How useful is the yield spread as a predictor of growth in Australia?

Abstract

Purpose – This paper examines the usefulness of the yield spread in forecasting growth in the Australia economy since 1969.

Design/Methodology/approach – This paper applies time series analysis to evaluate the in-sample and out-of-sample forecasting power of the spread-growth nexus in Australia for the period spanning from 1969 to 2014.

Findings – This paper concludes that the spread serves as a useful predictor of growth in output, private dwellings, private fixed capital formation, and inventories in Australia, both in-sample and out-of-sample. Its predictive content is not sensitive to the inclusion of monetary-policy variables or the switch to the inflation-targeting regime by the Reserve Bank of Australia in the early 1990s.

Original/value – This paper provides compelling evidence to policy makers and market participants on the usefulness of the spread in forecasting output growth for up to eight quarters ahead.

Keywords: Interest rates; leading indicators; yield spread; Australia

Research type: Research paper

1. Introduction

The yield spread, or the difference between the yields on long-term securities and those on otherwise comparable short-term securities, is frequently regarded by market participants and the monetary authority as an important predictor of output growth. According to the expectations hypothesis of the term structure, long-term securities generally command higher yields than their short-term counterparts because of the term premium associated with investors' preference to hold the latter. As a result, if we plot the yields on otherwise comparable securities of different maturities, we expect to observe an upward-sloping yield spread curve. However, one of the most enduring stylized facts in macroeconomics is the adage that an inversion of the yield curve caused by short-term yields rising fasters than long-term yields often signals an impending recession.[1]

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Despite an extensive literature on the predictability of output growth using the spread in the United States and Europe, the spread-growth nexus remains a largely underexplored issue in Australia. Nascent work in this area has produced mixed findings (Estrella and Mishkin, 1997; Stock and Watson, 2003; Schrimpf and Wang, 2010). According to Lowe (1992) and Alles (1995), the spread can forecast growth in Australia for up to nine and four quarters ahead, respectively. Meanwhile, Fisher and Felminham (1998) find that the real spread is useful in predicting real consumption in Australia for up to eight quarters ahead. Using the data from 1980 to 2002 and controlling for key determinants of growth, Valadkhani (2004) argues that the predictability of growth in Australia can be further enhanced by examining the spread within a future horizon of up to 11 quarters ahead. However, Benati and Goodhart (2008) point out that the major source of the marginal predictive content of the spread has undergone significant structural changes in Australia over

[1] See, *inter alia*, Stock and Watson (2003) and Wheelock and Wohar (2009) for comprehensive review on the early literature.

time. This is further supported by Poke and Wells (2009), who conclude that the switch to the inflation-targeting (IT) regime by the Reserve Bank of Australia (RBA) in 1993 improved the predictive power of the spread ever since.

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Our objective is to provide an extensive re-examination of the significance of the spread as a leading indicator in Australia from 1969 to 2014. Our analysis is innovative in the following ways. First, we extend the existing literature by not only analyzing the extent to which the spread can predict growth in output, but also in key components of gross national product (GNP). Next, we assess whether the spread carries predictive content over and above contemporaneous measures of monetary policy stance. Third, we evaluate the effect of the inflation-targeting (IT) regime, if any, on the spread-growth nexus. Last, but not the least, we review the out-of-sample forecast power of the spread as a predictor of economic activity. After a reappraisal of the available evidence in this study, we find that the spread remains a useful predictor of growth in Australia, particularly during the post-IT regime era.

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The remainder of this paper is structured as follows. A literature review is provided in the following section. Sections 3 and 4 contains a brief overview of our data and methodology, respectively. The main focus is on the assessment of the spread-growth nexus. In Section 5 we discuss the results of the baseline model, the role of monetary policy, the effect of the IT regime, and the out-of-sample forecasting performance of the spread. Section 6 concludes.

2. Literature Review

The yield spread, or the difference between yields on long-term and short-term securities, is regarded by many practitioners as a leading indicator of future economic activity. In part, this is because there is ample evidence suggesting that the narrowing of the spread frequently precedes the slowdown of growth, and in some instances, a recession. Despite this apparent spread-growth nexus, there is yet a coherent theory on the underlying transmission mechanism, and the positive association between these variables remains a stylized fact in many macroeconomic textbooks (Benati and Goodhart, 2008).

In the empirical literature, the spread is often defined as the long-term government security rate, say, the 10-year bond rate, minus the 3-month government bill rate.[2] In general, the yields on long-term securities typically exceed their shorter-term counterparts because it is inherently riskier to hold the former. This important feature is often being captured by an upward-sloping yield curve, with the yield on the vertical axis and the term-to-maturity on the horizontal axis. However, there is no predisposition as to why the yield curve has to always slope upwards. It is possible, and indeed, has occurred in the past, that the short rates have changed more than the long rates, leading to a flatter, or even an inversion of, the yield curve. This change, particularly if unexpected, is perceived by many as an indicator of slower growth to come. Therefore, a logical question to ask here is what can explain this apparent predictive power of the spread?

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The starting point of most empirical studies of the spread-growth nexus is to estimate a univariate model, with the spread being the only independent variable. However, it is a well-established fact in the forecasting literature that the past values of the dependent variable are often themselves useful predictors (Stock and Watson, 2003). As such, some studies have taken this into account by including both the spread and lagged growth to establish the bivariate model. In this set up, the spread contains useful information if, and only if, it remains statistically significant after the inclusion of lagged growth. Hamilton and Kim (2002, p.345) show that *"the yield spread provides additional information beyond that contained in current and lagged growth rates"* in the US. Using the moving-block bootstrap methodology

[2] Other commonly used definitions of the yield spread include: (1) the difference between 10-year government bond rate and the overnight cash rate (Stock and Watson, 2003); (2) the difference between 5-year government bond rate and the overnight cash rate (Poke and Wells, 2008); and (3) the difference between 2-year, 5-year and 10-year government bond rates and the 180-day bank accepted bill rate (Alles, 1995).

with lagged growth, Schrimpf and Wang (2010, p.840) conclude that the predictive power of the spread *"appears to be particularly strong in the cases of Canada and Germany"*, but *"is relatively weak in the UK"*. Taken together, this evidence suggests that the inclusion of lagged growth reduces possible overestimation of the predictive power of the spread (Stock and Watson, 2003).

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One distinct possibility why the spread might carry informational content is that it encapsulates market expectations and the stance of monetary policy. Temporary monetary tightening, for example, causes short-term nominal interest rates to rise more than long-term rates, flattening the slope of the yield curve. In the presence of price rigidities, such a policy stance also raises the short-term real interest rate, reducing consumption and investment demand, and therefore, output in the immediate future. While this explanation seems plausible, it is important to remember that the short-end of the spread is closely related to current monetary policy. In other words, the predictive power may not have emanated from the slope of the yield curve, but may simply be the result of changes in the short-end of the spread.

