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The information content of the yield spread about future inflation in South Africa

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Abstract: The proposition that inflation expectations can be extracted as inflation predictions from the government bond yield curve has been tested, with partially positive results, using data from the United States and European countries. Despite the abundance of empirical studies of the proposition, relatively few of these studies relate to emerging markets, as most emerging markets lack bond markets with the liquidity, breadth, information availability, and range of maturities that would permit such studies. South Africa's highly developed capital markets do have such characteristics, warranting this study's examination of the proposition's validity for South Africa. Using South African time series data, we find strong evidence for the proposition that the slope of the yield curve, measured as a long- to short-term spread, contains information on the future path of inflation. Examining the sub-periods separated by the adoption, in 2000, of inflation targeting, we find that the monetary policy regime shift strengthened the relationship between the yield spread and future inflation. The results suggest that the yield spread can be used by policy makers and the private sector to help forecast inflation in South Africa.

Keywords: expectations, inflation, monetary policy, South Africa, term structure, yield spread
JEL classification: E31, E37, E52, G12

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1 Introduction

The ability to predict future economic conditions, such as business cycle variables and an inflation measure, using presently available information is valuable for firms, households, and policy makers. In particular, a forward-looking inflation-targeting regime such as that the South African Reserve Bank (SARB) formally adopted in 2000 requires systematically unbiased estimators of expected inflation for Monetary Policy Committee interest rate decisions. In principle, the yield spread—the spread between market yields on short- and long-term government debt—contains information on expectations of future inflation that can be extracted as an estimate of them. The tests reported in this study support the notion that the yield curve does, in fact, contain useful information for inflation-targeting monetary policy in South Africa.

The relationship at any observation date between the market yields of fixed-interest government securities of differing terms to maturity can be represented by a yield curve. Because the instruments are multi-period assets (liabilities) and their yields relate future income streams to the present, the level, slope, and shape of the yield curve reflect rational agents' market views of future economic conditions. Studies of US and other markets have demonstrated that the yield curve does contain information on expected and actual future levels of gross domestic product (GDP) growth, and can be a lead indicator of business cycle downturns (Estrella and Mishkin 1998; Rudebusch and Williams 2009). Others have demonstrated that it contains information on expected and actual future inflation (inter alia, Kotlán 1999; Kozicki 1997; Mishkin 1989). The summary measure of yield curve slope used in existing research is a measure of the yield spread, the difference between yields on longer- and shorter-dated debt securities.

Although many studies indicate the inflation-predicting power of the yield curve in developed countries' markets, little is known of the relationship in emerging economies. The relatively underdeveloped nature of many such economies' fixed-income markets may account for that, but studies of South Africa's yield curve in its highly developed capital market are not subject to such limitations. South African government bonds with nominal value totalling more than R1 trillion and a dense range of maturities are listed on the Johannesburg Stock Exchange, together with a large volume of corporate and other debt. With nearly R25 billion traded daily, the government bond market, supported by the market-making role of appointed primary dealers and a developed ecosystem including markets in derivative products, has high liquidity.[1] This study contributes to the existing body of knowledge within the South African context by empirically examining the ability of the yield spread to provide information about future inflation. Additionally, we examine the effect of the monetary policy regime shift associated with the adoption of inflation targeting on the relationship between the yield spread and future inflation.

This paper is structured as follows: Section 2 reviews the key relevant research literature. Section 3 describes the methodology employed in this paper and the derivation of our model to be estimated. Section 4 details the data used, the empirical results, and interpretation of the findings; Section 5 concludes.

[1] www.jse.co.za/trade/debt-market.

2 Literature review

Empirical studies of the relation between the term structure and future inflation are predominantly founded on a combination of two theoretical propositions.

The first is a model of expectations. The core expectations model of the term structure underpinning modern research has its roots in literature of the 1940s (Hicks 1946; Lutz 1940). The long-term rate is determined by expected values of future interest rates and a risk premium. In models of a frictionless market[2] in which default-free securities are regarded as perfect substitutes distinguished only by their maturity, long rates are determined by rational expectations of short rates over the term to maturity plus a risk premium as the price for term-related uncertainty of future short rates (Cox et al. 1985; Cuaresma et al. 2005; Shiller and McCulloch 1990).

The second is the Fisher Effect, which relates an asset's nominal interest rate to its real interest rate plus expected inflation (Fisher 1930). With real interest rates assumed constant, the expected nominal rate at any maturity is determined by the expected inflation rate during its term and the term-related risk premium. An exogenous shock to the rate of inflation expected to persist over a given horizon will cause an equivalent shock to the nominal yield on bonds of the corresponding maturity (Sargent et al. 1973).

