THE TERM STRUCTURE OF INTEREST RATES, REAL ACTIVITY AND INFLATION

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ABSTRACT

This paper examines, both theoretically and empirically, the relationship between the slope of the yield curve and future changes in real activity and inflation. It argues that the existence of sticky prices allows current and expected future monetary shocks to affect the slope of both the *nominal* and the *real* yield curves. Changes in real money balances brought about by monetary policy cause a strong liquidity effect at the short end of the yield curve. This results in changes in real output in the short/medium term which eventually get translated into changes in prices.

The empirical results show that the spread between the 10 year Treasury bond and the 180 day bank bill predict the rate of change, over the subsequent one to two years, of a number of measures of real activity. Over both longer and shorter forecast horizons the spread has little predictive power. On the inflation front, the 10 year-180 day yield spread provides significant information about changes in inflation over the medium term (that is between one year and two and three years). Yield spreads between shorter dated securities are found to contain little information concerning future changes in inflation. This supports the view that at the shorter end of the yield curve changes in nominal rates often reflect changes in real rates.

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1. INTRODUCTION.

In the last few years the slope of the yield curve has received considerable attention for its ability to forecast both real and nominal macroeconomic variables. Mishkin (1990a, 1990b, 1991) and Jorion and Mishkin (1991) have demonstrated that the slope of the curve beyond one year is a relatively good predictor of the change in the rate of inflation. On the real side, Stock and Watson (1989), Bernanke (1990) and Bernanke and Blinder (1990) have shown, using a vector autoregression approach, that the spread between the yields on long and short bonds helps predict future economic activity. Similarly, Estrella and Hardouvelis (1991) show that the slope of the yield curve helps predict the change in real economic activity over horizons out to twelve quarters. This paper examines the ability of the slope of the yield curve to predict changes in real activity and inflation in Australia.

If prices adjust instantaneously to monetary shocks, monetary policy should have no effect on real outcomes including real interest rates. Changes in the slope of the nominal yield curve should simply reflect changes in the expected future path of inflation. If prices are sticky, however, monetary policy can affect the slope of the nominal yield curve independently of the inflation channel. This results in changes in real interest rates and real activity. Section 2 of the paper presents a simple model which formalises this notion. It introduces a long term interest rate into a Keynesian model with long-run monetary neutrality. Expansionary monetary policy causes the slope of the yield curve to steepen as the liquidity effect of higher real money balances lowers short term interest rates. This steepening of the yield curve is accompanied by lower real rates and increases in activity in the future. In Section 3 of the paper the ability of the yield curve to forecast changes in real activity is examined empirically.

Consistent with the international evidence it is found that since 1982 the slope of the yield curve predicts a wide range of real variables measuring economic activity. In contrast to the index of leading indicators, which is useful in predicting economic activity over only the subsequent six months, the yield curve's predictive ability reaches its maximum at about the 18 months horizon. At horizons longer than 30 months it has little predictive power. The gradual increase in predictive power over time, followed by a decline, is consistent with the monetary explanation of the predictive power of the yield curve. The results also show that prior to 1982 the yield curve contained essentially no information about the future path of economic activity. The difference in the results between the two periods is attributed to financial liberalisation and changes in the method by which interest rates are determined.

Following the examination of the power of slope of the yield curve to predict changes in real output, Section 4 examines the yield curve's ability to predict changes in inflation. It is found that the yield curve provides no information about future changes in inflation in the short term (less than six months) but does provide significant information for forecasting changes in inflation over longer horizons. Regardless of the horizon, the spread between the 10 year bond rate and the 180 bank bill outperforms other yield spreads in forecasting future changes in inflation. Finally, Section 5 summarises the principal findings of the paper. It is argued that the results from both the activity and inflation regressions are consistent with the hypothesis that monetary policy temporarily affects the real yield spread, and thus activity, in the short run, but that in the long run its effect is on inflation.

2. THEORY.

Standard Keynesian models typically have a single interest-bearing financial asset. The interest rate on this asset affects both the demand for money and investment. In order to examine the relationship between the yield curve and future changes in output a second asset must be introduced. This is done below in the context of a model in the IS-LM tradition with output being demand determined and prices adjusting slowly to their equilibrium value. It is similar in spirit to the model developed by Blanchard (1981); however it differs in that it allows investment to depend upon the real interest rate and does not consider the return on equities.

Investors are assumed to be able to invest in both a long and a short bond. The short bond is an instantaneous asset which cannot be traded across time while the long bond can be traded across time. With investors assumed to be risk neutral and having rational expectations, the relationship between yields on the short and long bonds is determined by the expectations theory of the term structure of interest rates. That is, the expected returns on short and long bonds are identical.

For simplicity assume the long bond is a consol paying interest (C) each instant with its price V = C/R, where R is the current market interest rate on the consol. The return from investing in the long bond consists of two parts; the interest payment (C) and the expected capital gain/loss ($\dot{V}$). Given risk neutrality, the return on the long bond must equal the real return on the short term bond (I). That is,

$$\begin{aligned} I &= \frac{C}{V} + \frac{\dot{V}}{V} \\ &= R - \frac{\dot{R}}{R} \quad \Rightarrow \quad \dot{R} = R\,(R - I) \end{aligned} \tag{1}$$

This relationship between the interest rates on long and short bonds should hold in both nominal and real terms. As is standard, the nominal short rate (i) is equal to the real rate plus the forecast of the rate of inflation where the forecast is the rational expectations forecast ($\dot{P}^{e}$):

$$i = I + \dot{P}^e \tag{2}$$

Goods market equilibrium occurs when aggregate demand equals aggregate supply. Aggregate demand is assumed to be a function of current income (Y) and the long real interest rate and is given by:

$$d = aY - bR \tag{3}$$

Output is assumed to adjust to demand over time according to the following[1]:

$$\begin{aligned} \dot{Y} &= \sigma\ (d-Y) \\ &= -\ \alpha Y - \beta R \end{aligned} \tag{4}$$

Following the standard convention, the demand for real money balances is a function of current income and the current nominal short term interest rate:

$$i = kY - h(M-P) \tag{5}$$

Money is assumed to be exogenous and under the complete control of the monetary authorities.

In this model, if prices are completely flexible, changes in the money stock have no real effect on the economy as prices adjust instantaneously keeping real balances constant. However, it is assumed that while, in the long run, prices do adjust one for one with changes in the money stock, they do so only slowly. This allows monetary policy to have real effects on output in the short run. The following simple price adjustment mechanism is assumed:

$$\dot{P} = \theta(\bar{P}-P) \qquad \theta \geq 0 \tag{6}$$

where $\bar{P}$ is the price level associated with equilibrium output ($\bar{Y}$) and the level of nominal money ($\bar{M}$).

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[1] This equation can be justified by arguing that spending adjusts slowly to its underlying determinants or alternatively that spending equals its underlying determinants but that firms respond to changes in demand by drawing down inventories and then increasing output.

First consider the extreme case in which θ equals zero (i.e. prices are fixed). In this case the system is defined by equations (1), (4) and (5). To find the steady state values of output ($\bar{Y}$) and the long bond rate ($\bar{R}$) set $\dot{Y}$ and $\dot{R}$ to zero and solve, obtaining:

$$\bar{Y} = \frac{\beta}{\alpha+\beta k} h\ (M-P) \tag{7}$$

$$\bar{R} = \bar{I} = \frac{-\alpha}{\alpha+\beta k} h (M-P) \tag{8}$$

As in the basic fixed price IS-LM model, monetary expansions increase output and reduce interest rates.

The dynamics of the system are derived in Appendix 2 and are summarised in Figure 1 which presents the phase diagram. Given the assumptions made about the signs of the parameters, the system exhibits a "saddle-path" shown by SS. Consider the effects of a monetary expansion. The $\dot{R}$ locus is shifted to the right increasing steady state output from $\bar{Y}_0$ to $\bar{Y}_1$ and reducing both the short and long steady state interest rates from $\bar{R}_0$ to $\bar{R}_1$. The mechanism is standard. With fixed prices, higher real money balances force down the interest rate which in turn increases aggregate demand.

