$

Optimal Decisions for the Planner

For the log utility and the production function (2), the Lagrangian is formed as

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t \ln C_t + \sum_{t=0}^{\infty} \lambda_t [A_t K_t^{\alpha} - C_t - K_{t+1}]$$

where λ_t is the Lagrange multiplier associated with the period t resource constraint $Y_t - C_t - I_t = 0$.

The F.O.Cs are

$$\beta^t C_t^{-1} = \lambda_t \tag{5}$$

$$\lambda_{t+1}[\alpha A_{t+1} K_{t+1}^{\alpha-1}] = \lambda_t \tag{6}$$

$$A_t K_t^{\alpha} - C_t - K_{t+1} = 0 \tag{7}$$

TVC: $$\lim_{t\to\infty} \beta^t \lambda_t K_{t+1} = 0 \tag{8}$$

The Solution to the system

Now the solution to the dynamic system is of the form[5]

$$C_t = F_t(K_t, A_t)$$

$$K_{t+1} = G_t(K_t, A_t)$$

In particular, we conjecture that

$$C_t = \Theta_1 A_t K_t^{\alpha} \tag{9}$$

$$K_{t+1} = \Theta_2 A_t K_t^{\alpha} \tag{10}$$

Using (5) and (6) to eliminate λ_t

$$\beta \alpha A_{t+1} K_{t+1}^{\alpha-1} = \left(\frac{C_{t+1}}{C_t}\right)$$

Using (9), we can re-write this as

$$\beta \alpha A_{t+1} K_{t+1}^{\alpha-1} = \frac{\Theta_1 A_{t+1} K_{t+1}^{\alpha}}{\Theta_1 A_t K_t^{\alpha}}$$

[5] McCallum (1989, pp21-22) and Campbell (1994, pp470-71) also use this conjecture.

$$\beta\alpha / K_{t+1} = \frac{1}{A_t K_t^{\alpha}}$$

Substitute (6) into the avobe expression and re-arrange to obtain

$$\Theta_2 = \alpha\beta$$

To find Θ_1 substitute (9) and (10) into (7), so that

$$\Theta_1 A_t K_t^{\alpha} + \Theta_2 A_t K_t^{\alpha} = A_t K_t^{\alpha}$$

$$A_t K_t^{\alpha} (\Theta_1 + \alpha\beta) = A_t K_t^{\alpha}$$

$$\Theta_1 = 1 - \alpha\beta$$

So the implicit solution (9) and (10) becomes

$$C_t = (1 - \alpha\beta) Y_t \qquad (11)$$

$$K_{t+1} = \alpha\beta Y_t \qquad (12)$$

which are the decision rules expressed as a function of output.

The Relationship between the real interest rate and output growth

It can be shown that within the stochastic growth model developed above the interest rate is linearly linked to real output growth. To see this, take the logs of (2) and using lower case letters to denote logarithms, we have

$$y_t = a_t + \alpha k_t \qquad (2')$$

Recall the equation

(4): $1+r_{1t} = [\alpha A_{t+1} K_{t+1}^{\alpha-1}]$

Take the logs of (4) and using lower case letters, we obtain

$$r_{1t} = \ln \alpha + a_{t+1} + (\alpha - 1)k_{t+1} \tag{4'}$$

where we have used the approximation, $\ln(1+r_{1t}) = r_{1t}$.

Update (2') one period and substitute into (4') to obtain

$$r_{1t+1} = \ln \alpha + y_{t+1} - k_{t+1}$$

Take logs of the decision rule (12)

$$k_{t+1} = \ln \alpha\beta + y_t$$

and substituting in to obtain

$$r_{1t+1} = -\ln \beta + \Delta y_{t+1}$$

or

$$r_{1t+1} = -\ln \beta + \ln (Y_{t+1}/Y_t) \tag{13}$$

Equation[6] (13) relates the riskless real interest rate linearly to real output growth. Since β is less than 1, the negative of log β will be positive. Thus (13) implies a positive relation between the one period interest rate and one period output growth.

First Order Condition for Optimal Consumption

To derive the condition for optimal consumption, update (5) one period and substitute the result into (6) to obtain

$$\beta C_{t+1}^{-1}[\alpha A_{t+1} K_{t+1}^{\alpha-1}] = C_t^{-1} \tag{14}$$

Recall again (4)

[6] It can be verified that the equation (13) also results from the use of the Cobb-Douglas production function with constant returns to scale, $Y_t = A_t{}^{\alpha} K_t^{1-\alpha}$.

$$1+r_{1t} = [\alpha A_{t+1} K_{t+1}^{\alpha-1}]$$

Substitute equation (4) into (14) and take the conditional expectation at time t to obtain

$$C_t^{-1} = \beta\,(1+r_{1t})\, E_t\, \{C_{t+1}^{-1}\} \tag{15}$$

This is the stochastic version of the Euler equation for optimal choice of consumption for the above problem.

The Relation between the term structure and consumption growth

To see the relation between the term structure and output more formally, we now assume that the purchase price of a bond is 1 unit of consumption, which can be written (where, again we assume log utility) as

$$(1+r_{1t})^{-1} = \beta\, C_t\, E_t\, \{C_{t+1}^{-1}\} \tag{16}$$

Similarly, for a bond with maturity n, where the yield is known at t, it follows that

$$(1+r_{n\,t})^{-n} = \beta^n\, C_t\, E_t\, \{C_{t+n}^{-1}\} \tag{17}$$

Now assume that consumption is lognormal and homoskedastic

$$\ln E_t(C_{t+1}^{-1}) = -\,E_t\,(\ln C_{t+1}) + (1/2)\, \mathrm{var}_t(\ln C_{t+1}) \tag{18}$$

Take the log[7] of equation (16), and substitute (18) into the result to obtain

$$r_{1t} = -\ln\beta + E_t(\ln C_{t+1} - \ln C_t) - (1/2)\mathrm{var}_t\,(\ln C_{t+1}) \tag{19}$$

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[7] Here, we use that for small x, $\ln(1+x) \approx x$

Similarly, take the log of equation (17), update (18) n−1 periods and substitute in to obtain

$$r_{nt} = -\ln\beta + (1/n)\, E_t(\ln C_{t+n} - \ln C_t) - (1/2n)\mathrm{var}_t(\ln C_{t+n}) \qquad (20)$$

[An equation analogous to (20) has also been derived by Breedon (1986) and Fisher and Richardson (1992).].

Equation (20) relates the riskless rate to expected growth in log consumption and to the conditional variance of log consumption. The n period real default free bond rate will be positively and linearly related to the n period expected average growth rate of aggregate consumption and negatively related to the conditional variance at time t of log consumption at t+n.

The yield differential between the long term and the short term rates can be obtained by subtracting (19) from (20)

$$r_{nt} - r_{1t} = (1/n)\, E_t(\ln C_{t+n} - \ln C_t) - E_t(\ln C_{t+1} - \ln C_t)$$
$$- (1/2n)\mathrm{var}_t(\ln C_{t+n}) + (1/2)\mathrm{var}_t(\ln C_{t+1}) \qquad (21)$$

The Relationship between the term structure and expected future output growth

Now recall that the decision path for consumption in the competitive equilibrium can be expressed as a function of output.

$$C_t = (1-\alpha\beta)Y_t \qquad (11)$$

This relation implies that the economic agent consumes a fixed proportion of output, with the proportionality factor being one minus the product of his or her rate of time preference and the technology parameter α. Intuitively, this is analogous to the formula derived by Hu (1992) in the continuous time stochastic asset pricing framework.

Now update (11) by one and n periods respectively to obtain

$$C_{t+1} = (1-\alpha\beta)Y_{t+1} \tag{22}$$

$$C_{t+n} = (1-\alpha\beta)Y_{t+n} \tag{22'}$$

Take logs of these equations and subtract (11) from (22) and (22') respectively, to obtain

$$\ln(C_{t+1}/C_t) = \ln(Y_{t+1}/Y_t) = \ln Y_{t+1} - \ln Y_t \tag{23}$$

$$\ln(C_{t+n}/C_t) = \ln(Y_{t+n}/Y_t) = \ln Y_{t+n} - \ln Y_t \tag{23'}$$

This implies that the growth rate of consumption and output are the same in competitive dynamic equilibrium.

Note that

$$\begin{aligned}
\mathrm{var}_t(\ln C_{t+n}) &= \mathrm{var}_t(\ln (1-\alpha\beta)Y_{t+n}) \\
&= \mathrm{var}_t(\ln (1-\alpha\beta) + \ln Y_{t+n}) \\
&= \mathrm{var}_t(\ln Y_{t+n})
\end{aligned}$$

Using this result and by substituting (23) and (23') into (21) we obtain the relationship between the real term structure[8] and production as

[8] According to Breedon (1986), the real term structure under the constant relative risk aversion utility and the lognormal assumption may have a variety of interesting shapes, depending on the expected growth rate of aggregate production as well as on the uncertainty of that growth.

$$r_{nt} - r_{1t} = (1/n)\, E_t(\ln Y_{t+n} - \ln Y_t) - E_t(\ln Y_{t+1} - \ln Y_t)$$
$$- \; (1/2n)\mathrm{var}_t(\ln Y_{t+n}) \; + \; (1/2)\mathrm{var}_t(\ln Y_{t+1}) \qquad (24)$$

Since log consumption is homoscedastic (i.e., $\mathrm{var}_t\,(\ln C_{t+n}) = \sigma^2$), then it is also the case that real income is homoscedastic (i.e., $\mathrm{var}_t\,(\ln Y_{t+n}) = \sigma^2$) so that[9]

$$r_{nt} - r_{1t} = (1/n)\, E_t(\ln Y_{t+n} - \ln Y_t) - E_t(\ln Y_{t+1} - \ln Y_t)$$
$$+ \left[(1/2)\sigma^2 \; - (1/2n)\sigma^2\right] \qquad (25)$$

Now equation (25) can be re-written, surpressing the constant terms, as

$$r_{nt} - r_{1t} = (1/n)\, E_t[\ln Y_{t+n} - \ln Y_{t+n-1} + \ln Y_{t+n-1} - \ln Y_{t+n-2} + \ln Y_{t+n-2} - \ln Y_{t+n-3}$$
$$+ \;..........+ \ln Y_{t+1} - \ln Y_t] \; - E_t\,[\ln Y_{t+1} - \ln Y_t]$$

or

$$r_{nt} - r_{1t} = (1/n)\, E_t[\Delta\ln Y_{t+n} + \Delta\ln Y_{t+n-1} + ... + \Delta\ln Y_{t+1}] \; - \; E_t\,[\Delta\ln Y_{t+1}]$$
$$(26)$$

For a special case of equation (26), consider n = 2. Then

$$r_{2t} - r_{1t} = \frac{1}{2} E_t[\ln Y_{t+2} - \ln Y_t] - E_t[\Delta\ln Y_{t+1}]$$
$$= \frac{1}{2} E_t[\Delta\ln Y_{t+2} + \Delta \ln Y_{t+1}] - E_t[\Delta\ln Y_{t+1}] \qquad (27)$$

Equations (25) and (26) relate the yield differential between an n period and a 1 period bond to the average of the n period ahead expected growth rate of output

[9] Note that $[(1/2)\sigma^2 \; - (1/2n)\sigma^2]$ will be positive for $n > 1$.

less the 1 period ahead growth rate of output. If the growth rate of real output in the economy is expected to be higher in the future (i.e. $E_t\Delta\ln Y_{t+n} > E_t\Delta\ln Y_{t+1}$, $n\geq2$), the yield curve will be upward sloping, assuming a constant risk adjustment term. Similarly, if recession is anticipated the slope of the yield curve will be negative. Thus the term structure, or the yield spread between long term and short term interest rates reflects the market's expectations about the future state of the economy, and hence it contains information about agent's expectations of future real activity.