Studies of US and European markets support a consensus that the yield spread contains predictive power for near-term economic activity, including the rate of growth of real GDP, but studies of the relation between the yield spread and future inflation have generated a variety of results. While Shiller et al. (1983), Tzavalis and Wickens (1996), and Mankiw and Summers (1984) point to weak or no evidence of the yield spread's ability to predict inflation, results published by Estrella (2005), Fama (1984), Fama and Bliss (1987), Mishkin (1990a, 1991), Mishkin and Posen (1998), Campbell and Shiller (1991), Kozicki (1997), Ang et al. (2008), Engsted and Tanggaard (1995), and Schich (1999) support the hypothesis that the yield spread does contain information about future inflation for the countries studied.

The differences in results are partly due to differences in estimation techniques, but generally implies that the inflation information content of the yield spread is conditional on factors such as definitions of the variables and segment of the yield curve, the data sample, the monetary policy regime and, more generally, the national economy under study (Berk 1998; Estrella 2005; Kozicki 1997; Schich 1999; Tabak and Feitosa 2009). The present study adds evidence from South Africa to the existing literature.

Recent studies provide evidence for the proposition that the yield curve does contain information about future levels of economic activity and is able to systematically predict business cycle downswings (Botha and Keeton 2014; Clay and Keeton 2011; Khomo and Aziakpono 2007). But there is little published evidence of a systematic relation between South Africa's yield curve and future inflation. Using South African quarterly data from 1985 to 1999, Wesso's vector error correction estimates indicate that long-term bond yields in that period are largely driven by inflation expectations, but he finds a steeper yield curve does not necessarily signal a rise in actual future inflation. Wesso (2000) interprets the results as implying that shifts in long-term yields could

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[2] In the absence of perfect substitutability, due to market frictions or other reasons for investors having strong maturity preferences, short and long securities will trade in markets that are at least partially segmented (Cox et al. 1985; Culbertson 1957; Vayanos and Vila 2009).

partly reflect shifts in the credibility of the central bank's commitment to low inflation, as, for example, could result, outside the sample period, from South Africa's adoption of inflation targeting. Deriving implicit inflation expectations from forward interest rates related to the term structure in a Fisher Effect expectations model, Reid (2009) found that inflation expectations in South Africa have indeed been well anchored by the SARB over the period (2004–09) after the establishment of inflation targeting.

Many emerging markets, including South Africa, have seen a shift in their monetary policy frameworks since the 1990s, adopting inflation-targeting regimes. In estimating the inflation predictive power of the yield curve, this study also examines whether South Africa's adoption of inflation targeting changed the predictive power of the yield spread. Estrella (2005), Estrella and Mishkin (1997), Bernanke (1990), and Tzavalis and Wickens (1996), for instance, did not only confirm that the yield spread helps in predicting inflation, but also revealed that the prevailing monetary policy regime and monetary policy stance have pivotal roles to play in this regard. The intuition is that the sizes of the reaction parameters are important if the monetary policy reacts to deviations of inflation from the target (Reid 2009). With South Africa having adopted an inflation-targeting regime since 2000, we can expect, a priori, that this has enhanced the forecasting power of the yield spread, in line with empirical findings of Laurent (1988), Blinder (1999), Bernanke and Blinder (1992), and Mankiw and Miron (1986).

3 Methodology

Our analysis is carried out using two building blocks. The first is the Fisher equation (1930), which decomposes the nominal interest rate into the (ex-ante) real interest rate and expected inflation rate. This then implies that if movements in nominal interest rates are primarily driven by fluctuations in expected inflation rate rather than changes in real interest rates, the yield spread will help predict the future path of inflation (see Fama 1975; Kotlán 1999). The second hypothesis is the existence of rational expectations. As is common in the literature, instead of a continuous yield curve, we use a short-term to ten-year yield spread as a measure of the slope of the yield curve.[3]

We estimate the inflation-change forecasting equation, which suggests that the yield spread has a predictive power for the future path of inflation. This forecasting equation is essentially a regression of the change in the future *m*-period inflation rate from the *n*-period inflation rate $(\pi_t^m - \pi_t^n)$ on the slope of the yield spread $(i_t^m - i_t^n)$. The predictive power of this equation is dependent on the estimated value of the coefficient of the spread, which is normally positive and increases with the length of the spread (Tzavalis and Wickens 1996).

This equation is expressed as:

$$\pi_t^m - \pi_t^n = \propto_{m,n} + \beta_{m,n}\left[i_t^m - i_t^n\right] + \varepsilon_t^{m,n} \tag{1}$$

[3] Daily zero coupon yield curves have been calculated since 2003; since 2012 they have been constructed and published daily as JSE Zero Coupon Yield Curves using an improved method (Johannesburg Stock Exchange 2012).