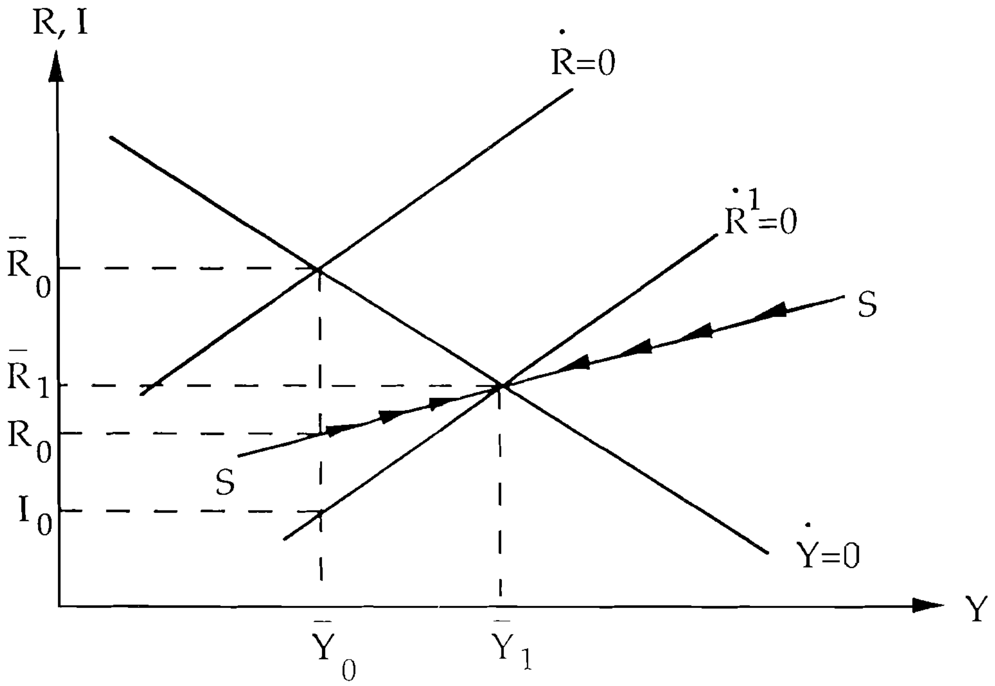
During the adjustment phase the equations of motion for R and Y are given by:

$$Y - \bar{Y}_1 = \frac{-\beta h}{\alpha+\beta k} e^{\psi t} dm \tag{9}$$

$$R - \bar{R}_1 = \frac{h(\alpha+\psi)}{\alpha+\beta k} e^{\psi t} dm \tag{10}$$

where ψ is speed of adjustment given by the negative eigen value. At any point in time the values of Y and R are read off the saddle path while the short rate is read off the $\dot{R}^1=0$ locus. How then does the term structure of interest rates react to the monetary expansion? The short interest rate falls

Figure 1: Phase Diagram: Adjustment to Monetary Expansion (Fixed Price Model)



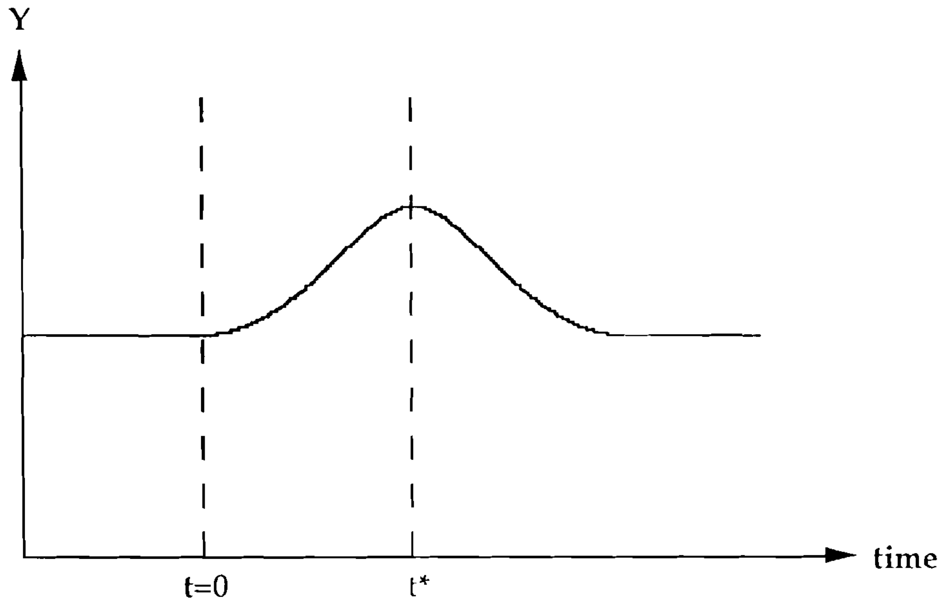
immediately (to I_0) due to the liquidity effect. Rational investors realise that in the medium/long run output will rise, increasing the demand for money. The short term interest rate must thus be expected to rise over time. As a consequence the long interest rate does not fall by as much as the short rate. In fact it falls to R_0 and then increases along the saddle-path towards the new equilibrium. Thus the yield curve initially becomes upward sloping in response to the monetary expansion and given rational expectations this upward slope of the curve is positively correlated with future increases in output. The speed of adjustment to the steady state is faster the larger are α, β and k.

Now consider the case in which prices adjust slowly. In the long run, real money balances do not change in response to an increase in the money supply. Consequently, steady state real interest rates and output do not change in response to the monetary expansion. However, as prices are sticky there are short run effects. The adjustment paths towards the new steady state are derived in Appendix 2 and are given by equations (A18), (A19) and (A20). The equations of motion for $Y-\bar{Y}_1$ and $R-\bar{R}_1$ are functions of two declining exponentials. This implies that there is at most a single extreme point in their adjustment paths. Output is thus above its equilibrium level at all points through the adjustment phase and does not cycle around the new equilibrium. The long interest rate after falling initially, due to the liquidity effect, increases and overshoots its new equilibrium level. Declining output and the attendant fall in money demand and short rates then causes the long bond rate to fall. Stylised adjustments paths for output and the interest rates are given in Figures 2a and 2b. Once again a positively sloped yield curve predicts future increases in output. However, in contrast to the fixed price model, the increases in output are not permanent.

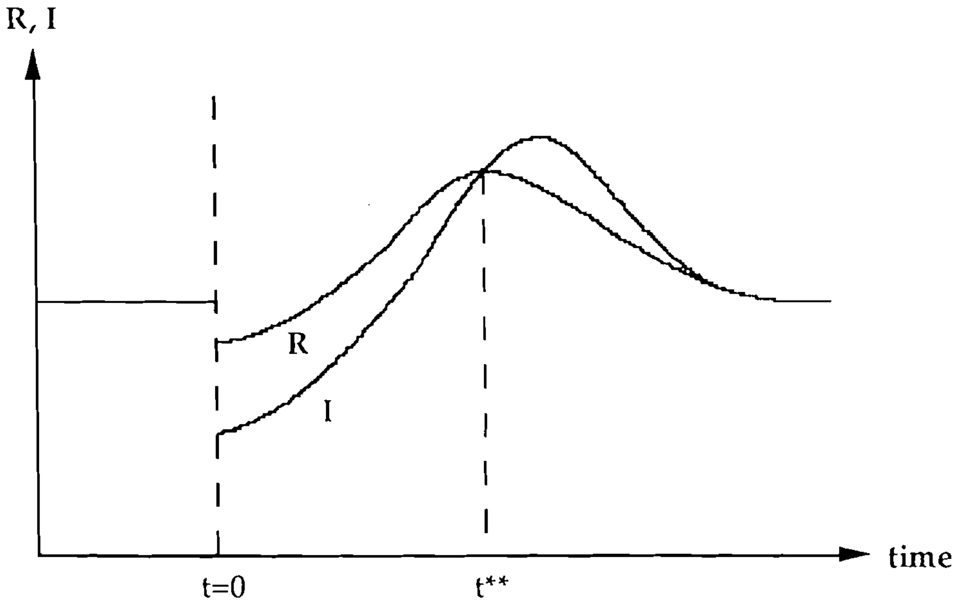
The above model focuses on *shifts* in the money supply. One frequent explanation for the shape of the yield curve is that in the future the *rate of growth* in the money supply is expected to change, altering expected future inflation. Such rate of growth shocks are analytically difficult to deal with in this type of model. Nevertheless, the general structure can be usefully employed to think about the effect of higher inflation expected some time in the future. It is clear that changes in the future expected rate of inflation