While the above relation gives the relationship between the real term structure and the expected future growth rate of output, it can also be shown that an analogous relation holds for the nominal term structure.

In the following development, we follow Fisher and Richardson (1989) and assume that money is a unit of account that has no real effects. Specifically, let P_t be the price of the single consumption good in terms of the unit of account (say dollars) and assume P_t is an exogenously given stochastic process. Then, as in Fisher and Richardson (1989), we can obtain the following expression (assuming log utility as before) for the nominal interest rate $i_{n\,t}$ on a n period bond.

$$\begin{aligned} i_{n\,t} = {} & \eta + E_t[(\ln C_{t+n} - \ln C_t)/n] + E_t[(\ln P_{t+n} - \ln P_t)/n] \\ & - \text{var}_t[(\ln C_{t+n} + \ln P_{t+n})/2n] \end{aligned}$$

Here it is aasumed that the stochastic processes for $\ln C_t$ and $\ln P_t$ are jointly normal. Under the assumption that $\ln C_t$ and $\ln P_t$ are homoscedastic, the risk adjustment term,

$$\text{var}_t (\ln C_{t+n} + \ln P_{t+n})/2n$$

is constant for given n.

Ignoring the constant risk adjustment term, we can derive the analogous expression to (26) as

$$i_{n\,t} - i_{1t} = (1/n)\, E_t[\, \Delta\ln Y_{t+n} + \Delta\ln Y_{t+n-1} + \dots\dots + \Delta\ln Y_{t+1}] - E_t[\Delta\ln Y_{t+1}]$$
$$+ (1/n)\, E_t[\, \Delta\ln P_{t+n} + \Delta\ln P_{t+n-1} + \dots\dots + \Delta\ln P_{t+1}] - E_t[\Delta\ln P_{t+1}]$$

where $\Delta\ln P_{t+i}$ is the rate of inflation from $t+i-1$ to $t+i$.

The above relation implies that in an economy where output and inflation are expected to grow (i.e. $E_t\Delta\ln Y_{t+n} > E_t\Delta\ln Y_{t+1}$ and $E_t\Delta\ln P_{t+n} > E_t\Delta\ln P_{t+1}$, for $n \geq 2$) the nominal term structure is positively linked to expected future output growth as well as the expected future inflation growth. Therefore, we conclude that while the real term structure is related to future expected real output growth the nominal term structure is related to this and also to the expected growth rate of inflation. When inflation is highly variable, the nominal yield spread may not be a good predictor of future real activity because movements in $(i_{n\,t} - i_{1t})$ are dominated by movements in the term $(1/n)\, E_t[\, \Delta\ln P_{t+n} + \Delta\ln P_{t+n-1} + \dots\dots + \Delta\ln P_{t+1}] - E_t[\Delta\ln P_{t+1}]$. Plosser and Rouwenhorst (1994) offer this as a possible explanation why the yield spread has no predictive power for real output in the UK as this country has experienced high and variable rates of inflation.

III. Empirical Analysis

1. Statistical Properties of the Data.

The slope of the yield curve can be represented as the spread between long-term and short-term yields on government securities or default-free bonds. The short and long term yield data used are the annualised quarterly percentage returns on 13 weeks treasury notes (TN13) and 10 year treasury bond (TB10Y).

We can compute the slope of yield curve as follows.

$$SPREAD1 = r^{g}_{10y} - r^{g}_{13w}$$

Alternatively, the spread[9] between the short-term bank-accepted bill (BB180) which contains a default risk premium and the long term government bond may be considered.

That is, we also consider

$$SPREAD2 = r^{g}_{10y} - r^{b}_{180d}$$

Throughout the analysis both measures of the yield spread will be used and their relative performance as a predictor for GDP will be examined.

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[9] Lowe (1992) used this measure of spread.

Figure 1.1: Spread between 10 year T-bond and 13 weeks T-note

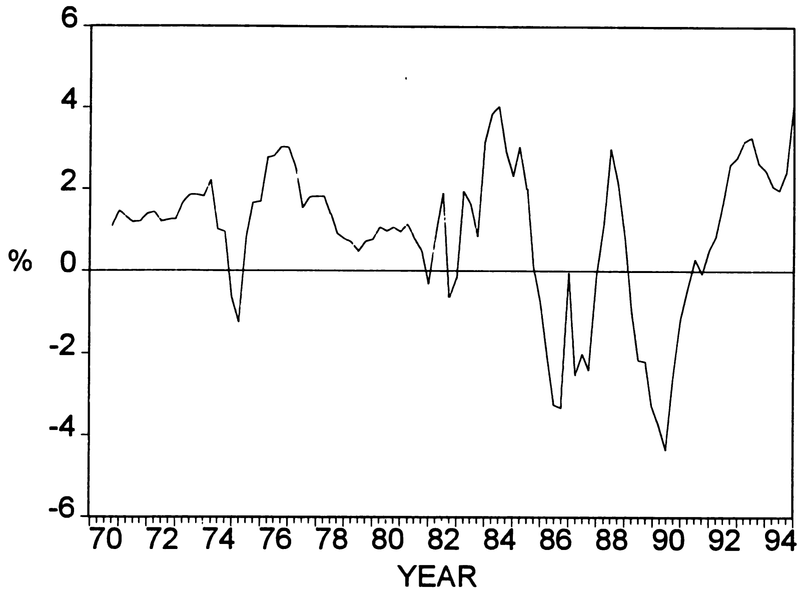
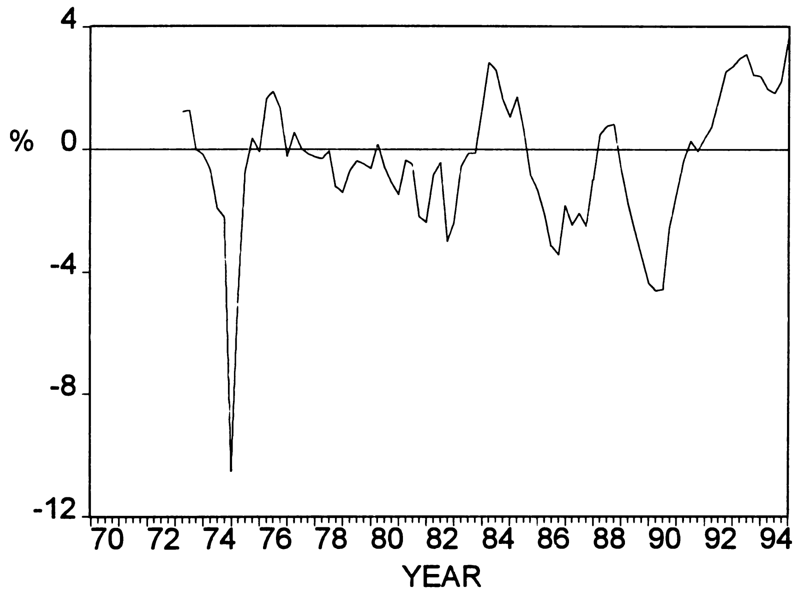


Figure 1.2: Spread between 10 year T-bond and 180 days bank bill



Note: The sharp fall in *Spread 2* experienced in 1974, as depicted above in Figure 1.2, was caused by extremely tight credit controls at that time which increased BB180 dramatically.

The main data series used in this study are taken from the DX Database and include the short-term (BB180, TN13) and long-term interest rate (TB10Y), and real GDP at 89/90 prices. In addition, the following series are used: the index of leading indicators (LEAD), M1, money base (MB) and loans and credit to private sector (CREDIT). All the series are seasonally adjusted and quarterly except interest rates which are monthly but are averaged to get quarterly series. The sample period to be used in this study is 1980:1 to 1995:2. (and when monthly data are used as in section 4, January 1980 to June 1995) Unlike Lowe (1992) and Alles (1995), we adopt this sample period for two reasons.

Firstly, there was a major recession in Australia over the years 1981 and 1982, so that this study includes the pre-recessionary period in the analysis. By doing so, we can see if the inclusion of this period significantly affects the results of Lowe and Alles. In fact, the plots of the yield spread and output growth in Figure 2 give an indication that the spread started to predict output growth from the beginning of the 1980's.

Secondly, by extending and updating the sample we can examine if the predictive power of spread is robust across sample periods.

The summary statistics in Table 1 reveal the following. First of all, the mean of the 10 year treasury bill is greater than the short-term 13 weeks T-notes implying the existence of a term premium.

Table 1: Summary Statistics for real GDP growth and Yield spreads

Variable	Mean	S.D.	Autocorrelations coefficients					
			ρ1	ρ2	ρ3	ρ4	ρ8	ρ12
TN13	11.50	3.80	.91	.82	.71	.59	.12	.03
BB180	12.32	4.03	.94	.85	.77	.65	.22	.06
TB10Y	12.19	2.31	.93	.86	.79	.72	.38	.14
GDP growth	2.92	2.55	.79	.58	.31	.03	.28	-.16
Spread 1	0.69	2.17	.86	.68	.52	.36	-.13	-.03
Spread 2	-0.19	2.17	.90	.73	.60	.45	-.02	-.06
LEAD	0.94	0.07	.96	.88	.78	.67	.38	.22

Note: LEAD is the index of leading indicators.