In the empirical literature, a common practice to disentangle these two considerations is to include both the spread and contemporaneous measure of monetary policy in the same model. The intuition is that if the spread contains additional information, then it must remain statistically significant after the introduction of monetary-policy instruments. Following this line of reasoning, Estrella and Hardouvelis (1991, p.566) include the real federal funds rate as the indicator of monetary policy stance and conclude that *"the information in the slope of the yield curve is mostly about variables other than current monetary policy"* in the US. Meanwhile, Hamilton and Kim (2002, p.346) extend the monetary-policy instruments to include key monetary aggregates and show that *"even when all these variables are included together, the result remains that the yield spread helps to predict economic growth up to two*

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years ahead" in the US. In Europe and the US, Estrella and Mishkin (1997, p.1394) find that the spread *"by itself is useful in predicting real economic activity, especially between 4 and 8 quarters ahead, independently of which measure of activity is used"*.

The monetary policy explanation seems intuitive given the role of monetary policy as a stabilization tool. However, Feroli (2004), Estrella (2005), and Estrella and Trubin (2006), among others, argue that the predictive power of the spread crucially depends on the credibility of the central bank. Specifically, if the central bank is more responsive to deviations of growth from potential than from the inflation target, then the spread can better forecast growth in the former. To see this, consider for a moment that there is no inflation target. In this scenario, an inflationary shock increases both the short and long rates by the same amount, leaving the spread, and therefore, economic activity, unchanged. However, the situation turns out quite differently for a temporary adverse real shock. As Campbell and Cochrane (1999) point out, if an individual expects a lower income during the recession one year in the future, he or she will switch from low-return, short-term securities to high-return, long-term securities now in order to safeguard against falling consumption in one year's time. This restructuring of the asset portfolio causes the short rates to temporarily rise faster than the long rates, leading to a narrowing of the spread and a reduction in economic activity.[3] In contrast, if the central bank follows an inflation target and defends it at all cost, then either an inflationary shock or a real shock would still raise the short rates, but the long rates would remain unchanged in both scenarios. In this environment, the positive association between the fall in the spread and economic activity is expected to be more pronounced in the former because the attempt to smooth consumption in the latter is likely to lessen the impact of the real shock (Ellingsen and Söderström, 2001; Bordo and Haubrich, 2004). As such, the

[3] Estrella et al. (2003) attribute this reduction in the spread to a falling marginal rate of substitution between current and future consumption associated with an impending recession.

stability of the spread-growth nexus crucially depends on the credibility of the central bank; the forecasting relationship tends to be stronger when there is low central-bank credibility.

Subsequent work to the preceding discussion has focused on the stability of the spread-growth nexus over time. For example, after comparing the performance of the spread against 131 monthly time series and professional forecasts, D'Agostino et al. (2006) conclude that the spread has not been a reliable predictor of growth in the US since the mid-1980s. This finding is further supported by Estrella *et al.* (2003, p.640), who find *"weak evidence (at the 10% level) of a break in 1983 with a break around September 1983 with a one-year horizon"* in the spread-growth nexus in the US. Meanwhile, Bordo and Haubrich (2004, 2008) detect multiple structural breaks in the forecasting relationship between the spread and growth in the US during the 1875–1997 period and attribute it to changes in monetary regime. Specifically, Giacomini and Rossi (2006) find strong evidence of forecast breakdowns during the Burns-Miller and the Volker Fed chairmanship, but the predictive power of the spread resurfaced again in the early part of the Greenspan era. However, using the Bayesian time-varying parameters vector autoregressions with stochastic volatility, Benati and Goodhart (2008) cast doubt over these results. As Wheelock and Wohar (2009, p.430) point out, these breaks could simply reflect *"the increased stability of growth and other macroeconomic variables since the mid-1980s (at least until 2007) as a possible reason for the apparent change"*.

Recent research has also focused on evidence outside the US and the out-of-sample forecast performance. For example, Stock and Watson (2003, p.822) find that while the spread *"was a useful predictor of growth in the United States and Germany prior to the mid-1980s"*, they notice a substantial reduction in the out-of-sample forecast accuracy for the G–7 countries over the period 1985–1999. Schrimpf and Wang (2010) also reach a similar conclusion for Canada, Germany, the UK, and the US. However, after controlling for the

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dynamic characteristics of the spread, De Pace (2013) argues that the forecasting reliability of the spread in major European countries and the US returned in 2008. In a recent study, Abdymomunov (2013, p.333) suggests that *"the dynamic yield curve model produces better out-of-sample forecasts of real GDP than those generated by the traditional term spread model"*.

In Australia, the evidence on the spread-growth nexus is mixed and remains largely an underexplored issue. Early studies by Lowe (1992) and Alles (1995) compare the predictive power of various definitions of the spread and suggest that, in general, the spread is able to predict growth for up to nine and four quarters ahead, respectively. Similarly, Fisher and Felmingham (1998) discover that the spread is useful in predicting consumption growth for up to eight quarters ahead. Valadkhani (2004) finds that the predictability of growth can be further enhanced by examining the spread within a future horizon up to 11 quarters ahead. However, Benati and Goodhart (2008) speculate that the forecasting relationship in Australia might have undergone significant changes in recent years. Indeed, after splitting the sample period into pre- and post-1982 to coincide with the implementation of the Checklist regime, Lowe (1992) and Alles (1995) conclude that the forecasting performance of the spread has improved in the later period. Poke and Wells (2009) then examine the effect of inflation target and find that the positive association between spread and growth has grown stronger since 1990. In terms of the out-of-sample forecasting of the growth in industrial output, Luo (2008, p.19) show that the spread is *"a good forecasting device for many industries, particularly for growth over longer horizons"*.

3. Methodology

3.1. The baseline model

A simple model for evaluating the predictive content of the spread is to consider the following *h*-step ahead linear regression model:

$$y^h_{t+h} = \alpha_0 + \alpha_1 s_t + \sum_{j=0}^{3} \beta_j y_{t-j} + u^h_{t+h} \qquad (1)$$

where y_t and $y^h_{t+h} = (400/h)\ln(y_{t+h}/y_t)$ denote the level of output at time *t* and the annualized cumulative growth rate *h*-step ahead, respectively.[4] s_t is the spread, or the difference between the long rate and the short rate, at time *t*. Since Stock and Watson (2003, p.790) suggest that y^h_{t+h} might be *"serially correlated, as is typically the case for time series variables, its own past values are themselves useful predictors"*, we include lagged growth rates (from the perspective of *h*-step ahead), y_{t-j}, in equation (1). We then test the null hypothesis that α_1 has no predictive content for y^h, above and beyond that in lags of *y*, by computing the *t*-statistic on α_1. However, because the data are overlapping, the error tem u^h_{t+h} in equation (1) is serially correlated, we estimate the *t*-statistic using heteroskedasticity- and autocorrelation-consistent (HAC) standard errors. Finally, we assess the economic significance of s_t by inspecting the coefficient of determination, $\bar{R}^2$, and the standard error of the regression (*SER*).[5]

Information on the predictive power of the spread is crucial to policy makers and market participants who rely on it as an indicator for the level of private-sector activities. As such, we also examine the predictability of cumulative changes in key components of real

[4] For example, if one needs to forecast the growth rate four quarters ahead, the dependent variable in equation (1) becomes $Y^4_{t+4} = (400/4)\ln(Y_{t+4}/Y_t)$, where the factor of 100 standardizes the units to be annual percentage growth rates.