Figure 2: Adjustment Paths in Response to Monetary Shock (Flexible Price Model)

(a) Output



(b) Interest Rates



should not affect the current short term interest rate as this rate is determined by instantaneous equilibrium in the money market. In contrast, the long bond is a forward looking asset whose price cannot jump when inflation actually moves to its new higher *expected* level. Thus, the price of the long bond must fall at the time that agents first expect higher inflation in the future. Following this fall, the yield on the long bond is higher than that on the short bond. The arbitrage condition requires that the price of the long bond must be expected to fall during the period preceding the future increase in inflation. As a result, higher expected future inflation must cause an initial jump in the interest rate on the long bond followed by further increases. With the short rate fixed, at least for the interim period, the yield curve steepens. With the assumption of some stickiness in prices, this upward slope will once again predict increases in output in the medium term. The issue of to what extent nominal interest rates reflect inflationary expectations is taken up in more detail in Section 4.

The above discussion attributes the ability of the slope of the yield curve to predict real activity to monetary policy. While real business cycle theory would generally eschew such an interpretation, it has difficulty explaining the forecasting success of the yield curve. Notwithstanding this difficulty, it is possible, by moving outside the strict real business cycle framework, to explain the forecasting ability with real shocks. In the above model the long term real interest rate and its time path are tied down by an arbitrage condition. Suppose instead that the long real interest rate is tied down by the marginal productivity of capital and that the short interest rate is determined in the money market. A permanent increase in the marginal productivity of capital would increase the long bond rate. Assuming that output increases only slowly in response to the productivity improvement, the demand for money increases only slowly. This gradually forces up the short term interest rate. In this world the initial increase in the yield spread correctly predicts future increases in output. The predictive power of the yield curve is thus not necessarily inconsistent with a real side explanation[2].

This real side explanation suggests that a positively sloped yield curve predicts higher output at all future horizons. This is in contrast to the monetary model with flexible prices (in the long run) which suggests that the slope of the yield curve should have little predictive ability for changes in output between today and some distant point in time. The empirical evidence presented below and in Estrella and Hardouvelis (1991) suggests that the yield curve has no predictive power for cumulative output changes over horizons longer than three years. This supports the hypothesis that the predictive ability of the yield curves works primarily through the monetary channel.

3. THE YIELD CURVE AND REAL ACTIVITY.

3.1 Estimation Procedure and Data.

To examine the ability of the slope of the yield curve to predict real activity, both monthly and quarterly data on a number of real activity variables are used. The quarterly data are taken from the Australian National Accounts and include data on GDP, aggregate consumption and aggregate investment. All data are in constant dollars and have been seasonally adjusted. Monthly indicators of real activity include the number of car registrations, the number of dwelling approvals and the Melbourne Institute Index of Industrial Production. This monthly data, as well as all interest rate data, are taken from the Reserve Bank of Australia Bulletin. The sample period runs from September 1972 to June 1991. Further details of the data are available in Appendix 1.

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[2] The real business cycle models, in the tradition of Kydland and Prescott (1988), have only a single interest rate. This rate is determined by the current and expected future marginal productivity of capital. The model is capable of generating predictions concerning the correlation between interest rates and output changes but does not address the question of the slope of the yield curve.

The approach of Estrella and Hardouvelis (1991) forms the basis of the forecasting tests. Their technique involves regressing future changes in real activity on the current slope of the yield curve. Specifically, the following equation is estimated for various forecast horizons:

$$\left[\left(\frac{Y_{t+j}}{Y_t}\right)^{\frac{12}{j}} - 1\right] * 100 = \alpha + \beta(10\ \textit{year bond} - 180\ \textit{day bank bill})_t + \varepsilon_t \tag{11}$$

where Y_t is the value of the forecast variable at time t and j is the forecast horizon in terms of the number of months. The spread between the 10 year Treasury bond rate and the 180 day bank bill rate is used as the measure of the slope of the yield curve[3]. Various other spreads were also examined for their information content and selected results for GDP are reported in Appendix 3.

In all but the one period forecasting regressions, the sampling interval is longer than the forecast horizon. The overlapping observations induce a moving average process of order j-1 into the residuals making the estimated standard errors inconsistent. To make the standard errors robust with respect to both this induced serial correlation and to any remaining serial correlation the Newey-West (1988) estimator of the covariance matrix is used with the number of lags equal to j+2. This covariance estimator also makes the standard errors robust to conditional heteroskedasticity. The actual coefficient estimates are calculated by Ordinary Least Squares.

[3] It is assumed that the growth rates and the yield spreads are stationary. While unit root tests are of limited value when the sample period is as short as that used in this paper, these tests do support the stationarity assumption.

3.2 Results.

In July 1982 the authorities moved from a tap to a tender system for issuing government bonds[4]. Under the tap system the interest rate was set by the authorities who then supplied the government bonds demanded at that rate. Under the tender system, the government determined the supply and the interest rate was determined in the market. While both systems can theoretically generate the same outcome, interest rates under the tender system have tended to reflect market conditions and expectations more accurately than was the case under the tap system. Graph 1 shows the yield spread between the 10 year Treasury bond rate and the 180 day bill rate over the period of study. It shows that the period prior to the scrapping of the tap system was characterised by a much more stable spread than the more recent period. The one obvious exception is in 1974 when extremely tight credit conditions caused the absolute value of the spread to increase to over ten percent for a short period of time. It might well be expected that the movement from rates being set by the authorities to being set directly in the market would alter the relationship between the yield curve and future output changes.

Given the change in operating procedures, the sample period is split into two periods. The first running from September 1972 to June 1982 and the second from September 1982 to June 1991. Tables 1 and 2 report the estimation results of equation (11) for the two periods using the quarterly National Accounts data.

The estimates for the latter period support the hypothesis that a positive slope of the yield curve implies faster growth in economic activity over the next one to two years. While the yield curve predicts changes in both consumption and investment, its predictive ability is higher for investment. The estimates suggest that a flat yield curve predicts growth in GDP over the next year of 4.2 percent. For every one percentage point steepening of the yield curve, the expected growth rate over the next twelve months increases by about 0.5 of a percentage point. The effect on investment is much more pronounced with

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[4] The tender system for Treasury notes was introduced in December 1979.