On the other hand, the mean of the 180 day bank-accepted bill is slightly above that of the long-term government bond implying that on average there is a risk premium on 180 day bank-accepted bills. So the *spread 2* has a negative mean while *spread1* has a positive mean.

This indicates that, on average, the yield curve for the riskless bonds generally slopes upward for the sample period. The 180 day bill is also more volatile[10] than either of the other two bond yields. However, despite the difference in the relative volatilities of the selected short term rates, the two measures of spread share the same degree of volatility.

[10] Using the 90 day bank-accepted bill was considered but ruled out because it is even more volatile than the 180 day bill. Harvey (1989) argues that volitility of a financial variable is more of a nuisance in reflecting the predictive information about output growth. However, Alles (1995) uses the 90 day bill rate.

Figure 2.1 : GDP growth and Lagged Yield Spread 1 in Australia

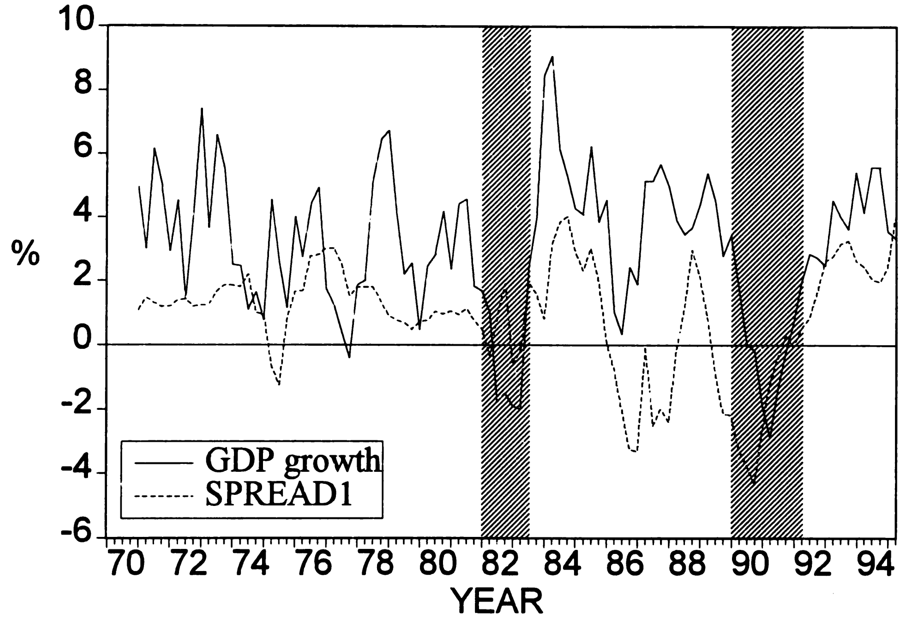
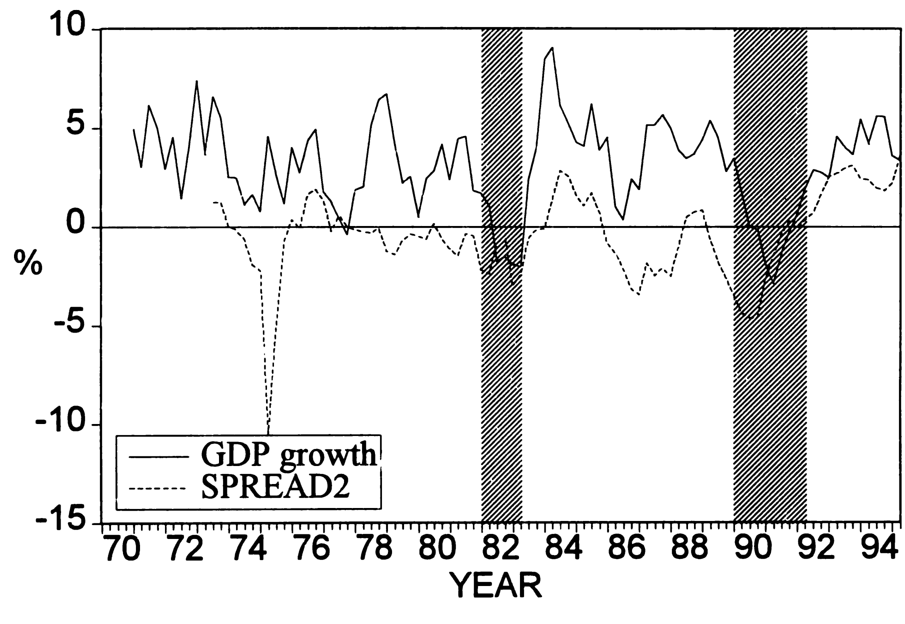


Figure 2.2 : GDP growth and Lagged Yield Spread 2 in Australia



Note: Shaded areas represent major recessionary periods since 1980.

Although the autocorrelation function provides an indication of whether the series are stationary or not , a formal test for stationarity of the series is now employed. To test for the stationarity of the spreads and GDP growth the augmented Dickey-Fuller test is performed, which is based on the following regression model

$$\Delta x_t = \tilde{\mu} + \tilde{\beta} \cdot t + \tilde{\alpha} \cdot x_{t-1} + \sum_{i=1}^{p} \tilde{\phi}_k \Delta x_{t-p} + \tilde{\varepsilon}_t$$

where p is the number of augmentation terms included to ensure approximately white noise residuals.

Table 2: ADF Unit-root Test results.

Series	Sample Period	p	t-statistics
TN13	70:1 - 95:2	0	-1.23
BB180	72:3 - 95:2	6	-1.23
TB10Y	70:1 - 95:2	0	-1.34
Spread1	70:1 - 95:2	4	-3.31**
Spread2	72:3 - 95:2	1	-3.47**
GDP	70:1 - 95:2	0	-1.89
GDP growth	70:1 - 95:2	4	-2.97*

Note:
- ** and * denote the rejection of the null hypothesis of unit root at 5% and 10% levels, respectively.
- We follow the sequential procedure suggested by Dolado et al (1990).

The test results indicate that measures of spread and output growth are stationary, so that in the single equation analysis, the 'spurious regression' problem will not arise.

2. Single Equations Estimation

In this section we empirically examine the respective predictive power of the interest rate spreads for future real output growth in a single equation framework.

To begin with, the following specifications of regression equations for forecasting output growth are used.

$$[\ln (Y_{t+4}/Y_t)*100] = a_0 + b_0 \text{ Spread}_{i,t} + e_{t+4} \qquad [1]$$

$$[\ln (Y_{t+4}/Y_t)*100] = a_0 + b_0 \text{ Spread}_{i,t-1} + e_{t+4} \qquad [1*]$$

$$[\ln (Y_{t+k}/Y_t)*400/k] = a_0 + b_0 \text{ Spread}_{i,t} + e_{t+k} \qquad [2]$$

$$[\ln (Y_{t+k}/Y_t)*400/k] = a_0 + b_0 \text{ Spread}_{i,t-1} + e_{t+k} \qquad [2*]$$

for $i = 1, 2$ and k is the growth horizon measured in quarters so that $k = 4$ corresponds to a growth horizon of one year, and Y is the real GDP. The LHS is the annualised percentage growth rate of real GDP.

The specification [1] was also employed by Lowe (1992) while specification [1*] is the one quarter ahead forecasting equation for the annual growth rate of output. The specification [1*] was also adopted in Harvey (1989) and Hu (1993).

Equation [2] is often referred to as the cumulative growth forecasting equation and we consider GDP growth horizons of up to 3 years (k = 12). The specification [2] is also employed by Estrella and Hardouvlis (1991) and Plosser and Rouwenhorst (1994).

However, we also examine the 1 quarter ahead forecasting equation for cumulative output growth, specified as [2*], which has not been considered in previous studies.

The crucial econometric problem that arises in the estimation of the regression equations is that the error terms are not spherical. The overlapping observations in constructing the regressand tend to cause serial correlation among the residuals which renders inferences based on conventional OLS estimated standard errors invalid. For example, the residuals from estimation of [1] and [2] by OLS will typically follow MA(3) and MA(k-1) processes, respectively.

To deal with the problem of serially correlated errors, the Newey-West (1988) autocorrelations consistent covariance matrix of the OLS estimates is

Table 4.1: Estimation of the forecasting equations (1980:1 - 1995:2)

Equation [1]	Constant	Spread	R^2 (Adj R^2)	SER	F-ratio
Spread1	2.66 (4.83)	0.52 (2.96)***	.19 (.17)	2.38	12.7
Spread2	3.18 (6.53)	0.57 (3.51)***	.21 (.19)	2.37	14.3
Equation [1*]					
Spread1	2.63 (5.01)	0.56 (2.79)***	.20 (.19)	2.29	15.5
Spread2	3.17 (7.52)	0.60 (3.64)***	.23 (.22)	2.26	15.6
Equation [2] **k=8**					
Spread1	2.70 (5.69)	0.44 (2.05)**	.24 (.23)	1.59	19.0
Spread2	3.18 (9.22)	0.50 (3.33)***	.29 (.28)	1.54	23.6
k=12					
Spread1	2.79 (7.25)	0.25 (1.36)*	.14 (.12)	1.24	9.4
Spread2	3.16 (10.17)	0.32 (2.03)**	.18 (.16)	1.22	11.9
Equation [2*] **k=8**					
Spread1	2.75 (5.09)	0.40 (1.75)**	.20 (.19)	1.74	12.94
Spread2	3.17 (7.88)	0.49 (3.12)***	.28 (.26)	1.62	19.7
k=12					
Spread1	2.91 (7.05)	0.22 (1.20)	.11 (.10)	1.33	6.05
Spread2	3.14 (9.79)	0.28 (1.54)**	.12 (.11)	1.35	6.7

Note: (1) Numbers in parentheses are t-statistics, which are corrected through the Newey-West procedure. Hereafter the t-ratio will be in parentheses.
(2) The asterisks, *, ** and *** denote the significance of the t-statistics at 10%, 5% and 1 % levels of significance, respectively.
(3) The forecasting equations were also estimated using the sample period beginning in either 1982:3 or 1983:4 and extending to 1995:2 (the latter being post financial deregulation period) [see Alles (1995) who also uses this sample period]. The estimated coefficients and standard errors (not reported) are similar to those reported in Table 4.1.

used in all single regression equations with various growth horizons in order to conduct valid inferences.