3.1 The derivation of the inflation-change forecasting equation

Following Mishkin (1990) and later writers, including Kozicki (1997) and Kotlán (1999), the model is based on the Fisher equation:

$$i_t^m = E_t \pi_t^m + r_t^m \qquad (2)$$

where: i_t^m is the nominal *m*-period interest rate at time *t*; E_t is the rational expectations operator based on information available at time *t*; π_t^m is the inflation rate between time *t* and *m*; and r_t^m is the (ex-ante) real *m*-period interest rate at time *t*.

The observed, actual inflation rate over the next *m*-period can be expressed as the expected rate of inflation plus the forecast error of inflation; that is:

$$\pi_t^m = E_t \pi_t^m + \varepsilon_t^m \qquad (3)$$

Substituting in for $(E_t \pi_t^m)$ from (2) into (3) yields the following:

$$\pi_t^m = i_t^m - r_t^m + \varepsilon_t^m \qquad (4)$$

To obtain an expression for the relationship between the slope of the yield curve and the change in the inflation rate, a similar *n*-period inflation rate equation is subtracted from (4), (*m* > *n*), yielding the slope of the yield curve:

$$\pi_t^m - \pi_t^n = (i_t^m - i_t^n) - (r_t^m - r_t^n) + (\varepsilon_t^m - \varepsilon_t^n) \qquad (5)$$

$$\pi_t^m - \pi_t^n = \propto_{m,n} + \beta_{m,n} \left[i_t^m - i_t^n \right] + \varepsilon_t^{m,n} \qquad (6)$$

where:

$$\propto_{m,n} = \overline{r}_t^n - \overline{r}_t^m \qquad (6a)$$

$$\beta_{m,n} = 1 \qquad (6b)$$

$$\varepsilon_t^{m,n} = (\varepsilon_t^m - \varepsilon_t^n) - (u_t^m - u_t^n) \qquad (6c)$$

$$u_t^m = r_t^m - \overline{r}_t^m \qquad (6d)$$

$$u_t^n = r_t^n - \overline{r}_t^m \qquad (6e)$$

To ensure consistent estimates, Mishkin (1990) assumes a constant slope for the real yield curve throughout time such that $\left(r_t^m - r_t^n\right) = \propto_{m,n}$ (constant). If this condition holds, the $u_t^m - u_t^n$ term in (6c) disappears and the error term $\varepsilon_t^{m,n}$ in equation (6) is reduced to $(\varepsilon_t^m - \varepsilon_t^n)$. Also, turning to the assumption of rational expectations, the forecast error cannot be forecasted given the information at time *t*. That is: $E_t \varepsilon_t^m = E_t \varepsilon_t^n = 0$ and the forecast errors ε_t^m and ε_t^n are then orthogonal to the right-hand side regressors of equation (6). A violation of these assumptions makes the interpretation of the yield curve complicated and reduces its forecasting power for inflation.

The constancy of the slope of the real interest rate has been subject to scrutiny. For example, Lowe (1992) asserts that if prices instantaneously adjust to monetary policy and are fully flexible, the assumption of a constant slope of the real interest rate is plausible and beta ($\beta_{m,n}$) should equate to 1. This is also supported by Frankel and Lown (1991), who claim that even though the real interest rate may be variable in the short run, it converges to a constant in the long run, ensuring a robust forecasting power. These assumptions therefore ensure that the ordinary least-squares (OLS) estimates of equation (6) produce consistent estimates of ($\beta_{m,n}$). However, if the price flexibility assumption fails and the real yield curve varies over time, the nominal yield spread will still contain information about the future inflation path, but it is no longer going to be the optimal predictor because $(u_t^m - u_t^n)$ is no longer zero.

This assertion therefore leads us to testing whether the spread, $(\pi_t^m - \pi_t^n)$, predicts the change in the *n*-period rate over the life of the (*m–n*) periods rate. We therefore go on to test for the statistical significance of the coefficient on the nominal interest rate spread ($\beta_{m,n}$) and also investigate whether it differs from 1 or not. The statistical rejection of the null hypothesis ($\beta_{m,n} = 0$) leads us to conclude that the slope of the yield spread contains significant information about the change in the future *m*-period inflation rate from the *n*-period inflation rate. This also implies that the yield spreads of both the nominal and real interest rates do not move one-for-one with each another. On the other hand, the rejection of the null hypothesis ($\beta_{m,n} = 1$) leads to the conclusion that the slope of the real yield curve is not constant over time and hence the nominal yield spread is not an optimal predictor of future inflation.