[5] Poke and Wells (2009) suggest that an alternative approach to equation (1) is to generate *h*-step forecasts by iterating a vector autoregression (VAR) system containing the spread and growth. However, while a correctly specified VAR can produce estimates that are asymptotically efficient, the *h*-step approach has the advantage in reducing *"the potential impact of specification error"*. (Stock and Watson, 2003, p. 791)

gross national product (GNP) for completeness. Specifically, we use the following equation to assess the in-sample forecasting accuracy of the spread:

$$x_{t+h}^{h} = \alpha_0 + \alpha_1 s_t + \sum_{j=0}^{3} \beta_j x_{t-j} + u_{t+h}^{h} \qquad (2)$$

where x_t is the contemporaneous measure of the components of real GNP, including consumption (*cons*), private dwelling (*pd*), private gross fixed capital formation (*pgfc*), inventories (*inv*), and government spending (*gs*). Notice that we include lagged growth of x_t in equation (2) to ensure that the spread carries predictive content above and beyond that in the past values of x_t.

In the literature, it is useful to consider the predictive power of the spread on marginal growth rate, which is defined as $y_{t+h-k}^{h} = (400/k)\ln(y_{t+h}/y_{t+h-k})$. The purpose of this exercise is to *"assess how far into the future the predictive power of the yield curve will reach"* (Schrimpf and Wang, 2010, p.840). For ease of exposition, we set $k = 4$ so that we are, in effect, measuring the marginal effect of the spread on year-to-year growth rates.[6]

3.2. The role of other monetary policy variables

It is possible that the predictive content of the spread for growth simply reflects the influence of monetary policy on interest rates, particularly on the short end. In order to ascertain the extent to which the spread contains useful information over and above that provided by other variables reflecting the stance of monetary policy, we extend equation (1) as follows:

$$y_{t+h}^{h} = \alpha_0 + \alpha_1 s_t + \alpha_2 m_t + \sum_{j=0}^{3} \beta_j y_{t-j} + u_{t+h}^{h} \qquad (3)$$

[6] As shown in Schrimpf and Wang (2010), this definition reaches exactly the same results for cumulative growth and marginal growth if we set both *k* and *h* equal to four.

where m_t is the contemporaneous measure of monetary policy. In very general terms, the predictive power of s_t would still remain after the inclusion of monetary policy variables. Similar to Estrella and Mishkin (1997), we begin by looking at the effect of introducing short-term interest rates as proxies for the monetary policy stance, including the overnight cash rate (*cr*), the 2-year government bond rate (*b2*), and the real overnight cash rate (*rcr*).[7] We then consider the one-quarter growth in the monetary base (*mb*), as well as in the narrow (*m1*) and broad (*bm*) monetary aggregates. In equation (2), we may conclude that the predictive power of the spread *"does not seem to be attributable solely or primarily to known information about other monetary policy variables"* if α_1 is statistically different from zero (Estrella and Mishkin, 1997, p. 1394).

3.3. The effect of the inflation-target regime

There is ample evidence suggesting that changes of monetary regime may render the spread-growth nexus unstable over time (Wheelock and Wohar, 2009). According to Macfarlane (1997), there were four major changes in Australian monetary policy regime from the mid-1970s to the early-1990s; namely, the abolishment of the fixed exchange rate regime in the early 1970s; the introduction of the monetary targeting regime between 1976 and 1985; the adaptation of the Checklist approach until the early 1990s; and the switch to IT regime since 1993. As discussed in Section 2, the move towards the IT regime is expected to have an enduring impact on people's behaviors, weakening considerably the predictive power of the spread in Australia. However, Poke and Wells (2009, p. 127) find that *"if attention is focused on the post-1990 sample, the spread is always significant and positive"*. In light of this strong evidence suggesting a time-varying relationship between the spread and growth, we divide

[7] The choice of these monetary policy variables are not arbitrary. For example, the overnight cash rate is a policy instrument used by the RBA to maintain the desired inflation target. Since the 3-month Treasury bond rate tracks closely the 90-day bank bill rate used in the spread, we select the 2-year government bond rate as the candidate for short-term government rate instead.

the 1969–2014 period into two sub-sample periods; namely, the 1969–1989 period and the 1990–2014 period. Notice that we have chosen the year 1990 as the break point on two grounds. The first is that the RBA decided to release its monetary policy actions immediately to the market in January 1990 as a means to increase transparency and credibility, while the second is that there was rapid disinflation since 1990, coinciding with the switch to the IT regime formally on 14th August 1996 (Poke and Wells, 2009). We then compare and contrast the statistical significance of α_1 in equation (1) in both sub-sample periods. Intuitively, if $\alpha_1 = 0$ in one sub-sample period, but not in the other, we may conclude that the announcement of an inflation target has a non-negligible effect on the stability of the forecasting relationship. In a passing note, we seek to extend on Poke and Wells (2009) by including the post-global financial crisis (GFC) years so that we can establish the effect, if any, the GFC may have had on the relationship.

3.4. Pseudo out-of-sample measures of predictive content

One key motivation for this study is to evaluate the usefulness of the spread as a predictor for growth. *Prima facie*, one can arrive at the conclusion by observing the in-sample spread coefficients under different model specifications. However, such an approach is deemed inappropriate here because of strong evidence pointing to a time-varying spread-growth nexus. In order to control for this, we obtain pseudo out-of-sample spread coefficients in equation (1) via real-time forecasting. Specifically, we set the first 10 years of the post-IT period (1996q1–2006q4) as the initialization period, which provides us with a pseudo out-of-sample forecast window of $n = T_2 - T_1 - h + 1$, where T_1 and $T_2 - h$ are the first and last dates over which the forecast window is computed. We then compute commonly used forecast-error statistics, including the root mean squared error (RMSE) and the Theil inequality coefficient (TIC) for equations (1) and (2). In general, an equation is said to have provided reasonable out-of-sample forecasting power if it possesses a smaller RMSE statistic and/or a TIC statistic that is close to zero.