Graph 1: Yield Spread

10 - Year Bond - 180 Day Bank Bill

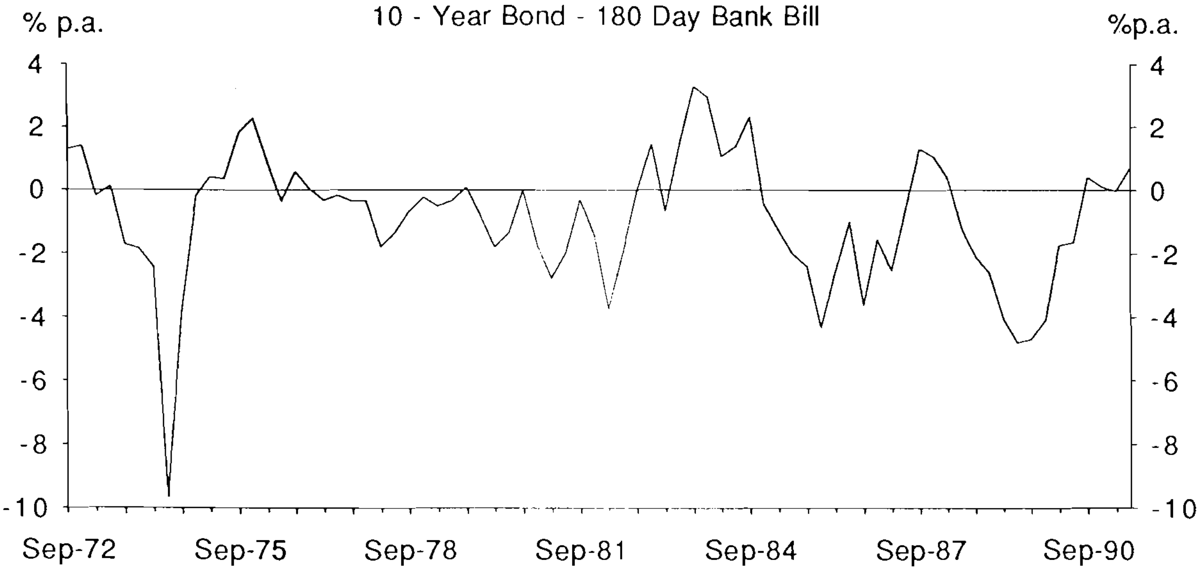

TABLE 1: THE YIELD CURVE AND FUTURE CHANGES IN REAL ACTIVITY (1972:3-1982:2)

$$\left[\left(\frac{Y_{t+j}}{Y_t}\right)^{\frac{12}{j}} - 1\right] * 100 = \alpha + \beta SPREAD_t + \varepsilon_t$$

	GDP			CONSUMPTION			INVESTMENT			
j	α	β	$\bar{R}^2$	α	β	$\bar{R}^2$	α	β	$\bar{R}^2$	Nobs
3	3.23 (0.71)	0.49 (0.31)	0.01	3.73 (0.68)	0.17 (0.25)	-0.02	4.76 (1.97)	1.83 (0.72)	0.03	40
6	2.87 (0.57)	0.34 (0.27)	0.02	3.66 (0.56)	0.18 (0.16)	-0.01	4.36 (1.66)	2.11 (0.61)	0.13	40
9	2.72 (0.46)	0.34 (0.24)	0.05	3.52 (0.46)	0.08 (0.18)	-0.02	3.38 (1.60)	1.59 (0.51)	0.09	40
12	2.58 (0.44)	0.26 (0.24)	0.03	3.34 (0.41)	-0.02 (0.16)	-0.03	2.73 (1.56)	1.23 (0.48)	0.05	40
15	2.60 (0.35)	0.30 (0.16)	0.08	3.30 (0.35)	0.00 (0.14)	-0.03	2.46 (1.48)	1.05 (0.48)	0.05	40
18	2.51 (0.32)	0.21 (0.09)	0.04	3.29 (0.33)	0.04 (0.11)	-0.02	2.02 (1.47)	0.76 (0.37)	0.03	40
21	2.43 (0.28)	0.07 (0.09)	-0.01	3.20 (0.29)	-0.01 (0.10)	-0.03	1.70 (1.44)	0.42 (0.39)	-0.01	40
24	2.45 (0.26)	0.03 (0.10)	-0.02	3.17 (0.28)	-0.03 (0.09)	-0.02	1.64 (1.37)	0.25 (0.36)	-0.02	40
36	2.59 (0.15)	0.03 (0.03)	-0.02	3.20 (0.21)	0.03 (0.06)	-0.02	2.33 (0.79)	0.31 (0.13)	0.03	40

NOTES.
1. The forecast horizon (j) is in terms of months.
2. Standard errors that are robust to serial correlation and conditional heteroskedasticity are reported in parentheses () below the coefficient estimates.
3. SPREAD is the spread between the yield on the 10 year Treasury bond and the 180 day bank bill.

TABLE 2: THE YIELD CURVE AND FUTURE CHANGES IN REAL ACTIVITY (1982:3-1991:2)

$$\left[\left(\frac{Y_{t+j}}{Y_t}\right)^{\frac{12}{j}} - 1\right] * 100 = \alpha + \beta SPREAD_t + \varepsilon_t$$

	GDP			CONSUMPTION			INVESTMENT			
j	α	β	$\bar{R}^2$	α	β	$\bar{R}^2$	α	β	$\bar{R}^2$	Nobs
3	3.47 (1.09)	0.26 (0.38)	-0.02	3.27 (0.44)	0.20 (0.23)	-0.02	4.77 (3.74)	1.51 (1.14)	0.01	35
6	3.68 (0.88)	0.31 (0.28)	0.01	3.16 (0.41)	0.09 (0.15)	-0.02	5.44 (3.38)	2.09 (0.81)	0.09	34
9	3.94 (0.67)	0.44 (0.21)	0.08	3.14 (0.39)	0.12 (0.15)	-0.01	6.38 (2.71)	2.40 (0.51)	0.20	33
12	4.20 (0.42)	0.54 (0.16)	0.21	3.33 (0.26)	0.21 (0.13)	0.08	7.20 (2.13)	2.63 (0.54)	0.35	32
15	4.28 (0.29)	0.55 (0.14)	0.34	3.43 (0.18)	0.28 (0.10)	0.25	7.38 (1.98)	2.63 (0.60)	0.43	31
18	4.34 (0.23)	0.56 (0.15)	0.51	3.48 (0.16)	0.29 (0.06)	0.37	7.46 (1.86)	2.49 (0.71)	0.48	30
21	4.21 (0.22)	0.49 (0.16)	0.46	3.46 (0.16)	0.30 (0.04)	0.46	6.97 (1.60)	2.06 (0.80)	0.36	29
24	4.09 (0.23)	0.41 (0.16)	0.36	3.41 (0.15)	0.26 (0.04)	0.40	6.46 (1.30)	1.52 (0.82)	0.21	28
36	3.78 (0.34)	0.05 (0.09)	-0.03	3.18 (0.08)	0.08 (0.04)	0.05	5.42 (0.71)	-0.42 (0.30)	0.02	24

NOTES.
See Table 1.

a one percentage point steepening of the yield curve increasing investment growth over the next year by 2.6 percentage points.

Consistent with the theory presented above, the predictive power of the yield curve disappears in the long run. The yield spread has no predictive power for GDP, consumption or investment growth at a forecasting horizon of 12 quarters. It also has little predictive power in forecasting economic activity in the initial 6 months. The yield curve does best in forecasting economic activity in the 12 to 18 months horizons.

An examination of Table 1 shows that over the period from September 1972 to June 1982 the yield curve had little predictive ability concerning the future path of economic activity. What little information content there was, once again was more useful for predicting investment than consumption. In fact the yield curve provided absolutely no information concerning the future path of consumption; the highest $\bar{R}^2$ for any of the consumption forecasting equations is -0.01. The comparable figure for the latter period is 0.46.

As mentioned above, the improved ability of the yield curve to predict economic activity can be attributed to changes in the operation and regulation of financial markets. Under the tap arrangements, the fixed rates were, in part, a reflection of market pressures. However, the relative constancy of the yield spread over the 1970's suggests that this reflection was less than complete. The increased ability of the yield curve to reflect monetary policy actions and expectations has played an important role in increasing the information content of the yield curve.