The estimation results indicate that the yield spreads predict real output growth, especially over horizons of 4 to 8 quarters. This can be seen from Table 4.1 where the coefficients in equations [1] and [2] (for k=8) are statistically significant at the 5% level or better and the $\overline{R}^2$ is between 0.19 and 0.30

The signs of the regression coefficients are all positive, indicating that a positively sloped yield curve foreshadows an increase in future economic activity. In fact, this empirical result is consistent with the prediction of the model presented in Chapter II. For equations [1] and [1*], the coefficients of the yield spreads are significant even at 1% level.

Although the sample period used is different, this result is consistent with Lowe (1992) and Alles (1995). We re-examine this in the next section using a VAR methodology and an innovations accounting approach.

Secondly, the spreads have some predictive power for real output growth over horizons in excess of two years. This result is surprising given that the predictive power of the spread beyond a GDP growth horizon of 8 quarters was found to be negligible by Lowe (1992). The estimation result for equation [2] with the growth horizon of 3 years (k=12) indicates that the *spread 2* variable is still statistically significant at 5% level. It is also to be noted that *spread 2* has a high $\overline{R}^2$ in every case.

It is now of interest to examine if the yield spread retains its predictive power in the presence of other indicators, especially, the index of leading indicators, over different growth horizons. To compare the forecasting ability of spreads relative to the index of leading indicators, we consider the regression equations as follows.

$$[\ln (Y_{t+4}/Y_t)*100] = a_0 + b_0 \text{ Spread}_{i,t} + b_1 \Delta \text{ LEAD}_t + e_{t+4} \qquad [3]$$

$$[\ln (y_{t+k}/y_t)*400/k] = a_0 + b_0 \text{ Spread}_{i,t} + b_1 \Delta \text{ LEAD}_t + e_{t+k} \qquad [4]$$

for i = 1, 2, where Δ LEAD[11] is the quarterly change in the index of leading indicators over the previous quarter.

The estimation results presented in Table 4.2 indicate that the index of leading indicators is highly significant in the equation for GDP growth over the next 4 quarters and that the significance and magnitude of the spread variables are little affected by inclusion of the index of leading indicators.

[11] The ADF test indicates that the index of leading indicators is found to be nonstationary and hence needs to be first-differenced to induce stationarity.

Table 4.2 : Estimation result of equations [3] and [4]

Equation [3]	Constant	Spread	Δ LEAD	R^2 (Adj R^2)	SER
Spread1	2.46 (5.53)	0.29 (1.99)**	0.21 (3.59)***	.37 (.35)	2.06
Spread2	2.73 (6.31)	0.28 (2.24)**	0.20 (3.47)***	.36 (.34)	2.07
Equation [4]					
k=8					
Spread1	2.63 (5.80)	0.35 (1.73)**	.08 (2.51)***	.30 (.27)	1.54
Spread2	3.04 (8.43)	0.40 (2.53)***	.07 (1.52)**	.32 (.29)	1.52
k=12					
Spread1	2.78 (7.10)	0.24 (1.33)*	0.01 (0.35)	.14 (.11)	1.25
Spread2	3.13 (10.73)	0.32 (2.08)**	-0.01 (-0.18)	.17 (.14)	1.23

Note: ***, ** and * significant at 1%, 5% and 10% level, and N-W procedure was used.

However, as the growth forecasting horizon increases beyond 8 quarters the index of leading indicators has no predictive power. The LEAD variable has predictive power for a growth horizon of GDP of less than 8 quarters only.

Previous studies have attempted to find if the predictive power of interest rate spreads stem from the transmission mechanism of monetary policy or is due to intertemporally-maximising agent's expectations about the future state of the economy. Those who argue that the predictive power of spread is a result of the conduct of monetary policy by the central bank maintain that since the short-term interest rate is a good indicator of the current stance of monetary policy, the predictive power of the interest rate spread is largely attibutable to policy induced variations in the short-term interest rate.

Lowe attributes the predictive power of the spread to the strong liquidity effect[12] of changes in the money supply by the central bank. He argues that the spread predicts future output growth because monetary policy has real output effects and acts through changes in the short term interest rate while leaving the long term rate unaffected.

If this proposition is true, one might expect *a priori* that the interest rate spread would have little predictive power left when the short term interest rate is also included as a regressor in the estimated equation. In order to see what the data tell us about the above proposition, we follow Plosser and Rouwenhorst (1994) and consider the regression equation.

$$[\ln (y_{t+4}/y_t)*100] = a_0 + b_0 \text{ Spread}_{i,t} + b_1 \Delta BB180_t + e_{t+4} \qquad [5]$$

where ΔBB180 is the quarterly change in the short term interest rate, BB180 and i = 1, 2.

We also consider the equation

$$[\ln (y_{t+4}/y_t)*100] = a_0 + b_0 \text{ Spread}_{i,t} + b_1 \Delta TB10Y_t + e_{t+4} \qquad [5*]$$

[12] That is, the hypothesis that a higher rate of money growth will cause a short term decline in interest rates.

for i = 1,2.

The ADF unit-root test results indicate that the yield variables, TN13, BB180 and TB10Y are $I(1)$ and the differences (quarterly changes) are stationary.

The purpose of estimating these equations is to determine if the spread variables still remain significant predictors in the presence of short-term and long term interest rates, respectively.

Table 5: Predictive powers of term spreads vs Short and Long rates

Equation [5]	**Constant**	**Spread**	**Δ BB180$_t$**	**R^2 (Adj R^2)**	**SER**
Spread1	2.63 (4.84)	0.57 (2.77)***	0.15 (0.59)	.20 (.17)	2.41
Spread2	3.22 (6.90)	0.61 (3.51)***	0.20 (0.72)	.22 (.19)	2.38
Equation [5*]	**Constant**	**Spread**	**Δ TB10Y$_t$**	**R^2 (Adj R^2)**	**SER**
Spread1	2.67 (4.82)	0.51 (2.70)***	-0.36 (-0.73)	.20 (.17)	2.40
Spread2	3.16 (6.27)	0.55 (3.39)***	-0.19 (-0.39)	.21 (.18)	2.39

Note: *** indicates significance at the 1% level.

The results show that the coefficients on quarterly changes in interest rates are insignificant in all cases and that the significance of the term structure variable hardly diminishes in all cases. Also there was no improvement in the R^2 values.

This indicates that the predictive power of the spread variables is not sensitive to the inclusion of either short or long term interest rates in the regression equation. We examine this issue more thoroughly in the next section using an innovations accounting approach.

Now we examine if the predictive power of the spread still holds when a monetary aggregate is included in the single equation analysis. The monetary aggregate we use is seasonally adjusted M1.

The regression equation to be estimated is

$$\ln(Y_{t+4}/Y_t) = a_0 + b_0 Spread_{i,t} + b_1 \ln(m_t/m_{t-4}) + b_2 \ln(m_{t+4}/m_t) + e_{t+4} \qquad [6]$$

where now current and lagged annual growth rates of money are included. The purpose of employing this specification is to examine if the term spread remains statistically significant when both the past and current annual growth rates of the money stock are added as regressors. This regression specification is also employed by Plosser and Rouwenhorst (1994).

The estimation results indicate that current, not past, money growth is a significant predictor of GDP growth, as expected *a priori*. But it should also be noted that the yield spread still retains a considerable degree of predictive power as indicated by the significant t-ratios and little change in the coefficient estimates.

Table 6.1: Inclusion of past and current money growth in the forecasting regression equation

Equation [5]	Constant	Spread	ln (m_t/m_{t-4})	ln (m_{t+4}/m_t)	R^2 (Adj R^2)	SER
Spread1	-0.06	0.39 (2.12)**	6.97 (0.77)	18.17 (2.49)***	.36 (.33)	2.1
Spread2	0.46	0.35 (1.85)**	7.02 (0.71)	16.45 (2.42)***	.33 (.30)	4.6

Note: *** and ** indicate significance at the 1% and 5 % levels, respectively. The N-W procedure is used.

The quarterly (not annual) growth rate of the money stock is now included as a regressor and the robustness of the predictive power of spread is examined. The above regression equation is modified to

$$[\ln (Y_{t+4}/Y_t)*100] = a_0 + b_0 \text{ Spread}_{i,t} + b_1 \Delta\ln (m_{t+1}/m_t) + e_{t+4} \qquad [7]$$

Table 6.2: The inclusion of the quarterly money growth in the regression

Equation [5]	Constant	Spread	Money growth	R^2 (Adj R^2)	SER
Spread1	1.79	0.43 (2.32)**	31.09 (2.03)**	.25 (.22)	2.25
Spread2	2.27	0.44 (2.83)	28.63 (2.11)**	.25 (.22)	2.25

Note: ** indicates significance at 5 % level. The N-W procedure is used.

The table 6.2 also indicates that the quarterly growth rate of the money stock is a statistically significant explanatory variable but the coefficients and the corresponding t-ratios of the spreads do not show much variation in either case. From the above set of results we conclude that the predictive content of the yield spread is, to a considerable extent, independent of monetary policy. To analyse the predictive ability of the spread further, we employ a VAR methodology in the next section.

3. VAR analysis of the predictive power of the interest rate spread

In this section, we empirically examine the predictive power of the yield spread by employing a VAR methodology. The primary objective of using the VAR approach in this section is to examine the interactions among GDP growth and the yield spread.

We begin with a bivariate VAR model, including GDP and each of the spread variables. In the previous section, we provided evidence that the yield spread has substantial predictive content for GDP growth, even beyond two years. This result will be checked in this section. In addition, for the purpose of comparing the predictive power of the yield spreads with other forecasting variables, a set of vector autoregressive models will be considered.

A VAR model with deterministic terms can be represented as follows.

$$z_t = A_0 + A_1 z_{t-1} + \dots\dots\dots\dots\dots + A_p z_{t-p} + e_t \qquad (1)$$

where z_t is an $n \times 1$ vector of series.

It can be shown that the above VAR system is the reduced form of some underlying structural system of equations. It is well known that a major purpose of employing VAR models is to infer the response of variables of interest to exogenous shocks (that is, innovations) in each of the variables.

The VAR model can be written as

$$A(L)z_t = A_0 + e_t \tag{2}$$

where $A(L) = I_n - A_1L - \ldots\ldots\ldots\ldots - A_pL^p$;

and $L^iz_t = z_{t-i}$.