However, it is important to note that while both RMSE and TIC are relatively easy to obtain, there are no benchmark to compare them against. In order to address this, we use the following univariate autoregression as the benchmark model:[8]

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$$z^{h}_{i,t+h} = \alpha_0 + \sum_{j=0}^{3} \beta_j z_{i,t-j} + u^{h}_{i,t+h} \qquad (4)$$

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where $z^{h}_{i,t+h}$ denotes the growth of the i^{th} dependent variable in equations (1) and (2). Following Stock and Watson (2003), we then compute the *h*-step ahead relative mean squared forecast error (RMSFE) between the pair of equations (1)–(4) and the pair (2)–(4) as below:

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$$\text{RMSFE} = \frac{n^{-1} \sum_{t=T_1}^{T_2-h} \left(x^{h}_{t+h} - \hat{x}^{h}_{t+h|t} \right)^2}{n^{-1} \sum_{t=T_1}^{T_2-h} \left(x^{h}_{t+h} - \hat{z}^{h}_{t+h|t} \right)^2} \qquad (5)$$

where $\hat{x}^{h}_{i,t+h|t}$ and $\hat{z}^{h}_{i,t+h|t}$ are, respectively, the pseudo out-of-sample forecasts of the i^{th} dependent variable and the benchmark model, made using data through time *t*. Intuitively, since RMSFE is the ratio of RMSE from equation (1) or (2) to MSE from equation (4), a less-than-one RMSFE implies that the former outperforms the latter. In contrast, if RMSFE is greater than one, then the benchmark model is said to have outperformed equation (1) or (2). If this were the case, the spread should not be used as a predictor of the dependent variable, on the basis that it does not possess predictive content over and above the simple univariate autoregression.

[8] It is common in the literature to use an AR(1) model as the benchmark to evaluate the predictive content of the yield spread (see, *inter alia*, Stock and Watson (2003); Ang et al. (2006); Schrimpf and Wang (2010)).

4. Data

We collected data on up to 14 series from 1959 to 2014. However, some of these series were only available for a shorter period. Data were obtained from two main sources; namely, the Australian Bureau of Statistics (ABS) and the Reserve Bank Bulletin. Additional series, including the spread and the real overnight cash rate, were constructed from these original 14 series, bringing the total number of series to 16. Specifically, we define the spread as the 10-year government bond rate minus the 3-month government bill rate.[9] Meanwhile, because we cannot directly observe the ex-ante real overnight cash rate, we follow Estrella and Mishkin (1997) by calculating the ex-post real overnight cash rate as the difference between the average nominal overnight cash rate for a given period and the actual inflation rate over the same period. Table 1 lists the summary statistics, the source, and the sample period of these series.

[Insert Table 1 Here]

Before proceeding with the empirical tests, the data were subject to the following transformations. First, as we are interested in the growth rate of real GDP, key components of GNP, and monetary aggregates, we take the natural logarithm and first-difference these variables. Second, whenever the data were available on a monthly basis, we aggregate the data to quarterly observations by using the average of monthly values. Finally, it is not clear whether interest rates should be included in levels or after first differencing, we check the stationarity of these series before including them.

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[9] We also considered the yield spread between 5-year government bond rate and the 3-month government bill rate. We found that the results are generally consistent with the chosen spread in this study. Further details can be provided on request from the authors.

5. Results

5.1. The baseline model

Table 2 presents the results for the baseline model on the predictive power of the spread for growth in Australia. There is very consistent evidence that the widening of the spread implies higher growth in the future, as previous work for Australia had shown. For example, if the current quarter's spread between the 10-year government bond rate and the 3-month government bill rate is 100 basis points or one per cent, the Cumulative Change Panel of the fourth row of Table 2 shows that over the course of one full year from current quarter *t* to quarter *t* + 4, real GDP is predicted to grow by 3.67 per cent $\left(3.362\% + 0.303(1\%) = 3.665\%\right)$. The values of the estimated coefficient are generally smaller than the corresponding coefficients in Alles (1995) and Valadkhani (2004) because these studies did not include lagged growth in the model. Meanwhile, our results differ from Poke and Wells (2009) not only in that they define the spread differently to ours, but also they examine the forecasting relationship over a shorter time span.

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I have adhered to present tense in describing Poke and Wells (2009) to conform with the rest of the article.

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[Insert Table 2 Here]

In Table 2, the coefficient of determination, $\bar{R}^2$, provides a measure of in-sample forecasting accuracy, while the statistical significance of the spread coefficient, α_1, provides information on the reliability of the baseline model in predicting the direction of a future change in growth. As expected, cumulative change in growth are more predictable than its marginal change counterpart. The predictive power for cumulative changes last for about four years, while the comparable figure only lasts for up to 6 quarters. Furthermore, the size of $\bar{R}^2$ is consistently higher for the Cumulative Change Panel *vis-à-vis* the Marginal Change Panel.

Finally, notice that all constant terms α_1 in both panels are positive, indicating that an inversion of the spread need not necessarily imply negative future growth. In our previous example of cumulative changes from current quarter t to future quarter $t+4$, a prediction of a negative growth would have only occurred if the spread were less than minus 11.10 per cent $(-3.36\%/0.303=-11.10\%)$. From the outset, such yield inversion seems highly unlikely in reality. Nevertheless, it provides anecdotal evidence why recession has been a rare event in Australia during the post-war era.

Table 3 examines the predictability of cumulative changes in major components of real GNP; namely, household consumption (*cons*), private dwellings (*pd*), private gross fixed capital formation (*pgfc*), inventories (*inv*), and government spending (*gs*). The table shows that the spread has predictive power for all components, except household consumption and government spending. Furthermore, the spread predicts changes in private fixed capital formation and inventories better than private dwellings.

[Insert Table 3 Here]

A few points are in order here. First, we find that the coefficients on household consumption are, for most forecasting horizons, negative and statistically insignificant. This contradicts the Campbell-Cochrane (1999) consumption capital asset pricing model (CCAPM), which predicts a positive relationship between future consumption and the spread. However, as explained by Fisher and Felmingham (1998), this can be interpreted as anecdotal evidence that Australian households do not suffer from money illusion. When the real spread is used instead, they find a positive real spread-consumption nexus for up to eight quarters ahead. Second, if we focus on $\bar{R}^2$, it is clear that the spread is able to predict growth in private dwellings, private gross fixed capital, and inventories with good accuracy. In fact, our baseline model has the highest forecasting accuracy for changes in inventories, accounting for more than 70 per cent of the variations at quarter $t+4$. This is consistent with our current understanding that these components are sensitive to movements in interest rates. Finally, we find some evidence that the spread-growth nexus in Australia cannot be explained by the standard IS-LM model as it would require the spread to be *"a better predictor of the most exogenous of the components of aggregate demand because it is expected exogenous shows to the IS curve that rationalized the story"* (Estrella and Hardouvelis, 1991, p.569). However, Table 3 shows that, as the most exogenous component of aggregate demand, future government spending is the most unpredictable component. In short, our results suggest that the forecasting relationship in Australia remains, by and large, a stylized fact, and hence, there is a need to search for the underlying theory.