This method carries a number of drawbacks. (1) It cannot be assumed that the error terms are independent and identically distributed. This could emanate from the fact that the error term is made up of three components—real interest rate, risk premium, and inflation innovations, which could cause estimation bias and heteroscedasticity. (2) The existence of sticky prices is another drawback, with Frankel and Lown (1991) and Lowe (1992) arguing that the assumption of a constant slope of the real yield curve is overly restrictive. This implies that a long-term interest rate is more likely to reflect inflationary expectations more accurately than are short-term rates. (3) Since the quarterly interval of data is shorter than the forecast horizon, the forecasts are overlapping. This is therefore likely to result in serial correlation with the moving average (MA) process. To account for these problems of autocorrelation and heteroscedasticity, a Newey–West correction procedure is employed (Newey and West 1987). We now turn to the empirical analysis for this study, in which a description of the data used is given.

4 Data and empirical results

4.1 Data

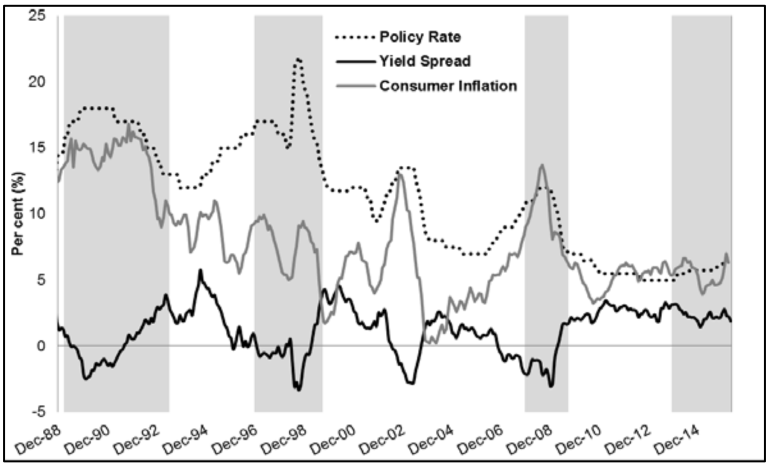
This analysis uses South African quarterly data on inflation rates (consumer price index), the government's 91-day Treasury bill, and ten-year government bond yields (the difference between 91-day and ten-year yields being our measure of the yield spread). The analysis spans the period 1988–2016; data for the ten-year government bond rate before July 1988 were not available. The Treasury bill, government bond data, and inflation data were all obtained from the SARB.

Unit root tests using the augmented Dickey–Fuller (ADF) and the (Kwiatkowski–Phillips–Schmidt–Shin) KPSS procedures showed that long- and short-term yields are not stationary in levels but are all integrated of order one (Harris 1992; Syczewska 2010). It is, however, noteworthy that the yield spread is stationary in levels, that is, integrated of order zero. Inflation, on the other hand, is stationary at the 10 per cent level only when we test for stationarity from 1991Q1; it is therefore assumed that inflation is stationary. This guarantees the feasibility of the usage of OLS regression in levels. The standard errors of the OLS regression are, however, likely to be incorrect due to serial correlation caused by the use of overlapping data. This implies that the horizon of the inflation rate and yields is longer than the observation interval. To account for this, as in Mishkin (1989) and Kotlán (1999), we estimate equation (6) using the Newey–West correction procedure, which accounts for any possible autocorrelation and heteroscedasticity in residuals.

The analysis is first conducted on the full sample period (1991Q1–2016Q1); the series is then split at February 2000, since a shift in the South African monetary policy regime occurred at that time. Towards the end of the 1980s and prior to February 2000, the SARB moved to an 'eclectic' inflation-targeting regime (Van der Merwe 2004). This regime is normally pursued by countries with high credibility in maintaining low and stable inflation without the need for being fully transparent and accountable. We suspect that this new framework may have provoked a change in the information content of the yield spread on future inflation.

Figure 1 shows the SARB's repo rate, inflation, and the yield spread (difference between yields on the ten-year South African government bond and 91-day Treasury bill) series over the period 1988Q3–2016Q1. The shaded bands show historical recessions as defined by the SARB business cycles. The figure shows that the spread tends to decline as the repo rate and inflation increase, and in some cases as the economy enters the downward phase of the cycle. The spread tends to move in the opposite direction to the monetary policy cycle, which is in line with economic theory. Higher short-term rates imply lower future inflation and lower short rates in the future.