More general financial liberalisation has also played a role. The reforms which took place in the financial system in the early 1980's have made access to finance for both firms and households considerably easier. This has increased the potential for intertemporal substitution in both consumption and investment. One outcome of this liberalisation is that activity may now be more sensitive to interest rate changes. When interest rates are high, consumers delay consumption and conversely, when rates are low, consumers increase consumption. If the slope of the yield curve predominantly reflects current monetary policy, an upward sloping yield curve reflects relatively loose current or expected policy. Relatively low interest rates in turn induce consumers to substitute consumption and investment across time periods.

While the above results suggest that the slope of the yield curve is useful in predicting changes in real economic activity, it is also of interest to know whether or not it provides additional information over and above that provided by other indicators. The index of leading indicators should be a good summary statistic of information available to forecasters about the future course of the economy. Accordingly, the percentage change in the index over the previous quarter is included in the estimated forecasting equation. Given the previous results, only data for the period in which interest rates have been directly market determined have been used. The results are reported in Table 3.

As expected, the index of leading indicators is most useful in predicting economic activity in the very short run. In the GDP forecasting equation the index has a statistically significant coefficient for only the first three quarters, while in the investment equation it is only significant in the first quarter. In contrast to the index of leading indicators, the yield spread has little information content in the first few quarters but by four quarters shows considerable forecasting ability. The time profile of the forecasting ability of the yield curve is similar to that reported in Table 1.

We now turn to an examination of the monthly data. Table 4 presents the estimation results for forecasting equations of various horizons for the index of industrial production, dwelling approvals, and car registration. As in the above regressions, the dependent variable is the annualised percentage change in the relevant variable. Once again the slope of the yield curve is useful in forecasting the real variables although the results differ across the three variables. As was the case for GDP, the yield spread's ability to predict future changes in the production index increases through time out to about 18 months and then gradually declines. The yield curve is, however, less useful in predicting the changes in the production index than it is in predicting GDP changes. The results for car registrations exhibit a similar time profile to that of GDP and production although the usefulness of the yield curve in predicting changes in registrations is considerably less than is the case for the

TABLE 3: THE YIELD CURVE AND FUTURE CHANGES IN REAL ACTIVITY (1982:3-1991:2)

$$\left[\left(\frac{Y_{t+j}}{Y_t}\right)^{\frac{12}{j}} - 1\right] * 100 = \alpha + \beta_1 LEAD_t + \beta_2 SPREAD_t + \varepsilon_t$$

	GDP				CONSUMPTION				INVESTMENT			
j	α	β_1	β_2	$\bar{R}^2$	α	β_1	β_2	$\bar{R}^2$	α	β_1	β_2	$\bar{R}^2$
3	2.64	0.23	0.11	0.10	3.18	0.02	0.19	-0.04	2.39	0.65	1.09	0.08
	(1.08)	(0.07)	(0.43)		(0.45)	(0.06)	(0.24)		(3.80)	(0.21)	(1.12)	
6	3.04	0.17	0.20	0.14	3.09	0.02	0.08	-0.05	3.53	0.50	1.75	0.16
	(1.03)	(0.07)	(0.35)		(0.39)	(0.04)	(0.16)		(3.53)	(0.27)	(0.89)	
9	3.31	0.15	0.33	0.22	2.94	0.05	0.09	0.00	4.92	0.35	2.14	0.24
	(0.80)	(0.07)	(0.26)		(0.42)	(0.03)	(0.16)		(2.86)	(0.28)	(0.61)	
12	3.73	0.10	0.45	0.30	3.08	0.06	0.17	0.15	6.22	0.22	2.45	0.36
	(0.55)	(0.06)	(0.17)		(0.29)	(0.02)	(0.13)		(2.23)	(0.21)	(0.51)	
15	4.00	0.06	0.51	0.37	3.25	0.04	0.25	0.28	6.25	0.24	2.44	0.46
	(0.34)	(0.05)	(0.12)		(0.20)	(0.01)	(0.10)		(1.90)	(0.18)	(0.52)	
18	4.23	0.02	0.54	0.51	3.45	0.01	0.29	0.35	6.59	0.18	2.36	0.49
	(0.22)	(0.04)	(0.13)		(0.14)	(0.01)	(0.06)		(1.65)	(0.15)	(0.62)	
21	4.19	0.00	0.49	0.44	3.47	0.00	0.30	0.44	6.52	0.09	2.02	0.34
	(0.23)	(0.03)	(0.15)		(0.14)	(0.01)	(0.05)		(1.51)	(0.13)	(0.77)	
24	4.04	0.01	0.40	0.34	3.45	-0.01	0.26	0.38	6.28	0.03	1.51	0.18
	(0.24)	(0.03)	(0.16)		(0.10)	(0.01)	(0.04)		(1.28)	(0.12)	(0.81)	
36	3.81	-0.01	0.05	-0.08	3.17	0.00	0.08	0.00	5.92	-0.10	-0.39	0.03
	(0.31)	(0.01)	(0.09)		(0.08)	(0.01)	(0.04)		(0.60)	(0.03)	(0.24)	

NOTES.

1. The forecast horizon (j) is in terms of months.
2. Standard errors that are robust to serial correlation and conditional heteroskedasticity are reported in parentheses () below the coefficient estimates.
3. LEAD is the annualized percentage change in the Index of Leading Indicators over the previous quarter and SPREAD is the spread between the yield on the 10 year Treasury bond and the 180 day bank bill.

TABLE 4: THE YIELD CURVE AND FUTURE CHANGES IN REAL ACTIVITY (1982:9-1991:6)

$$\left[\left(\frac{Y_{t+j}}{Y_t}\right)^{\frac{12}{j}} - 1\right] * 100 = \alpha + \beta SPREAD_t + \varepsilon_t$$

	PRODUCTION INDEX			DWELLING APPROVALS			CAR REGISTRATIONS			
j	α	β	$\bar{R}^2$	α	β	$\bar{R}^2$	α	β	$\bar{R}^2$	Nobs
1	7.35 (2.08)	-1.22 (1.39)	-0.01	36.17 (7.48)	11.66 (2.67)	0.06	54.26 (18.95)	3.15 (3.94)	-0.01	105
3	3.51 (1.12)	0.59 (0.50)	0.00	15.88 (5.21)	8.50 (1.74)	0.25	6.63 (4.40)	1.88 (1.79)	0.00	103
6	3.71 (0.82)	0.79 (0.35)	0.06	12.31 (5.84)	7.34 (1.68)	0.33	3.82 (3.95)	2.73 (1.78)	0.06	100
9	3.77 (0.65)	0.90 (0.26)	0.15	10.54 (6.51)	6.37 (1.78)	0.29	3.71 (3.64)	2.84 (1.59)	0.11	97
12	3.89 (0.57)	0.93 (0.19)	0.27	8.67 (6.73)	5.12 (1.63)	0.22	4.35 (3.52)	3.11 (1.28)	0.16	94
18	3.67 (0.58)	0.74 (0.11)	0.34	4.10 (6.07)	2.22 (1.54)	0.05	3.98 (4.28)	2.77 (0.61)	0.20	88
24	3.31 (0.54)	0.52 (0.12)	0.19	0.83 (4.31)	-0.02 (1.98)	-0.01	2.13 (4.37)	1.63 (0.50)	0.07	82

NOTES.

1. The forecast horizon (j) is in terms of months.
2. Standard errors that are robust to serial correlation and conditional heteroskedasticity are reported in parentheses () below the coefficient estimates.
3. SPREAD is the spread between the yield on the 10 year Treasury bond and the 180 day bank bill.

other variables. In contrast to the other measures of activity changes in housing approvals over the one month horizon are predicted by the yield curve. The yield curve remains useful in predicting future cumulative changes in housing approvals for about 18 months and is most useful at the 6 month horizon.