The implied moving average representation of z_t can be written as

$$z_t = \mu + A(L)^{-1}e_t$$

$$= \mu + \sum_{s=0}^{\infty}\psi_s e_{t-s} \tag{3}$$

where $\mu = [A(L)]^{-1}A_0$

This can be transformed into the recursive form

$$z_t = \sum_{s=0}^{\infty}\psi_s^* \varepsilon_{t-s} \tag{4}$$

by using a lower triangular matrix S where $\psi_i^* = \psi_i S^{-1}$ and $\varepsilon_t = Se_t$, so that the impulse response functions to a shock to the orthogonalised innovations, ε_i, can be generated. However, a major drawback[13] of this technique is that the choice of the S matrix is not unique, so that a different ordering of the variables in z will typically lead to a different S, thus altering the impulse response functions and innovation accounting decompositions. Sims (1980) suggests trying various plausible orderings of the variables to check for robustness of results. In ordering the variables, we place the yield spread last so that it is affected contemporaneously by all the other variables in the VAR. Although

[13] This was critically reviewed by Cooley and LeRoy (1985).

the yield spread is not likely to be most endogenous, we follow the practice of Bernanke and Blinder (1992) and Friedman and Kuttner (1993) and order it last.

In the VAR models the following series are used: the money base [MB] as a narrow measure of money, loans and credit [CR] to private sector, and the index of leading indicators [LEAD]. In addition, we also consider the predictive performance of the spread in the presence of the short term and long term rates, respectively. The objective here is simply to see if the predictive power of the spread is mainly due to variations in the short term interest rate. Also the relative importance of the short term and long term interest rate in predicting output growth can determined in a VAR framework.

In order to determine the appropriate order of the VAR models, sequential Sims' Likelihood Ratio tests and Akaike's Information Criterion (AIC)[14] are used to choose the appropriate lag length p. However, we base our lag length decisions on Sims' LR test as it suggests more parsimonious[15] lag lengths. The lag length chosen for the particular VAR model is indicated in the respective tables. [The appendix contains the results of lag length tests for each VAR model considered in this section].

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[14] That is, to minimise -ln likelihood + number of parameters.

[15] It is well known that the AIC has a tendency to overestimate the correct order of p. See Paulsen (1984).

We first of all consider the VAR equivalent of equations [1] and [2] in Section 2 in order to examine the predictive ability of the spread. The results from the VAR can be compared with the results from the single equation estimation. The sample period used here is again 1980:1 to 1995:1. For the bivariate VAR, GDP is ordered first and the yield spread second.

Table 7 : Variance Decomposition of GDP growth : Bivariate VARs

	Decomposition of Forecast Error Variance of			
	Annual GDP growth		**Quarterly GDP growth**	
A One S.D. Shock to	**Spread1**	**Spread2**	**Spread1**	**Spread2**
Qts. 4	6.8	6.6	2.4	4.7
8	16.9	18.6	5.7	8.8
12	17.3	20.2	6.4	10.7
16	17.3	20.5	6.4	10.8

Note: The lag lengths used for the VARs are 6 and 5 for annual and quarterly growth of GDP, respectively. The ordering for orthogonalisation: GDP , Spread_i for i =1, 2.

From the variance decomposition table, the spread between the 10 year T- bond rate and the 180 day bank bill rate explains more than 20 % of the forecast error variance of GDP growth after 12 quarters. But for predicting quarterly changes in GDP, this spread variable accounts for only 10 % of the forecast error variance at long horizons.

The other measure of the yield spread, namely the spread between the 10 year T-bond rate and the 13 weeks T-note rate, appears to be not as successful as *Spread 2* in explaining the forecast error variance in both annual and quarterly GDP growth. One possible reason for the superior predictive ability of *Spread 2* is that the 180 day bank bill is more actively traded in the market, and consequently its yield reflects agent's expectations. The other reason could be that the risk premium, absent on government bonds, is informative about expected real activity.

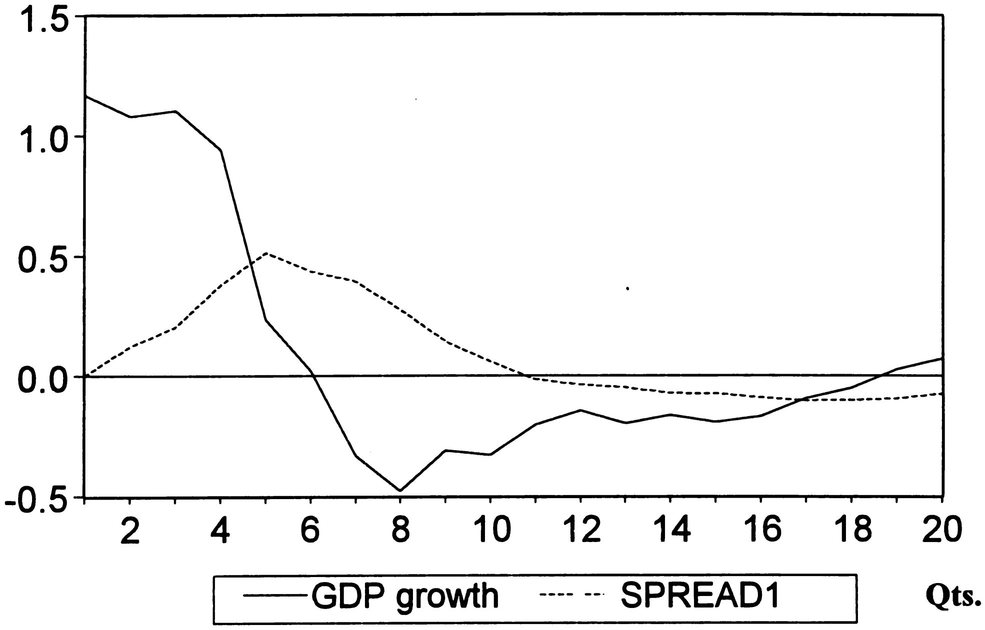
Figures 3.1 and 3.2 exhibit impulse responses of GDP growth (both annual and quarterly) to an exogenous shock to *Spread 1* and *Spread 2*, respectively.

The impulse responses of GDP (for both annual and quarterly) confirm the results of the variance decompositions. In particular, it can be noted that the response of GDP growth (annual) to a shock to *Spread 2* persists up to 12 quarters with most impact occurring between 3 and 6 quarters.

However, the impact of a one standard innovation in the spread on quarterly GDP growth is not, as indicated by the variance decomposition result, significant. Given the results from both the variance decompositions and impulse response functions, we will only consider *Spread 2* as a predictor of annual GDP growth in the subsequent analysis.

Figure 3.1: Impulse Responses of GDP growth (Annual)

Response of GDP growth to One S.D. Innovations in GDP and Spread 1



Response of GDP growth to One S.D. Innovations in GDP and Spread 2

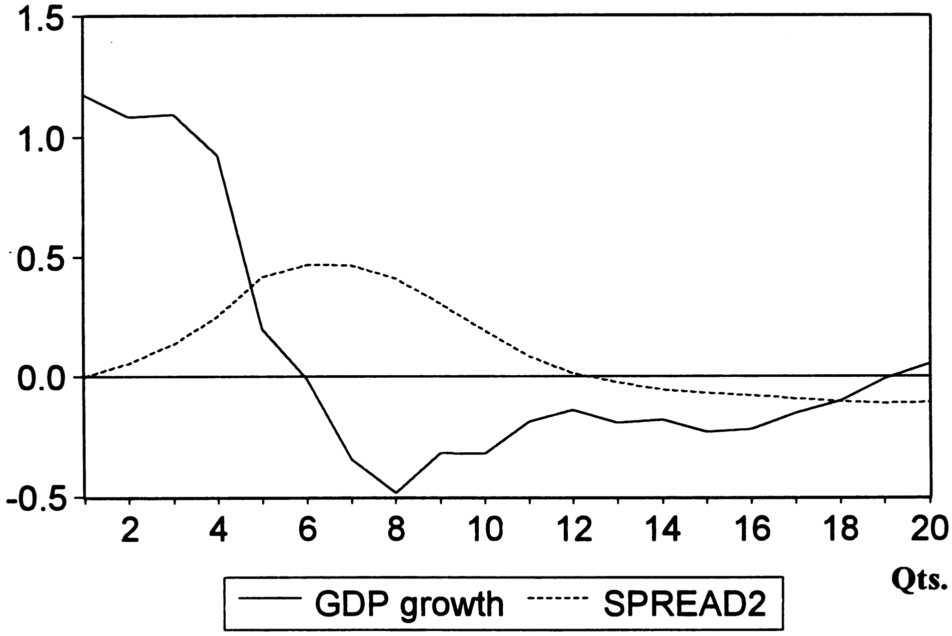
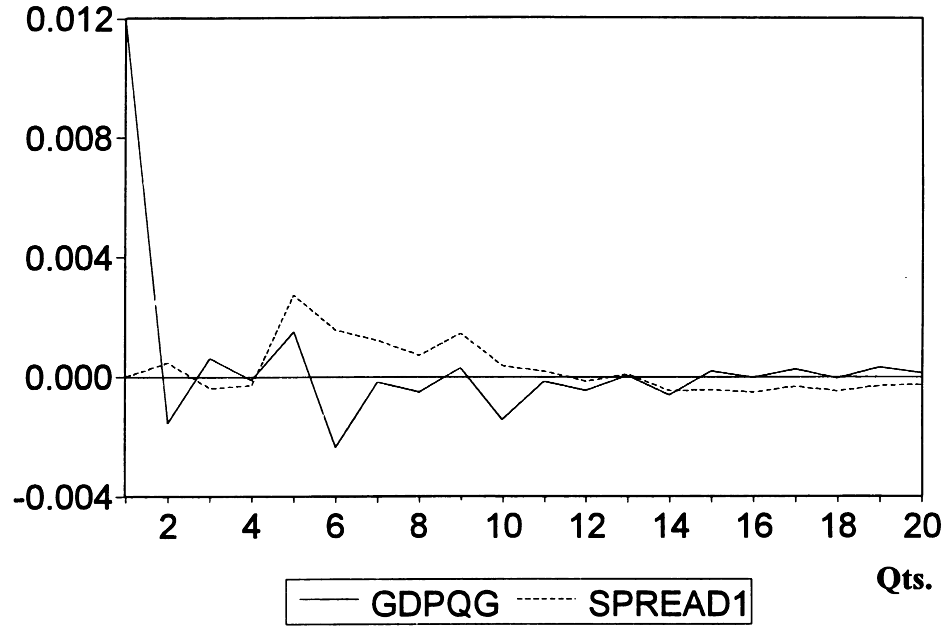
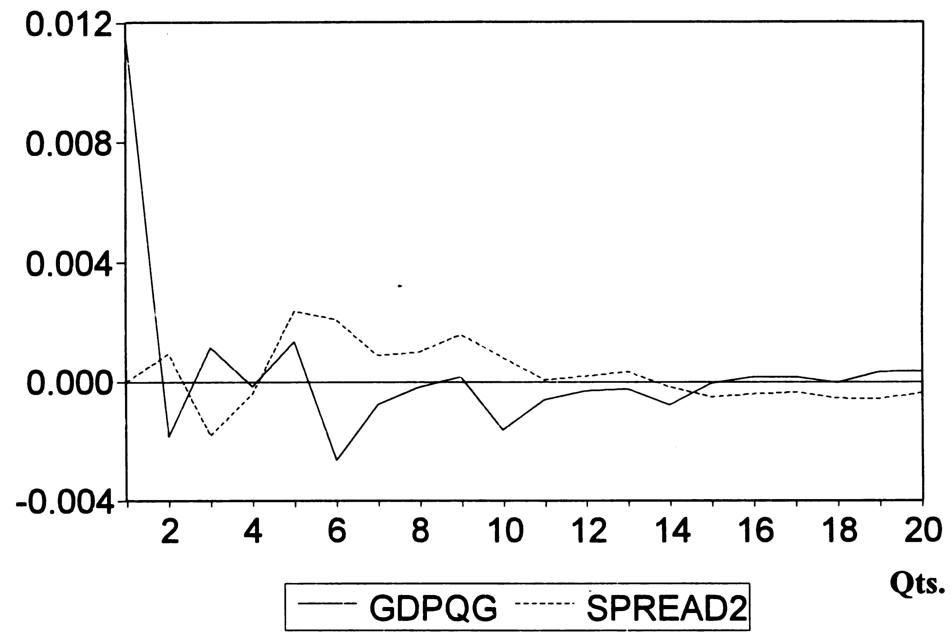