5.2. The role of other monetary policy variables

As discussed in Section 2, there is a view that the predictive content of the spread may simply capture the effects of monetary policy on the long and short rates. While such a view is valid, we are equally interested in the usefulness of the spread as a simple barometer of future growth. Obviously, for this to be the case, the spread coefficient must remain statistically significant after the inclusion of monetary policy variables. It is common in the literature to consider short-term interest rates and monetary aggregates as proxies of monetary policy stance. In the former category, we select the overnight cash rate (*cr*), the real overnight cash rate (*rcr*), and the 2-year government bond rate (*b2*), In order to avoid spurious results, we check stationarity of these variables before adding them to our baseline model. The results from conventional unit root tests suggest that we cannot reject unit roots in these variables, so they are included in first differences.[10]

[10] Common unit root tests were considered and all reached the same conclusion that there is unit root in *cr*, *b2*, and *rcr* in levels, but is free of unit root in first differences; these tests include the augmented Dickey-Fuller test, the Phillips-Perron test, and the Kwiatkowski-Phillips-Schmidt-Shin test.

[Insert Table 4 Here]

The results are presented in Table 4 in four panels. The first restates the baseline results in Table 2 for selected even-numbered quarters up to 16 quarters ahead, which is where the predictive power was most significant. With the exception of *b2*, we find that not only the spread coefficients are significant, but their magnitude is also consistently larger than the baseline model. It is important to note that while the sign of the short-term rates is against our a priori expectation, they are, for most part, insignificant. This result runs counter to Valadkhani (2004, p.137), who find that *"the short end of the yield curve (proxied by the cash rate) exerts a negative and significant impact on future output growth when the forecasting horizon (k) varies from 2 to 12 quarters"*. From the outset, this discrepancy may be attributed to different model specifications; Valadkhani (2004) also included the spread in Australia's major trading partners, narrow monetary aggregate M1, the share price index, and the composite leading indicator. However, the results in the *b2* panel are harder to interpret. We suspect that those results were primarily driven by either the shorter sample period examined or the fact that the RBA has never formally considered the 2-year bond rate as its primary policy instruments. Finally, observe that adding the short-term rates generally improves the goodness-of-fit of the model. Taken together, we may conclude that the predictive power of the spread remains robust to the inclusion of short-term rates.

In addition to the interest rate proxies of monetary policy, monetary aggregates were used, as reported in Table 5. Since the monetary base (*mb*), narrow monetary aggregate (*m1*), and broad monetary aggregate (*bm*) variables are nonstationarty in levels, they are included as the one-quarter growth rate. Once again, we find that, irrespective of the type of monetary aggregate included, the spread retains predictive power for up to a minimum of 12 quarters ahead. Consistent with Valadkhani (2004), we also observe that the inclusion of *m1* marginally improves the goodness-of-fit of the model for the forecasting horizon up to four quarters ahead.

[Insert Table 5 Here]

In summary, the spread by itself is useful in predicting growth, especially between six and eight quarters ahead, independent of the measures of contemporaneous monetary policy. Furthermore, such predictive power does not seem to be attributable solely or primarily to known information about current monetary policy.

5.3. The effect of the inflation-target regime

The predictive power of the spread can also be seen by plotting the annualized growth rate from quarter $t - 4$ to quarter t and the spread during quarter $t - 4$ on the same figure. Figure 1 shows that, in general, the spread tracks the future realization in growth rather well. In fact, a yield inversion often preceded the six episodes of recession prior to the 1990s. However, the figure also shows that the association between these two variables is not very precise following the switch to the IT regime in 1996. This momentous change could serve as a reminder that any historical statistical relationship based on precise economic principles may easily disintegrate in the future (Estrella and Hardouvelis, 1991).

[Insert Figure 1 here]

The results on the predictive power of the spread pre- and post-IT regimes are presented in Table 6. We find that the spread coefficients are significantly larger and statistically different from zero during the post-IT regime period. In addition, the baseline model seems to fit this period better than the others. These findings suggest that the spread appears to exert greater influence on growth since 1990. This is an important result because it rejects the hypothesis that the spread should possess lesser predictive power under an IT regime. So how can we reconcile this apparent inconsistency? Poke and Wells (2009) attribute it to falling rationally expected spread as a result of the RBA defending proactively the 2–3 per cent inflation target.[11] Meanwhile, the forecasting relationship could have been enhanced by moderated volatility in the growth rate since 1984 (Smith and Summers, 2002).

[Insert Table 6 Here]

5.4. Pseudo out-of-sample measures of predictive content

Table 7 presents the pseudo out-of-sample forecasting power of the spread. In terms of RMSE, the spread is a good predictor of growth in output (*y*), private dwellings (*pd*), private fixed capital formation (*pgfc*), and inventories (*inv*), but not in consumption (*cons*) and government spending (*gs*). This is in line with the in-sample results in Section 5.1, whereby the spread displays good predictive power for interest-sensitive components of GNP. Since there appears to be a sudden jump in RMSE after the forecasting horizon h = 8 in most variables, we may conclude that the spread provides reasonable forecasts for up to eight quarters ahead. This conclusion is further supported by the fact that TIC is fairly close to zero for *y*, *pd*, *pgfc*, and *inv*, prior to h = 8. Importantly, RMSFE is consistently less than unity for *y*, *pd*, *pgfc*, and *inv*, indicating that models with the spread consistently outperform those without. In short, our findings are similar to Luo (2008, p.25), who conclude that *"the out-of-sample analysis indicates that the yield spread is an important device in predicting the output growth for most industries and total GDP. This is particularly true when the growth rates are over longer horizons such as 4 or 8 quarters"*.

[Insert Table 7 Here]

[11] Following Hamilton and Kim (2002), Poke and Wells (2009) decompose the spread into the effect of expected future changes in short rates (or the rational term spread) and the effect of the time-varying term premium.

6. Conclusions

We set out to examine the extent to which the spread between long-term and short-term interest rates can predict economic activity in Australia for the period spanning from 1969 to 2014. Through this study, we find that firstly, the spread is capable of predicting cumulative and marginal changes for up to four years and six quarters, respectively. Secondly, the spread proves to be most useful for predicting changes in interest-sensitive components of GNP, including private dwellings, private gross fixed capital formation, and inventories. Importantly, we find evidence rejecting the positive consumption-spread nexus hypothesized in the CCAPM model. Thirdly, there appears to be a structural break in the forecasting relationship around 1990, coinciding with the implementation of an inflation target by the RBA. Specifically, we find that positive association between spread and growth has become more robust during the post-IT regime era. This is at odds with the view that inflation target should have weakened the predictive power of the spread. Finally, the out-of-sample forecast analysis shows that models containing the spread consistently report less-than-unity RMSE and RMSFE statistics and close to zero TIC statistic for growth in output, private dwellings, private gross fixed capital formation, and inventories. These results indicate that the spread contains predictive power over and above the univariate autoregressive models for up to eight quarters ahead. In short, we conclude that the spread has served as a simple predictor for changes in economic activity in Australia since 1990.