4. THE YIELD CURVE AND CHANGES IN INFLATION.

4.1 The Mishkin Methodology.

The literature on the ability of the yield curve to predict changes in inflation typically begins with the standard Fisher equation:

$$E_t \pi_t^m = i_t^m - r_t^m \tag{12}$$

where E_t denotes the expectation at time t, π_t^m the inflation rate between time t and m, i_t^m the nominal m period interest rate and r_t^m the real m period interest rate.

The observed rate of inflation (π_t^m) equals the expected rate plus a forecast error:

$$\pi_t^m = E_t \pi_t^m + \varepsilon_t^m \tag{13}$$

Substituting (13) into (12) yields:

$$\pi_t^m = i_t^m - r_t^m + \varepsilon_t^m \tag{14}$$

To obtain a relationship between the slope of the yield curve and the change in the inflation rate the n period inflation rate is subtracted from (14) yielding:

$$\pi_t^m - \pi_t^n = (i_t^m - i_t^n) + (r_t^m - r_t^n) + (\varepsilon_t^m - \varepsilon_t^n) \tag{15}$$

Mishkin (1990) assumes that the slope of the real yield curve is constant through time so that r_t^m-r_t^n is a constant. Given the additional assumption of rational expectations, the forecast errors cannot be forecasted given information at time t. The dual assumptions of a constant real term structure and rational expectations underpin the following equation which forms the basis of Mishkin's tests:

$$\pi_t^m - \pi_t^n = \alpha + \beta(i_t^m - i_t^n) + v_t^{m,n} \tag{16}$$

If prices are fully flexible and instantaneously adjust to changes in monetary policy, the assumption of a constant real rate spread is appropriate and β should equal one. The model presented in Section 2, however, shows that when such price flexibility does not exist, the slope of the real yield curve does change over time and the results in Section 3 suggest that these changes have real effects on the economy.

As Frankel and Lown (1991) argue, the assumption of a constant slope to the real yield curve is overly restrictive. Indeed, due to the existence of sticky prices, long term interest rates are more likely to accurately reflect inflationary expectations than short term rates. They argue that in an inflation change equation such as (15) the slope of the entire yield curve is likely to outperform the spread between securities matching the period for which the change in inflation is being forecast. They develop a technique to obtain a summary measure of the slope of the yield curve using yields on securities of all maturities. Their technique is difficult to apply to Australian data due to the lack of data on yields on securities over a wide range of maturities. However, failure of the real interest rate spread to be a constant allows the possibility of superior forecasts of future changes in the inflation rate being generated by using a long-short spread compared to those generated by securities which match the period over which the change in inflation is being forecast.

4.2 Estimation Procedure and Data.

In the following tables, results are reported for the "Mishkin regressions" (that is, those using interest rate maturities which match the period over which the change in inflation is being forecast as in (16)) as well as for the less restrictive regressions where the spread between the 10 year bond rate and the 180 day bank bill is used to predict inflation. Two sets of estimates are presented for the Mishkin regressions. The first (Table 5) are Ordinary Least Squares results where the standard errors have been corrected for serial correlation and heteroskedasticity using the same procedure outlined in the previous section. The second set of results (Table 6) are obtained using the Seemingly Unrelated Regression (SUR) technique. The forecast errors from the equation for the change in inflation over the period *m* to *n* should be correlated with those from the equation for the change in inflation over the period *i* to *n*. The SUR technique uses the extra information contained in these correlations to obtain more efficient estimates.

The SUR standard errors have also been corrected to account the serial correlation induced by the overlapping observations[5]. SUR results are not reported for the equations estimated using the 10 year-180 day spread because they are identical to the OLS results as each equation has the same regressor. Other long-short spreads were examined, however the 10 year-180 day spread consistently proved superior. Mishkin regressions cannot be conducted for all horizons due to the lack of appropriate interest rates at certain maturities. The sample period runs from September 1982 to June 1991. This covers the period over which all government securities were issued by tender.

To estimate equation (16) as written, the price level needs to be observed at times *t*, *m* and *n*. However, available price indices are for prices averaged over a period of time and not prices at a particular point in time. For example the CPI for the June quarter represents average prices over the months of April, May and June and not the level of prices at the end of June. Accordingly, in estimating equation (16), the average of the three end-month

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[5] The variance-covariance matrix is given by:

$$V = \left[X'(\Sigma^{-1}\otimes I_T)X\right]^{-1} E\left[X'(\Sigma^{-1}\otimes I_T)\varepsilon\varepsilon'(\Sigma^{-1}\otimes I_T)X\right]\left[X'(\Sigma^{-1}\otimes I_T)X\right]^{-1}$$

where ε is the vector of residuals and Σ is the variance-covariance matrix of the contemporaneous residuals from the various equations. Each block of the second term (i.e. E[.]) is estimated using the Newey-West (1988) procedure. Under the assumptions of no conditional heteroskedasticity and no serial correlation $\varepsilon\varepsilon' = \Sigma\otimes I_T$ and thus the above expression for the variance collapses to the standard SUR variance-covariance matrix. In calculating the SUR estimates the same number of observations are used for all three forecast horizons.

interest rates for the quarter is used in place of the end quarter interest rate. π_t^m is calculated as follows:

$$\pi_t^m = \left[\left[\frac{CPI_m}{CPI_t} \right]^{\frac{12}{m}} - 1 \right] * 100 \qquad (17)$$

where CPI_t is the Consumer Price Index (adjusted for Medicare changes) for the quarter ending at time t. The CPI data are taken from the Reserve Bank of Australia Database.

4.3 Results.

The results in both Tables 5 and 6 suggest that the slope of the yield curve provides no information about the change in inflation between 3 and 6 months. This is the case for both the 6-3 month spread and the 10 year-180 day spread. The Mishkin equations also perform poorly in explaining the change in inflation between two years and three months. Using the OLS estimates it is not possible to reject the hypothesis that the coefficient on the yield spread equals zero. In contrast, the hypothesis can be rejected using the SUR estimates. In both cases, however, the standard errors are relatively large making it difficult to distinguish between economically quite different hypotheses.

The spread between the two year bond rate and the 180 day bill does provide some statistically significant information about the change in inflation between six months and two years. Using both the SUR and OLS estimates it is possible to reject the hypothesis that the coefficient equals zero while it is not possible to reject the hypothesis that the coefficient equals one. The standard errors are once again relatively large making precise inferences difficult.

A comparison of the first and second blocks of Table 5 shows that the 10 year-180 day spread outperforms the "Mishkin" equations. Once one moves beyond the shortest period, the coefficient on the 10 year-180 day spread is generally significantly different from zero and is estimated more precisely than the comparable coefficients from the Mishkin equations. This long-short spread does best in explaining the difference between the inflation rate over

TABLE 5: OLS ESTIMATES OF INFLATION CHANGE EQUATION

$\pi_t^m-\pi_t^n$	$\pi_t^m-\pi_t^n=\alpha+\beta(i_t^m-i_t^n)+\varepsilon_t$			$\pi_t^m-\pi_t^n=\alpha+\beta(i_t^{10\,y}-i_t^{180\,d})+\varepsilon_t$			Nobs
	α	β	$\bar{R}^2$	α	β	$\bar{R}^2$	
$\pi_t^6-\pi_t^3$	-0.18 (0.17)	0.27 (0.55)	-0.03	-0.20 (0.20)	-0.01 (0.07)	-0.03	34
$\pi_t^{24}-\pi_t^3$	0.03 (0.55)	0.46 (0.25)	0.04	-0.05 (0.49)	0.47 (0.14)	0.14	28
$\pi_t^{24}-\pi_t^6$	0.39 (0.43)	0.76 (0.23)	0.20	0.05 (0.37)	0.48 (0.11)	0.28	28
$\pi_t^{12}-\pi_t^6$				-0.15 (0.26)	0.08 (0.08)	-0.01	32
$\pi_t^{36}-\pi_t^6$				0.08 (0.26)	0.53 (0.11)	0.26	24
$\pi_t^{24}-\pi_t^{12}$				0.11 (0.21)	0.42 (0.05)	0.55	28
$\pi_t^{36}-\pi_t^{12}$				0.17 (0.14)	0.50 (0.11)	0.48	24