Figure 3.2: Impulse Responses of GDP growth (Quarterly)

Response of GDP growth to One S.D. Innovations in GDP and Spread 1



Response of GDP growth to One S.D. Innovations in GDP and Spread 2



Figures 3.1 and 3.2 show that GDP growth, both annual and quarterly, responds positively to a shock to the yield spread. This is consistent with the prediction of the model presented in Chapter 2.

We now compare the predictive performance of the spread with other financial variables or indicators. The following financial variables are included successively in the VAR models: LEAD, CREDIT and MB. As the unit root test results indicate that these series are integrated of order 1, first differences of these series enter the VAR models. We consider 3 variable VAR models which include GDP growth, the spread variable and one of LEAD, CREDIT or MB respectively, for evaluating the predictive performance of the spread relative to the other variables. In each model, GDP is ordered first, the other forecasting variables second and the spread last.

The variance decomposition of GDP growth for these 3 variable VAR models indicates that the spread significantly outperforms each of the three competing variables in explaining the forecast error variance of GDP growth. This result is also robust to alternative orderings.

Table 8: Variance Decomposition of GDP growth: Trivariate VARs

	Decomposition of Forecast Error Variance of GDP growth					
A One S.D. shock to	Spread	ΔLEAD	Spread	ΔCREDIT	Spread	ΔMB
Qts. 4	2.0	2.6	6.1	3.4	8.8	13.0
8	13.1	2.4	13.5	4.5	20.0	14.1
12	16.0	3.3	14.4	7.5	19.3	17.4
16	16.7	3.5	15.6	7.4	20.5	18.0

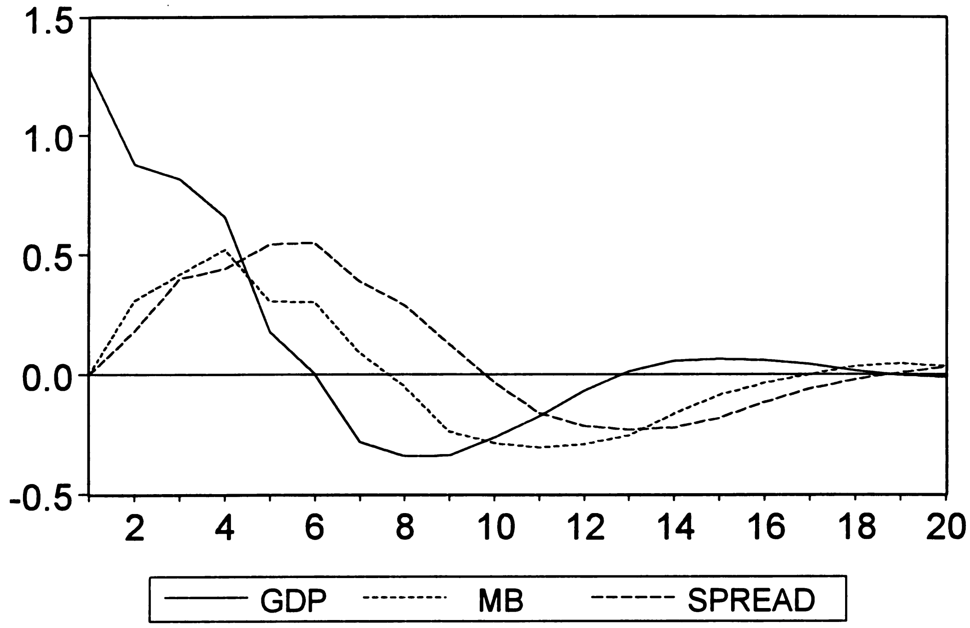
Note: The lag length used is 5 for the LEAD and CREDIT models and 4 for the model with MB. The ordering is GDP growth, ΔLEAD/ CREDIT/ MB, Spread.

Figure 4 presents the impulse responses of GDP growth to innovations in GDP, the spread, and respectively, MB, CREDIT and LEAD.

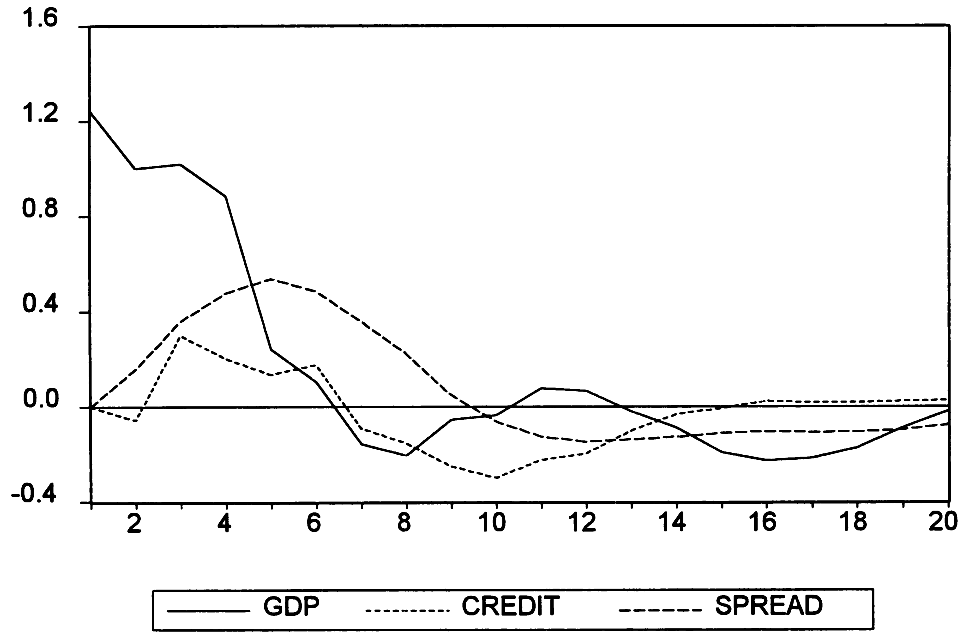
The following graphs show that, in all three VAR models, GDP growth responds positively to a shock in the yield spread. Also as expected, a shock to money has a positive impact on GDP. The response of GDP to an innovation in the yield spread is more pronounced than to innovations in MB, CREDIT and LEAD.

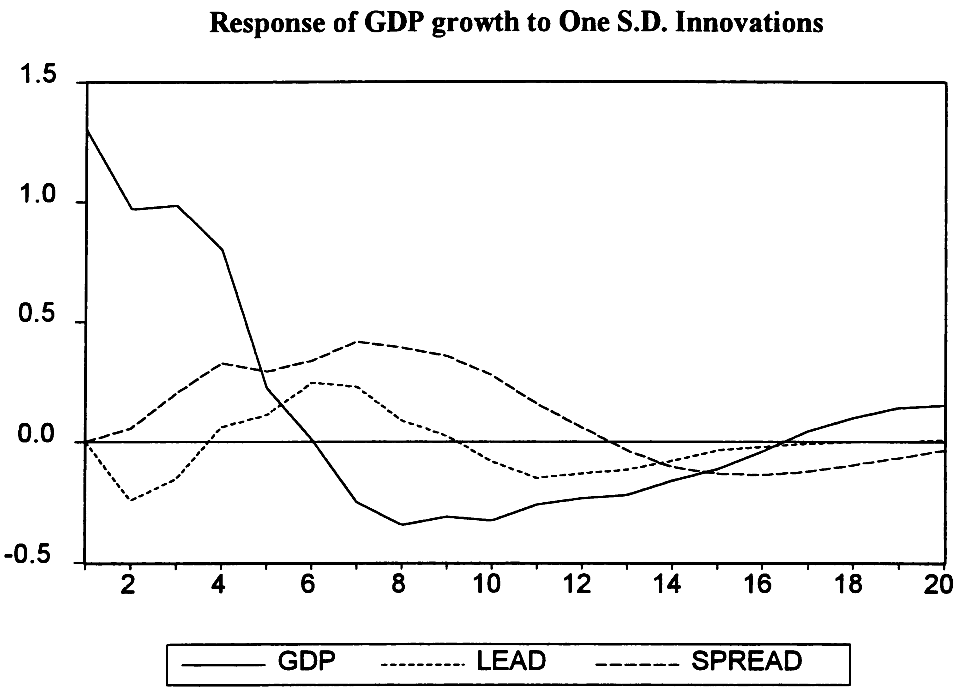
Figure 4: Impulse Responses of GDP growth : Trivariate VARs

Response of GDP growth to One S.D. Innovations



Response of GDP growth to One S.D. Innovations





We now examine the validity of the claim that movements in short term interest rates explain the predictive power of the spread. To see this we consider trivariate VARs which include, respectively, the short term and long term rate. However, we now use the sample period from 1982:3 onwards, as used in previous Australian studies, for the purposes of comparison. [See Lowe (1992) and Alles (1995)]. We update the sample period up to 1995:1.