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Appendix

Table 1. Summary statistics and series description

Variable label	Sample period (frequency)	Description	Mean	Max.	Min.	Standard deviation	Source
cr	1976–2014 (M)	Interest rate: overnight (%)	8.143	18.355	2.500	4.342	Reserve Bank Bulletin Table F1.1
b3mth	1969–2014 (M)	Interest rate: 3-month government bills (%)	8.364	19.470	2.591	4.234	Reserve Bank Bulletin Table F1.1
b2yr	1995–2014 (M)	Interest rate: 2-year government bonds (%)	5.093	9.711	2.448	1.488	Reserve Bank Bulletin Table F2.1
b10yr	1969–2014 (M)	Interest rate: 10-year government bonds (%)	8.443	16.033	3.056	3.385	Reserve Bank Bulletin Table F2.1
s	1969–2014 (M)	Yield spread: *b10yr* – *b3mth* (%)	0.079	4.107	-10.150	1.744	Author's own calculation
rcr	1976–2014 (M)	Interest rate: real overnight (%)	6.959	16.329	0.842	3.848	Author's own calculation
y	1959–2014 (Q)	Real GDP (seasonally-adjusted, chain volume measures; $million)	216115.60	397341.00	96497.00	89444.54	ABS cat. no. 5206.0 Table 2
cons	1959 -2014 (Q)	Final consumption: household (seasonally-adjusted, chain volume measures; $million)	119041.90	202781.00	50008.00	42433.54	ABS cat. no. 5206.0 Table 2
gs	1959 -2014 (Q)	Final consumption: general government (seasonally-adjusted, chain volume measures; $million)	14193.57	27403.00	6503.00	6398.96	ABS cat. no. 5206.0 Table 2
pd	1959 -2014 (Q)	Gross fixed capital formation: total private dwellings (seasonally-adjusted, chain volume measures; $million)	12108.38	19550.00	5288.00	4482.44	ABS cat. no. 5206.0 Table 2
gfc	1959 -2014 (Q)	Gross fixed capital formation: total private (seasonally-adjusted, chain volume measures; $million)	36371.99	91896.00	11529.00	23797.06	ABS cat. no. 5206.0 Table 2
inv	1985–2014 (Q)	Total inventories (seasonally-adjusted, chain volume measures; $million)	114788.20	152164.00	79626.00	26037.24	ABS cat. no. 5676.0
inf	1976–2014 (M)	Inflation rate (%)	1.185	6.100	-0.500	1.001	Reserve Bank Bulletin Table G1
m1	1975–2014 (M)	Money: M1 ($ billion)	105.018	310.040	8.344	90.447	Reserve Bank Bulletin Table D3
mb	1976–2014 (M)	Money: monetary base ($ billion)	27.770	89.357	4.166	19.683	Reserve Bank Bulletin Table D3
bm	1975–2014 (M)	Money: broad money ($ billion)	550.856	1724.312	50.954	463.906	Reserve Bank Bulletin Table D3

Table 2. Predicting future changes in output using the yield spread

$$y_{t+h}^{h} = \alpha_0 + \alpha_1 s_t + \sum_{j=0}^{3} \beta_j y_{t-j} + u_{t+h}^{h}$$

Cumulative Change					Marginal Change				
h	α_0	α_1	$\bar{R}^2$	SEE	h	α_0	α_1	$\bar{R}^2$	SEE
1	3.323*	0.197*	0.048	3.661	4	3.362*	0.303*	0.066	1.767
	(0.607)	(0.070)				(0.419)	(0.096)		
2	3.366*	0.305*	0.039	2.568	5	3.414*	0.331*	0.094	1.732
	(0.488)	(0.092)				(0.367)	(0.086)		
3	3.246*	0.319*	0.052	2.012	6	3.431*	0.310*	0.082	1.746
	(0.411)	(0.079)				(0.343)	(0.113)		
4	3.362*	0.303*	0.066	1.767	7	3.613*	0.237	0.056	1.776
	(0.419)	(0.096)				(0.279)	(0.184)		
5	3.402*	0.306*	0.109	1.500	8	3.564*	0.213	0.038	1.796
	(0.399)	(0.077)				(0.224)	(0.149)		
6	3.421*	0.312*	0.139	1.325	9	3.432*	0.145	0.016	1.815
	(0.337)	(0.065)				(0.256)	(0.164)		
7	3.471*	0.276*	0.133	1.235	10	3.438*	0.082	0.002	1.830
	(0.283)	(0.072)				(0.278)	(0.162)		
8	3.481*	0.261*	0.145	1.132	11	3.327*	0.095	-0.007	1.841
	(0.268)	(0.099)				(0.271)	(0.101)		
12	3.347*	0.202*	0.155	0.832	12	3.052*	0.087	-0.003	1.843
	(0.169)	(0.062)				(0.244)	(0.082)		
16	3.334*	0.185*	0.199	0.676	13	3.003*	0.098	0.006	1.826
	(0.133)	(0.072)				(0.205)	(0.086)		
20	3.257*	0.196	0.297	0.533	14	2.869*	0.087	0.001	1.832
	(0.160)	(0.135)				(0.329)	(0.091)		

NOTE: a. In parentheses are Newey and West (1987) heteroskedasticity and autocorrelation consistent standard errors corrected with twelve lags. b. * denotes statistically significant at the 5 per cent level in two-tailed tests. c. $\bar{R}^2$ and SEE refer to the coefficient of determination adjusted for degrees of freedom and the regression standard error, respectively. d. Row h in the Cumulative Change Panel is based on estimation for t = 1969:Q3 through 2014:Q4 – h. Meanwhile, row h in the Marginal Change Panel is based on estimation for t = 1969:Q3 + h through 2014:Q4 – h, with k = 4. e. All estimation results are based on models including lagged output growth rates (estimates not reported, for the sake of brevity).