TABLE 6: SUR ESTIMATES OF INFLATION CHANGE EQUATION

$\pi_t^m-\pi_t^n$	$\pi_t^m-\pi_t^n=\alpha+\beta(i_t^m-i_t^n)+\varepsilon_t$	
	α	β
$\pi_t^6-\pi_t^3$	-0.09 (0.11)	0.60 (0.46)
$\pi_t^{24}-\pi_t^3$	0.20 (0.54)	0.65 (0.24)
$\pi_t^{24}-\pi_t^6$	0.32 (0.42)	0.69 (0.20)

NOTES.
1. $\pi_t^m-\pi_t^n$ is the difference in the inflation rate between time t and t+m and the inflation rate between time t and time n. $i_t^m-i_t^n$ is the difference between the m period nominal interest rate and the n period nominal interest rate at time t.
2. Standard errors that are robust to serial correlation and conditional heteroskedasticity are reported in parentheses () below the coefficient estimates.

the next year and the inflation rate over the next two years. In also does well in explaining the difference in the inflation rate over the next year and the inflation rate over the next three years. The results also suggest that the 10 year-180 spread provides little information about the change in inflation between six months and one year.

The failure of the slope of the yield curve to predict changes in inflation in the short run but its ability to predict changes in inflation in the medium run, is broadly consistent with international evidence[6]. It suggests that changes in the slope of the short end of the *nominal* yield curve reflect, to a substantial degree, changes in the slope of the *real* yield curve, largely brought about by the liquidity effects of monetary policy. The slope of the short end of the yield curve is thus a poor indicator of future changes in inflation.

If one accepts the expectations theory of the term structure, long term rates are not immune from the liquidity effects of monetary policy; however, the longer is the maturity the less important is the effect. Changes in long term interest rates thus more accurately reflect changes in inflationary expectations. The fact that the spread between the 10 year bond rate and the 180 day bill rate outperforms the spreads between the bill rate and both the two and five year rates supports this view. The greater accuracy of long term rates in measuring inflationary expectations allows the long-short spread to serve as an indicator of changes in inflation in the medium term. In the short run this spread is of limited use in predicting inflation because the bulk of the impact of expansionary monetary policy falls on output and not prices.

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[6] In a study of the US term structure for maturities less than 12 months, Mishkin (1990a) finds that for maturities of 6 months or less the term structure provides no information on inflation while for maturities of 9 to 12 months the term structure does provide some information. In a more comprehensive study of the "less than 12 months" term structure for a number of OECD countries, Mishkin (1991) finds little evidence that the term structure provides information about future changes in inflation. Examining the slope of the US yield curve between one and five years, Mishkin (1990b) concludes that at longer maturities the term structure can be used to assess inflationary expectations. Jorion and Mishkin (1991) provide similar evidence for a range of OECD countries. Browne and Manasse (1990), however, present conflicting evidence arguing that the inflation forecasting ability declines as the maturity lengthens.

5. SUMMARY AND CONCLUSIONS.

The evidence presented in this paper suggests that the slope of the nominal yield curve is useful in predicting the future path of economic activity and inflation. The results suggest that the steeper the upward slope of the yield curve, the faster will be the rate of growth of output over the next one and a half years. However, slower growth after about six quarters eventually dissipates the additional increase in output. The results suggest that the yield curve should not be used to forecast economic activity in the near term (that is, less than three quarters). Such forecasting is much better done by the index of leading indicators. The yield curve does, however, provide a good guide to the cumulative growth in activity over the following six quarters. On the inflation front, the slope of the yield curve provides little information on changes in inflation over periods less than one year but is useful in predicting the difference between the inflation rate over the next two years and the inflation rate over the next year.

If expected inflation affects only nominal interest rates and has no effect on real rates then the slope of the nominal yield curve should provide no information about the path of real activity but should help predict the change in inflation. The fact that the slope of the nominal yield curve does help predict activity suggests that the slope of the real yield curve is not constant. Indeed, the fact that, in the inflation change equations, the long-short spread provides more information than the slope of the yield curve over shorter maturity differences also suggest that the real yield spread is not constant.

Taken together, the results on activity and inflation are consistent with monetary policy having effects on real interest rates through price stickiness. Long term interest rates more accurately reflect expected inflation than do short term rates which are heavily influenced by the liquidity effect. For example, higher expected inflation as the result of higher expected future monetary growth initially has little effect on short term rates as real money balances remain unchanged. In contrast, the higher inflationary expectations are reflected in long rates. Over time, as prices gradually adjust, real short rates can rise to reflect the higher inflation.

The above empirical results are not without their qualifications. Foremost amongst these is the relatively short period over which market determined interest rates are available. Such data exists for only nine years. This leaves relatively few truly independent observations, especially when looking at cumulative output and inflation changes over periods longer than a year. At a more abstract level, it is difficult to assess the degree to which both the monetary authorities and the agents in the economy take into account the above correlations in the making and interpreting of policy. The above tests are predicated on the assumption that both the authorities and other agents in the economy did not change their behaviour with respect to the yield curve over the sample period. Any such changes could alter the relationship between the slope of the yield curve and the future path of economic activity. Notwithstanding these qualifications this paper provides both theoretical and empirical support for using the slope of the yield curve as an indicator of the future paths of both real economic activity and inflation.

APPENDIX 1 : DATA

1. INTEREST RATES.

All interest rates are from the Reserve Bank of Australia Bulletin database. The 2, 5 and 10 year Treasury bond rates are from Table F.2. and are assessed secondary market yields as at the last day of the month. The overnight cash rate (that is the "Authorised dealers: weighted average rate") and the 90 and 180 day bill rates are from Table F.1. In the inflation change regressions, the three end-month interest rates are averaged for the quarter while, in the activity regressions, the interest rate at time t is used.

2. ACTIVITY VARIABLES.

Data on automobile registrations, the number of dwelling approvals and the Melbourne Institute Production Index (all groups) are from Table G.1. of the Reserve Bank of Australia Bulletin. Real seasonally adjusted GDP, consumption and investment data are taken from the DX database.

3. INFLATION.

Inflation rates are calculated as percentage changes in the CPI (adjusted for Medicare changes). The CPI is taken from the Reserve Bank of Australia Database.

APPENDIX 2 : DERIVATION OF DYNAMICS

This appendix derives the equations of motion for the model presented in Section 2. As in Section 2, it begins with the model where prices are assumed fixed. To obtain an equation for $\dot{R}$ in terms of Y and R first note that, with fixed prices, I=i and then substitute (5) into (1). Linearizing both the resulting equation and (4) around the steady state values $(\bar{Y},\bar{R})$, the system can be written as follows:

$$\begin{bmatrix} \dot{Y} \\ \dot{R} \end{bmatrix} = \begin{bmatrix} -\alpha & -\beta \\ -\bar{R}k & \bar{R} \end{bmatrix} \begin{bmatrix} Y-\bar{Y} \\ R-\bar{R} \end{bmatrix} \tag{A1}$$

As the determinant of the above matrix is negative, the system has both a positive (ϑ) and a negative (ψ) root. The negative root is given by:

$$\psi = 0.5 * \left[-(\alpha-\bar{R}) - \sqrt{(\alpha+\bar{R})^2 + 4\beta k \bar{R}} \right] \tag{A2}$$

The characteristic vector associated with ψ, (x_1,x_2) is such that:

$$\frac{x_1}{x_2} = \frac{-\beta}{\alpha+\psi} \tag{A3}$$

The equations of motion along the saddle-path are thus given by:

$$Y-\bar{Y} = -\gamma\beta e^{\psi t} \tag{A4}$$

$$R-\bar{R} = \gamma(\alpha+\psi)e^{\psi t} \tag{A5}$$

where γ is a constant to be solved for.