The variance decomposition results in Table 4 indicate that, unlike in the single equations analysis, the short rate now has substantial predictive power for GDP growth.

Table 9: Variance Decomposition of GDP growth: Trivariate VARs

	Decomposition of Forecast Error Variance of GDP growth			
A One S.D. Shock to	ΔBB180	Spread	ΔTB10Y	Spread
Qts. 4	6.6	1.0	1.6	4.7
8	13.5	10.8	2.1	17.4
12	14.0	10.9	2.5	17.9
16	15.1	10.9	2.9	19.8

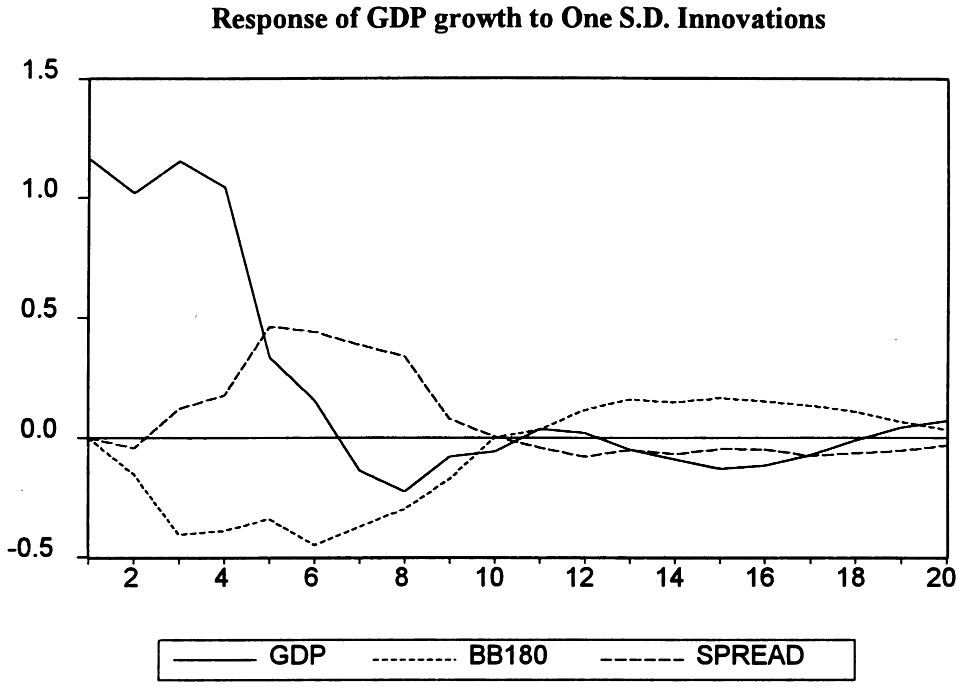
Note: The lag length used is 5 for both VARs.
The ordering is GDP growth, Δr, Spread

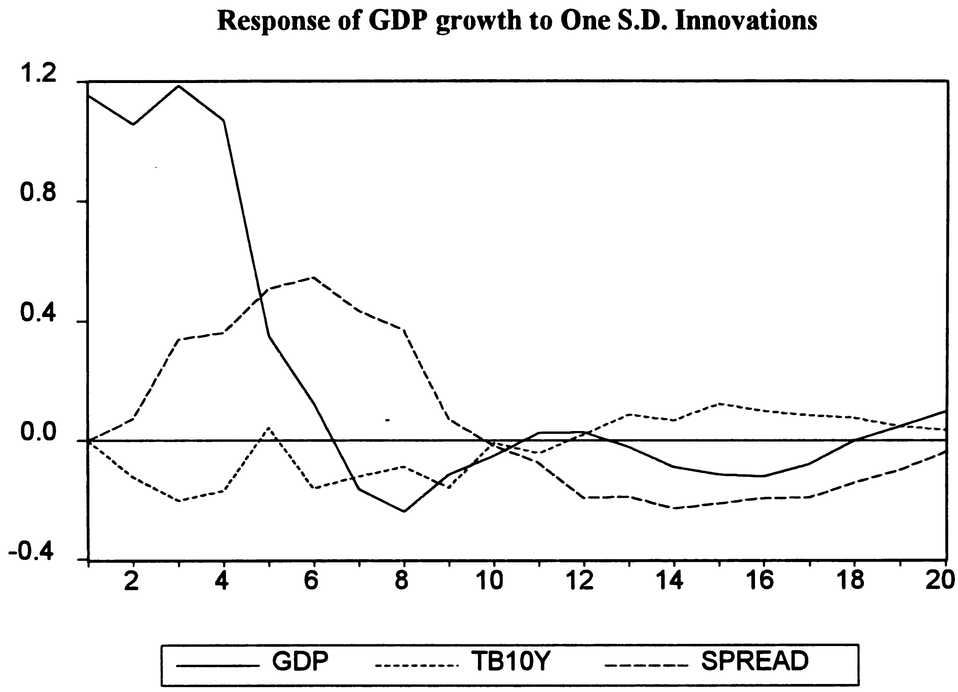
The short rate explains more of the forecast error variance of GDP growth than the spread at all forecast horizons whereas the long rate explains less at all horizons. This result might be interpreted in favour of the claim that only movements in the short term rate accounts for the predictive power of the spread.

However, the fact that the spread still retains some predictive content in the presence of the short term and long term rates, respectively, could be a result of the high collinearity between the spread and the respective interest rate.

The impulse responses indicate that a positive innovation in either the short or long term interest rate has a negative impact on future growth in real output, while GDP growth increases in response to a positive shock to the yield spread.

Figure 5 : Impulse Responses of GDP growth : Trivariate VARs with each of the short end and long end.





This is consistent with the standard notion that a high interest rate today deters consumption and investment, leading to sluggish economic activity in the future.

In order to compare the short end and long end of the yield spread in explaining GDP growth, we now consider a VAR model without the spread variable.

Table 10: Variance Decomposition of GDP growth: Trivariate VARs

	Decomposition of Forecast Error Variance of GDP growth			
	(1)		(2)	
A One S.D. Shock to	**ΔBB180**	**ΔTB10Y**	**ΔBB180**	**ΔTB10Y**
Qts. 4	0.4	13.5	4.9	9.1
8	6.3	18.2	12.8	11.7
12	7.9	17.7	13.0	12.7
16	8.6	17.7	13.6	12.7

Note: The lag length used is 5.
The ordering is GDP growth, ΔTB10Y, ΔBB180 for (1)
and GDP growth, ΔBB180, ΔTB10Y for (2)

The results of the variance decompositions are quite sensitive to the ordering of the variables, indicating the two interest rate series are highly contemporaneously correlated. One useful way of addressing this issue is to determine the *causality* between the two interest rate series. This is not only important in its own right but it is crucial to investigating the validity of the argument that the predictive content of the spread is mainly due to movements of short term interest rates. We now turn to this issue.

4. Granger Causality Tests

In examining the relative predictive content between short and long interest rates we investigate which variable is Granger causally prior.

We presents the plots of the short term and long term interest rates in Figure 6.

Figure 6 : The movements of short term and long term interest rates

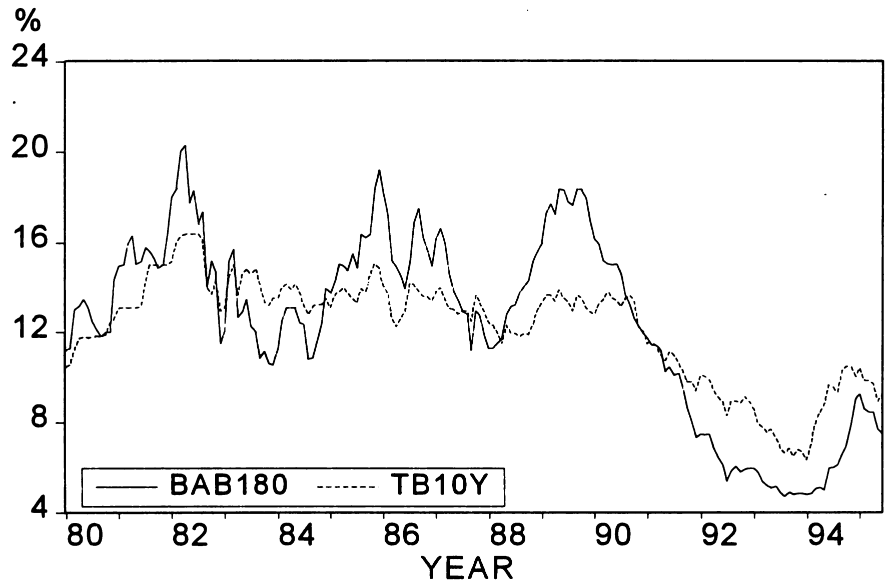


Figure 6 indicates that the short term rate is more volatile than the long term rate. It also appears that the two series move together over time (i.e. are cointegrated so that the spread is stationary). We first consider whether there is cointegration between the rates. Although Johansen's system approach[16] is also feasible, for the bivariate case, the Engle-Granger test for stationarity of the residuals from the cointegrating regression can be used.

Consider the following model to be tested.

$$\text{SPREAD}_t = r_t^L - r_t^S = (\rho - 1)\, r_t^S + u_t$$

where we use TB10Y and BB180 respectively for r_t^L and r_t^S.

Cointegration requires that u_t is an $I(0)$ process. Further, according to Karfakis and Moschos (1993), only when the cointegrating coefficient $\rho = 1$, is the spread a stationary process. Otherwise the spread contains the same degree of persistence as the short rate.

We use two tests, the ADF test and the KPSS test[17] (where the latter is a test for the null of stationarity versus the alternative of unit root) to see if $u_t \sim I(0)$. Both tests indicate that the residual term is stationary[18]. The estimated coefficient of ρ is 0.94, with the standard error equal to 0.01. Thus the hypothesis that $\rho = 1$ cannot be rejected.

[16] The Johansen cointegration test indicates that there is a cointegrating relationship between the two interest rates only at 20 % level.

[17] See Kwiatkowski et al (1992) for theoretical discussion.

[18] The ADF test rejects the null of a unit root at 5 % level whereas the KPSS test is sensitive to the number of autocovariances estimated in the long-run covariance matrix.

For Granger causality test between the long term and short term rates, we consider two cases. Since it is well known that for nonstationary data standard F-statistics do not have a standard limiting distribution, we test for Granger causality using the first differences of the data.

However, it has also been shown that, although the level variables contain unit roots, the Granger causality test is valid in a bivariate cointegrated VAR model. [See Lütkepohl and Reimers (1992) and Toda and Phillips (1993)].