Table 3. Predicting future changes in real GNP components using the yield spread

$$x_{t+h}^{h} = \alpha_0 + \alpha_1 s_t + \sum_{j=0}^{3} \beta_j x_{t-j} + u_{t+h}^{h}$$

	y			*cons*			*pd*			*pgfc*			*inv*			*gs*		
h	α_1	$\bar{R}^2$	*SEE*	α_1	$\bar{R}^2$	*SEE*	α_1	$\bar{R}^2$	*SEE*	α_1	$\bar{R}^2$	*SEE*	α_1	$\bar{R}^2$	*SEE*	α_1	$\bar{R}^2$	*SEE*
2	0.305*	0.039	2.568	-0.203	0.111	2.118	2.959*	0.210	13.931	1.898*	0.161	9.915	0.604*	0.255	3.071	-0.249	0.184	6.561
	(0.092)			(0.113)			(0.939)			(0.283)			(0.069)			(0.222)		
4	0.303*	0.066	1.767	-0.069	-0.001	1.605	2.584*	0.219	10.920	1.692*	0.167	8.528	0.302*	0.752	1.536	-0.233	0.238	3.877
	(0.096)			(0.094)			(0.715)			(0.231)			(0.035)			(0.372)		
6	0.312*	0.139	1.325	0.036	-0.022	1.346	1.460*	0.209	8.857	1.634*	0.189	6.399	0.480*	0.630	1.689	-0.119	0.156	2.783
	(0.065)			(0.094)			(0.514)			(0.287)			(0.052)			(0.205)		
8	0.261*	0.145	1.132	0.067	0.006	1.160	0.832	0.233	7.086	1.371*	0.201	5.330	0.615*	0.550	1.705	-0.078	0.147	2.228
	(0.099)			(0.065)			(0.519)			(0.403)			(0.047)			(0.072)		
12	0.202*	0.155	0.832	0.098	0.037	0.846	0.360	0.311	4.323	0.986*	0.198	3.886	0.761*	0.345	1.716	0.003	0.057	1.691
	(0.062)			(0.076)			(0.210)			(0.342)			(0.193)			(0.044)		
16	0.185*	0.199	0.676	0.111*	0.048	0.678	0.480*	0.141	4.146	0.829*	0.220	3.029	0.738*	0.467	1.321	-0.044	0.125	1.459
	(0.072)			(0.052)			(0.191)			(0.197)			(0.194)			(0.057)		

NOTE: a. In parentheses are Newey and West (1987) heteroskedasticity and autocorrelation consistent standard errors corrected with twelve lags. b. * denotes statistically significant at the 5 per cent level in two-tailed tests. c. $\bar{R}^2$ and SEE refer to the coefficient of determination adjusted for degrees of freedom and the regression standard error, respectively. d. Row *h* is based on estimation for *t* = 1969q3 through 2014q4 – *h*. e. All estimation results are based on models including a constant and lagged output growth rates (estimates not reported, for the sake of brevity).

Table 4. Predicting future changes in output using the yield spread and short-term interest rates

$$y_{t+h}^{h} = \alpha_0 + \alpha_1 s_t + \alpha_2 m_t + \sum_{j=0}^{3} \beta_j y_{t-j} + u_{t+h}^{h}$$

	y				*cr*				*rcr*				*b2*			
h	α_1	α_2	$\bar{R}^2$	*SEE*	α_1	α_2	$\bar{R}^2$	*SEE*	α_1	α_2	$\bar{R}^2$	*SEE*	α_1	α_2	$\bar{R}^2$	*SEE*
2	0.305*	n.a	0.039	2.568	0.296*	0.067	0.038	2.327	0.314*	0.156*	0.045	2.318	0.425	-0.179	0.013	1.490
	(0.092)				(0.062)	(0.080)			(0.057)	(0.055)			(0.225)	(0.249)		
4	0.303*	n.a	0.066	1.767	0.349*	-0.026	0.082	1.727	0.367*	0.064	0.084	1.725	0.433	-0.375	0.073	1.044
	(0.096)				(0.053)	(0.114)			(0.057)	(0.053)			(0.226)	(0.205)		
6	0.312*	n.a	0.139	1.325	0.363*	0.028	0.163	1.342	0.374*	0.083*	0.169	1.337	0.435*	-0.331	0.114	0.841
	(0.065)				(0.057)	(0.073)			(0.052)	(0.031)			(0.172)	(0.197)		
8	0.261*	n.a	0.145	1.132	0.350*	-0.021	0.218	1.107	0.363*	0.042	0.219	1.106	0.549	-0.307	0.275	0.687
	(0.099)				(0.041)	(0.041)			(0.050)	(0.030)			(0.167)	(0.168)		
12	0.202*	n.a	0.155	0.832	0.248*	-0.029	0.205	0.847	0.253*	-0.002	0.204	0.847	0.488*	-0.352*	0.387	0.510
	(0.062)				(0.057)	(0.025)			(0.069)	(0.016)			(0.103)	(0.084)		
16	0.185*	n.a	0.199	0.676	0.237	0.094*	0.244	0.670	0.237	0.094*	0.244	0.670	0.352	-0.323*	0.323*	0.447
	(0.072)				(0.177)	(0.020)			(0.177)	(0.020)			(0.122)	(0.068)		

NOTE: a. In parentheses are Newey and West (1987) heteroskedasticity and autocorrelation consistent standard errors. The *y*, *cr* and *rcr* panels are corrected with twelve lags, while the *b2* panel are corrected with three lags due to limited observations. b. * denotes statistically significant at the 5 per cent level in two-tailed tests. c. $\bar{R}^2$ and *SEE* refer to the coefficient of determination adjusted for degrees of freedom and the regression standard error, respectively. d. With the exception of the *b2* panel, row *h* is based on estimation for t = 1969q3 through 2014q4 – *h*. For the *b2* panel, row *h* is based on estimation for t = 1995q2 through 2014q4 – *h*. e. All estimation results are based on models including a constant and lagged output growth rates (estimates not reported, for the sake of brevity).

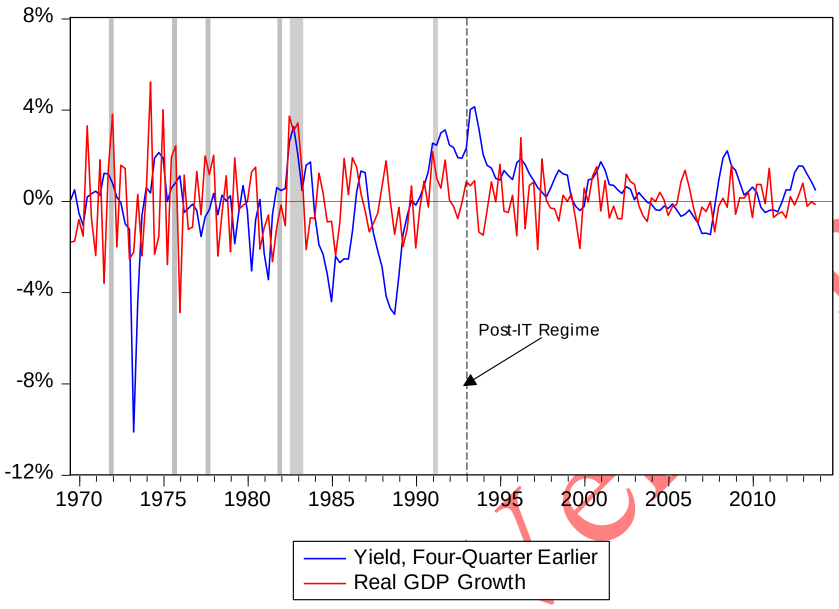
Table 5. Predicting future changes in output using the yield spread and monetary aggregates

$$y_{t+h}^{h} = \alpha_0 + \alpha_1 s_t + \alpha_2 m_t + \sum_{j=0}^{3} \beta_j y_{t-j} + u_{t+h}^{h}$$