Consider the change in the steady state values following a monetary expansion.

$$\bar{Y}_1 - \bar{Y}_o = \frac{-\beta\bar{R}h}{\psi\vartheta}\,dm = \frac{\beta h}{\alpha+\beta k}dm \tag{A6}$$

$$\bar{R}_1 - \bar{R}_o = \frac{\alpha\bar{R}h}{\psi\vartheta}\,dm = \frac{-\alpha h}{\alpha + \beta k}dm \tag{A7}$$

Initially (at time t=0), Y is fixed so that:

$$(Y-\bar{Y}_1)|_{t=0} = \bar{Y}_0 - \bar{Y}_1 \tag{A8}$$

This implies that

$$\gamma = \frac{-\bar{R}h}{\psi\vartheta}\,dm = \frac{h}{\alpha+\beta k}dm \tag{A9}$$

Substituting this back into equations (A4) and (A5) gives the equations of motion along the saddle path.

$$Y-\bar{Y}_1 = \frac{\bar{R}h\beta}{\psi\vartheta}e^{\psi t}\,dm = \frac{-h\beta}{\alpha+\beta k}e^{\psi t}dm \tag{A10}$$

$$R-\bar{R}_1 = \frac{-\bar{R}h(\alpha+\psi)}{\psi\vartheta}e^{\psi t}\,dm = \frac{h(\alpha+\psi)}{\alpha+\beta k}e^{\psi t}dm \tag{A11}$$

Since $|\alpha| < |\psi|$, both Y and R are less than their steady state values along the saddle path.

Now consider the system with flexible prices. Substituting (5) into (2) and then substituting the result and (4) into (1), the system can be written as follows:

$$\begin{bmatrix} \dot{Y} \\ \dot{R} \\ \dot{P} \end{bmatrix} = \begin{bmatrix} -\alpha & -\beta & 0 \\ -\bar{R}k & \bar{R} & -\bar{R}(\theta + h) \\ 0 & 0 & -\theta \end{bmatrix} \begin{bmatrix} Y - \bar{Y} \\ R - \bar{R} \\ P - \bar{P} \end{bmatrix} \tag{A12}$$

This system has three roots, two of which are the same as the fixed price model (ψ and ϑ) while the third is $-\theta$. The eigen vector associated with ψ is $(-\beta \quad \alpha+\psi \quad 0)$ while the vector associated with $-\theta$ is:

$$\left(-\beta \quad \alpha - \theta \quad \frac{(\theta + \vartheta)(\theta + \psi)}{-\bar{R}(\theta + h)} \right) \tag{A13}$$

The equations governing the evolution of the system along the saddle path are thus given by:

$$Y - \bar{Y} = -C_1 \beta e^{-\theta t} - C_2 \beta e^{\psi} t \tag{A14}$$

$$R - \bar{R} = C_1 (\alpha - \theta) e^{-\theta t} + C_2 (\alpha + \psi) e^{\psi t} \tag{A15}$$

$$P - \bar{P} = C_1 \frac{(\theta + \vartheta)(\theta + \psi)}{-\bar{R}(\theta + h)} e^{-\theta t} \tag{A16}$$

where C_1 and C_2 are constants. From the steady state conditions, we know that in steady state changes in M leave Y and R unchanged and that $\bar{P}_0 - \bar{P}_1 = -dm$. This implies that:

$$C_1 = \frac{\bar{R}(\theta + h)}{(\theta + \vartheta)(\theta + \psi)} dm \tag{A17}$$

Given that $C_1 = -C_2$, the equations of motion can be rewritten as :

$$Y - \bar{Y} = \frac{-\bar{R}(\theta + h)\beta}{(\theta + \vartheta)(\theta + \psi)} \left[e^{-\theta t} - e^{\psi t}\right] dm \tag{A18}$$

$$R - \bar{R} = \frac{\bar{R}(\theta + h)}{(\theta + \vartheta)(\theta + \psi)} \left[(\alpha - \theta)e^{-\theta t} - (\alpha + \psi)e^{\psi t}\right] dm \tag{A19}$$

$$P - \bar{P} = -e^{-\theta t} dm \tag{A20}$$

As $(Y-\bar{Y})$ and $(R-\bar{R})$ are both the sums of declining exponentials, they both have at most one interior maximum/minimum. To find the time at which these extreme points occur, equations (A18) and (A19) are differentiated with respect to t and then solved for t^* (t^{**}). This yields:

$$\frac{\delta(Y - \bar{Y})}{\delta t} = 0 \quad \Rightarrow \quad t^* = \frac{\ln\left(\frac{-\theta}{\psi}\right)}{\theta + \psi} \tag{A21}$$

$$\frac{\delta(R - \bar{R})}{\delta t} = 0 \quad \Rightarrow \quad t^{**} = \frac{1}{\theta + \psi} \ln\left[\left(\frac{\theta - \alpha}{\psi + \alpha}\right)\left(\frac{\theta}{\psi}\right)\right] \tag{A22}$$

The larger is θ, the quicker the output and interest rate responses reach their maxima. In the limit, as $\theta \rightarrow \infty$, both t^* and t^{**} go to zero.

APPENDIX 3 : FORECASTING ABILITY OF SELECTED YIELD SPREADS

TABLE A1: PREDICTIVE ABILITY OF THE YIELD CURVE (1982:3-1991:2)

$$\left[\left(\frac{Y_{t+j}}{Y_t}\right)^{\frac{12}{j}} - 1\right] * 100 = \alpha + \beta\ SPREAD_t + \varepsilon_t$$

	SPREAD									
j	10 year - o'night			10 year - 90 day			2 year - 180 day			Nobs
	α	β		α	β		α	β		
3	3.22 (0.80)	0.47 (0.27)	0.06	3.47 (1.09)	0.25 (0.36)	-0.01	3.51 (1.39)	0.30 (0.68)	-0.02	35
6	3.36 (0.62)	0.50 (0.16)	0.18	3.67 (0.86)	0.30 (0.25)	0.02	3.83 (1.14)	0.46 (0.52)	0.00	34
9	3.50 (0.50)	0.49 (0.13)	0.25	3.94 (0.63)	0.42 (0.17)	0.10	4.23 (0.84)	0.73 (0.35)	0.06	33
12	3.61 (0.40)	0.50 (0.12)	0.39	4.15 (0.41)	0.47 (0.14)	0.21	4.52 (0.54)	0.84 (0.25)	0.15	32
15	3.66 (0.34)	0.45 (0.12)	0.48	4.23 (0.28)	0.48 (0.13)	0.34	4.63 (0.34)	0.88 (0.24)	0.26	31
18	3.70 (0.32)	0.42 (0.11)	0.56	4.27 (0.22)	0.48 (0.14)	0.48	4.76 (0.23)	0.95 (0.29)	0.46	30
21	3.63 (0.36)	0.36 (0.12)	0.48	4.14 (0.24)	0.41 (0.15)	0.41	4.57 (0.25)	0.82 (0.30)	0.39	29
24	3.63 (0.34)	0.28 (0.12)	0.35	4.03 (0.26)	0.33 (0.14)	0.30	4.40 (0.26)	0.67 (0.28)	0.33	28
36	3.69 (0.22)	0.08 (0.06)	0.03	3.78 (0.34)	0.04 (0.08)	-0.03	3.87 (0.38)	0.14 (0.13)	-0.01	24

NOTES.
1. The forecast horizon (j) is in terms of months.
2. Standard errors which are robust to serial correlation and conditional heteroskedasticity are reported in parenthesis () below coefficient estimates.
3. Y_t is real seasonally adjusted GDP at time t.

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