To develop the test of Granger causality in the cointegrated VAR model, let x_t and y_t denote the levels of the short term and the long term rates, which are respectively $I(1)$, so that Δx_t and Δy_t are stationary.

Then a bivariate VAR of order p can be written as

$$\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \sum_{i=1}^{p} \begin{bmatrix} a_{11,i} & a_{12,i} \\ a_{21,i} & a_{22,i} \end{bmatrix} \begin{bmatrix} x_{t-i} \\ y_{t-i} \end{bmatrix} + \mu + \varepsilon_t$$

where $\varepsilon_t = (\varepsilon_{it}, \varepsilon_{2t})'$ is assumed to be an independently and identically distributed Gaussian process with the mean and variance $(0, \Lambda)$.

This representation can be re-arranged as a vector error correction (VEC) model

$$\begin{bmatrix} \Delta x_t \\ \Delta y_t \end{bmatrix} = \sum_{i=1}^{p-1} \Gamma_i \begin{bmatrix} \Delta x_{t-i} \\ \Delta y_{t-i} \end{bmatrix} - \Pi \cdot \begin{bmatrix} x_{t-p} \\ y_{t-p} \end{bmatrix} + \mu + \varepsilon_t$$

where $\Gamma_i = -(I_k - A_1 - A_2 - \ldots\ldots - A_i)$ for $i = 1, \ldots, p-1$.

and $\Pi = I_k - A_1 - A_2 - \ldots\ldots - A_p = \alpha\beta'$

and $A_i = \begin{bmatrix} a_{11,i} & a_{12,i} \\ a_{21,i} & a_{22,i} \end{bmatrix}$, $i = 1, \ldots, p$.

The test of the null hypothesis that x_t does not Granger cause y_t is a test of:

$$a_{12,i} = 0, \quad \forall\, i = 1, \ldots, p$$

and conversely the test of Granger noncausality of y_t is a test of:

$$a_{21,i} = 0, \quad \forall\, i = 1, \ldots, p$$

Lütkepohl and Reimers (1992) maintain that the Wald statistic has an asymptotic χ^2 (p) distribution if the cointegration rank r =1 or 2. If r =0, the VAR coefficients may be estimated in first differences and the resulting Wald statistic for the above coefficient restrictions has an asymptotic χ^2 (p-1) distribution. That is, the test of noncausality is consistent regardless of the cointegration rank r in the bivariate case.

The following tables report the causality test results for the two aforementioned cases. (i.e., for first differenced VAR and the cointegrated VAR). The VAR and VEC models are estimated with monthly observations from January 1980 to June 1995.

Table 11: Granger Causality in the stationary VAR model. (r = 0)

Sample 1980:01 - 1995:06		
Lags = 5 **H_0**	F - Statistic	P-value
Δr^L does not Granger Cause Δr^S	2.38**	0.04
Δr^S does not Granger Cause Δr^L	1.19	0.32

Note: The lag length test selects p = 5. The critical values have χ^2 distribution.
** significant at 5 % level.

Table 12 : Granger Causality tests in the cointegrated VAR. (r = 1)

Sample 1980:01 - 1995:06		
Lags = 6 **H_0**	F - Statistic	P-value
r^L does not Granger Cause r^S	2.56**	0.021
r^S does not Granger Cause r^L	1.82*	0.099

Note: The lag selection test applied, assuming a maximum lag of 10, in unrestricted VAR models in levels suggests p = 6. *, ** significant at 10% and 5% level.

The test results do not support the hypothesis that the short term rate Granger causes the long term rate. Rather, long term rate appears to Granger cause short term rate with a possible feedback, as the short term rate is significant only at 10 % level. Therefore the causality tests give the same results whether we specify the model as a stationary VAR or cointegrated VEC model. This is consistent with the evidence presented by Lütkepohl and Reimers (1992) using the US term structure data.

We now examine the causality between the spread and short term rate. Since the spread is already found to be stationary while the short term rate contains a unit root, the appropriate procedure is to difference the short term rate and then to perform the causality test. The test result from the stationary VAR model indicates that the spread Granger causes the short term rate, as presented in below.

Table 13: Granger Causality between Spread and Short end.

Sample 1980:01 - 1995:06		
Lags = 7 **H_0**	F - Statistic	P-value
SPR does not Granger Cause Δr^S	2.71**	0.01
Δr^S does not Granger Cause SPR	1.15	0.33

Note: Lag length test indicates VAR order of 7. ** indicates significance at 5 % level.

The causality test cannot reject the hypothesis that the short term rate does not Granger cause the yield spread whereas the hypothesis that the yield spread does not Granger cause the short term interest rate is rejected at the 5% level. Therefore, the proposition that movements in the spread are due to movements at the short end of the term structure is not well supported by data. This suggests that the predictive power of spread is not mainly due to movements in the short term interest rate. From the above set of causality tests, we find that the long term rate and the spread, respectively, Granger cause the short term rate. While there is evidence that short term rate also Granger causes long term rate, the short term rate does not Granger cause the spread. These results do not support the argument that the movement of the short term rate is the source of the predictive power of the spread.

IV. Concluding Remarks

This project report has examined the hypothesis that the spread between long term and short term rates predicts real output growth in Australia. It has also investigated the claim that the predictive power of the yield spread is due to the effect of monetary policy on short term interest rates.

This report presented a theoretical model which shows that the yield spread is related to the expected growth of future output. In this model, bonds are priced in the context of a simple stochastic growth model with production.

On the empirical side, this report provided evidence that the yield spread predicts future real output growth, which is consistent with the theoretical model. In all the single equation estimations, both the yield spread variables were significant in explaining real GDP growth over horizons from one to three years.

Moreover, it was shown from the variance decompositions that the yield spread outperforms other financial variables such as the money base, credit and the index of leading indicators, as a predictor of future output growth. The assertion that the yield spread predicts future output growth as a consequence of monetary policy operating on short term interest rates, as argued by previous researchers, was investigated using VAR models and causality tests. The evidence does not support this assertion. The Granger causality tests indicate that the short term rate fails to Granger cause the spread while there is a two way causality between short and long term rates.

It should be noted that our results are for a sample period which cover the deregulation of the Australian financial system. Hence it remains to be seen whether the predictive content of the yield spread will change as the financial system evolves further.

To summarise, the term structure of interest rates or the yield spread has predictive power for future real activity in Australia, and hence, it should be incorporated in the construction of the index of leading indicators. This implies that the yield spread can provide useful information about future economic activity to policy makers which they can incorporate into the formulation of current monetary policy.

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Appendix 1: Data

All data are obtained from the DX database and all variables except interest rates are seasonally adjusted. All data are available from the period January 1970 (1970:1 for GDP), except for BB180, which is available from June 1972.

1. Interest Rates.

The following monthly interest rate series are used:

- 10 year Treasury bond yields (TB10Y)

- 13 weeks Treasury note yields (TN13)

- 180 days bank accepted bill yields (BB180)

2. Other predictive variables.

- The composite index of leading indicators (LEAD)

- Monetary aggregates: Money base (MB) and M1

- Loans and credit to private sector by financial institutions (CREDIT)

All the variables listed above are monthly series. For quarterly series, we take the average of three monthly data for the quarter.

3. GDP growth.

- Quarterly GDP (expenditure based): at constant 89/90 prices

Appendix 2: Unit root and Lag length Tests

Table I: ADF Unit-root Test results.

Series	Sample Period	p	t-statistics
Δr (TN13)	80:1 - 95:2	1	-4.99*
Δr (BB180)	80:1 - 95:2	5	-3.98*
Δr (TB10Y)	80:1 - 95:2	2	-3.81*
GDP annual Growth	80:1 - 95:2	4	-2.81*

Note: * denotes rejection of the null of a unit root using 10% asymptotic critical values.

Table II: Lag Selection Tests : Bivariate VARs

[GDP growth, Spread2]

	GDP annual growth		**GDP quarterly growth**	
lag (p)	LR	AIC	LR	AIC
7	3.81	0.71	2.95	-9.15
6	10.44	-0.20	9.32	-10.07
5	10.41	0.04	11.25	-9.86
4	7.15	0.27	4.98	-9.61
3	6.38	0.42	5.90	-9.51
2	7.64	0.54	25.92*	-9.40

Note: Lag chosen on the basis of LR test.

Table III : Lag Selection Tests : Trivariate VARs :

[GDP growth, Spread2 and <u>each</u> of LEAD, CREDIT and MB in turn]

Variables	ΔLEAD		ΔCredit		ΔMB	
Lag	LR	AIC	LR	AIC	LR	AIC
7	6.9	-9.09	11.7	-8.16	13.5	-8.80
6	14.7	-9.88	14.9	-8.79	16.1	-9.38
5	21.1	-9.47	17.9	-8.38	20.6	-8.93
4	18.2	-8.94	11.8	-7.93	40.1	-8.41
3	10.4	-9.53	14.4	-8.66	11.8	-8.50
2	19.1	-9.31	13.3	-8.36	14.7	-8.26

Table IV: Lag Length Tests : Trivariate VARs :

[GDP growth, Spread2, <u>each</u> of BB180 and TB10Y in turn]

Δr	ΔBB180		ΔTB10Y	
Lag	LR	AIC	LR	AIC
7	5.8	-0.18	12.4	-0.35
6	19.9	-1.0	16.9	-0.96
5	20.5	-0.45	26.1	-0.50
4	9.8	0.06	5.5	0.16
3	14.4	-0.71	13.2	-0.72
2	9.2	-0.41	11.7	-0.44

Table V: Lag Length Tests : Trivariate VARs :

[GDP growth, BB180, TB10Y]

Lag	LR	AIC
7	9.9	-0.34
6	20.3	-1.03
5	22.1	-0.46
4	10.6	0.09
3	11.7	-0.67
2	10.3	-0.42

Table VI : Selecting Lag lengths: Bivariate VAR

[ΔTB10Y, ΔBB180]

Lag	LR	AIC
8*	12.5	-2.53
7	6.2	-2.45
6	6.5	-2.41
5*	8.9	-2.37
4	3.1	-2.32
3	5.9	-2.30
2	0.3	-2.27

Table VII : Selecting Lag lengths: Bivariate VAR

[TB10Y− BB180, ΔBB180]

Lag	LR	AIC
8	3.6	-2.49
7*	10.0	-2.47
6	9.4	-2.41
5	2.6	-2.35
4	2.9	-2.34
3	4.6	-2.32
2	2.1	-2.30