	y				*mb*				*m1*				*bm*			
h	α_1	α_2	$\bar{R}^2$	*SEE*	α_1	α_2	$\bar{R}^2$	*SEE*	α_1	α_2	$\bar{R}^2$	*SEE*	α_1	α_2	$\bar{R}^2$	*SEE*
2	0.305*	n.a	0.039	2.568	0.333*	1.371	0.021	2.461	0.293*	26.950*	0.081	2.385	0.398*	33.199*	0.062	2.296
	(0.092)				(0.069)	(1.917)			(0.084)	(8.795)			(0.073)	(11.713)		
4	0.303*	n.a	0.066	1.767	0.367*	-0.514	0.081	1.727	0.334*	20.052*	0.146	1.665	0.452*	28.420*	0.116	1.695
	(0.096)				(0.098)	(1.330)			(0.089)	(8.647)			(0.069)	(11.890)		
6	0.312*	n.a	0.139	1.325	0.359*	0.124	0.151	1.348	0.340*	11.735	0.185	1.321	0.427*	20.130	0.191	1.315
	(0.065)				(0.063)	(0.806)			(0.056)	(6.015)			(0.041)	(13.169)		
8	0.261*	n.a	0.145	1.132	0.335*	0.798	0.197	1.117	0.325*	7.379	0.215	1.105	0.404*	14.661	0.238	1.094
	(0.099)				(0.056)	(0.840)			(0.054)	(3.806)			(0.033)	(11.385)		
12	0.202*	n.a	0.155	0.832	0.245*	0.373	0.196	0.847	0.244*	1.057	0.196	0.846	0.244*	-2.958	0.204	0.848
	(0.062)				(0.102)	(1.041)			(0.061)	(3.067)			(0.058)	(2.934)		
16	0.185*	n.a	0.199	0.676	0.211	0.182	0.218	0.677	0.213*	-1.377	0.219	0.676	0.195*	-6.836*	0.241	0.672
	(0.072)				(0.126)	(0.553)			(0.107)	(3.777)			(0.072)	(3.423)		

NOTE: a. In parentheses are Newey and West (1987) heteroskedasticity and autocorrelation consistent standard errors are corrected with twelve lags. b. * denotes statistically significant at the 5 per cent level in two-tailed tests. c. $\bar{R}^2$ and *SEE* refer to the coefficient of determination adjusted for degrees of freedom and the regression standard error, respectively. d. With the exception of the *b2* panel, row *h* is based on estimation for t = 1969q3 through 2014q4 – *h*. e. All estimation results are based on models including a constant and lagged output growth rates (estimates not reported, for the sake of brevity).

Figure 1. Australian yield spread and recessions



NOTE: a. The spread refers to the difference between the 10-year government bond rate and the 3-month government bill rate. b. The shaded region represents a recession, defined as at least two periods of consecutive negative real GDP growth rate. In total, there are six recessions, and in chronological order, occurred in 1971q4–1972q1, 1975q3–1975q4, 1977q3–1977q4, 1981q4–1982q1; 1982q3–1983q2, and 1991q1–1991q2.

Table 6. Predicting future changes in output using the yield spread, by IT regime

$$y_{t+h}^{h} = \alpha_0 + \alpha_1 s_t + \sum_{j=0}^{3} \beta_j y_{t-j} + u_{t+h}^{h}$$

	1969q3-2014q4			Pre-IT Regime			Post-IT Regime		
h	α_1	$\bar{R}^2$	*SEE*	α_1	$\bar{R}^2$	*SEE*	α_1	$\bar{R}^2$	*SEE*
2	0.305*	0.039	2.568	0.342*	0.039	3.276	0.454*	0.093	1.739
	(0.092)			(0.165)			(0.167)		
4	0.303*	0.066	1.767	0.284	0.060	2.172	0.484*	0.177	1.267
	(0.096)			(0.169)			(0.127)		
6	0.312*	0.065	1.325	0.284	0.131	1.605	0.467*	0.263	0.959
	(0.337)			(0.207)			(0.101)		
8	0.261*	0.145	1.132	0.185	0.106	1.396	0.471*	0.351	0.758
	(0.099)			(0.236)			(0.087)		
12	0.202*	0.155	0.832	0.102	0.056	1.019	0.403*	0.429	0.540
	(0.062)			(0.143)			(0.077)		
16	0.185*	0.199	0.676	0.093	0.086	0.810	0.343*	0.451	0.443
	(0.072)			(0.072)			(0.055)		

NOTE: a. In parentheses are Newey and West (1987) heteroskedasticity and autocorrelation consistent standard errors are corrected with three lags due to data limitation. b. * denotes statistically significant at the 5 per cent level in two-tailed tests. c. $\bar{R}^2$ and *SEE* refer to the coefficient of determination adjusted for degrees of freedom and the regression standard error, respectively. d. Row h in the pre-IT and post-IT regime panels is based on estimation for t = 1969q3 through 1989q4 – h and t = 1990q1 through 2014q4 – h, respectively. All estimation results are based on models including a constant and lagged output growth rates (estimates not reported, for the sake of brevity).

Table 7. Pseudo out-of-sample performance of the yield spread, by selected forecasting evaluating statistics

	y	*cons*	*pd*	*pgfc*	*inv*	*gs*
h = 2						
RMSE	0.223	2.341	0.443	0.521	0.222	4.532
TIC	0.231	0.980	0.121	0.341	0.064	0.776
RMSFE	0.852	1.290	0.674	0.801	0.321	1.373
h = 4						
RMSE	0.312	2.456	0.356	0.531	0.281	3.431
TIC	0.301	0.921	0.081	0.450	0.062	0.791
RMSFE	0.760	1.892	0.741	0.765	0.321	1.331
h = 6						
RMSE	0.281	3.431	0.445	0.483	0.243	5.432
TIC	0.256	0.890	0.123	0.281	0.051	0.816
RMSFE	0.761	1.651	0.889	0.524	0.401	1.345
h = 8						
RMSE	0.299	2.998	0.389	0.473	0.554	6.082
TIC	0.163	0.991	0.157	0.445	0.069	0.871
RMSFE	0.782	1.320	1.002	0.781	0.341	1.983
h =12						
RMSE	0.412	3.414	0.481	0.556	0.514	5.865
TIC	0.282	0.801	0.371	0.541	0.142	0.990
RMSFE	0.693	1.114	0.997	0.888	0.499	1.887
h = 16						
RMSE	0.446	4.012	0.515	0.671	0.764	6.874
TIC	0.203	0.804	0.661	0.522	0.113	0.801
RMSFE	0.701	1.342	1.124	0.934	0.501	1.553

NOTE: a. RMSE, TIC, and RMSFE denote, respectively, the root mean squared error, the Theil inequality coefficient, and the relative mean squared forecast error. b. The initialization period is 1996q1 through 2006q4.