Figure 1: Inflation, yield spread, and the SARB's repo rate

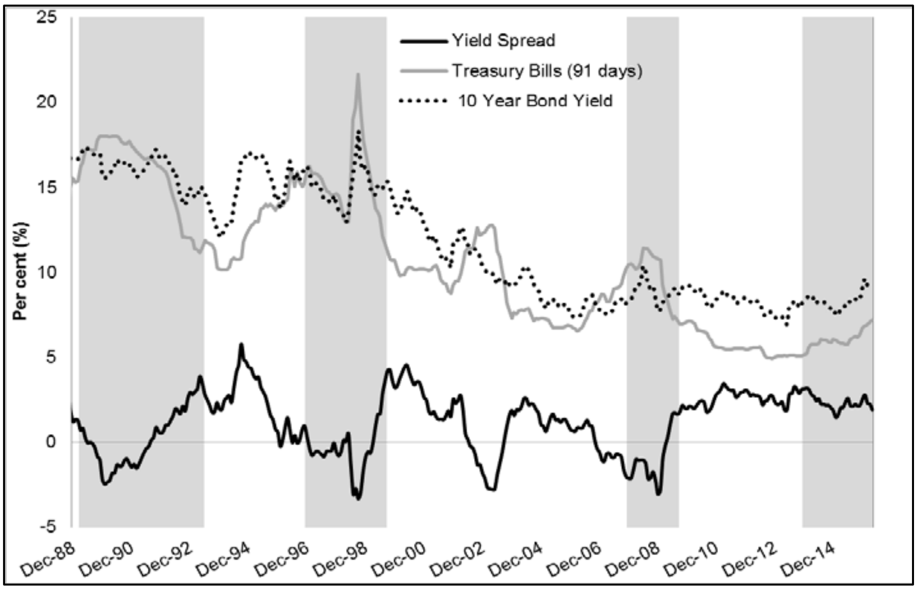


Note: grey shaded area denotes the downward phases of the business cycle as defined by the SARB.

Source: authors, based on data from the SARB.

Figure 2 shows the movements of the yield spread against its individual components (long-term and short-term yields). This graph shows whether changes in the yield spread are driven either by the longer or shorter end of the yield curve. It is clear in Figure 2 that short-term yields generally move faster than long-term yields during a monetary policy easing/tightening cycle. Recessionary periods are generally associated with inverted yield curves, with the spread becoming negative.

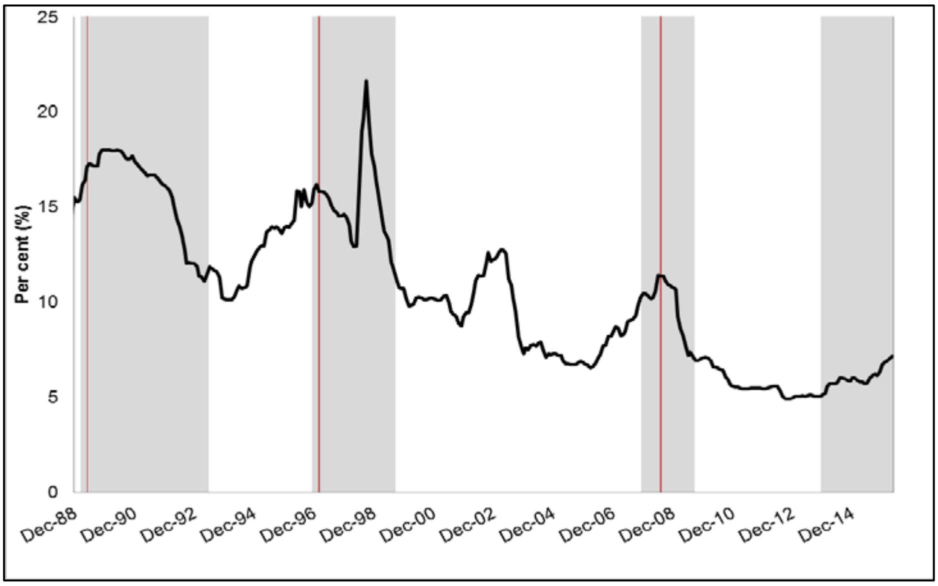
Figure 2: 91-day Treasury bill, yield spread, and ten-year bond



Source: authors, based on data from the SARB.

Figure 3 shows the SARB's repo rate and the end of monetary policy tightening cycles. These cycles are defined as when one of the following conditions is satisfied: (1) the repo rate is higher than at any time from twelve months prior to nine months after and it is 50 basis points higher than at the beginning of the period; (2) the SARB's repo rate is higher than at any time from six months before to six months after and is 150 basis points higher than the average at these points (Adrian et al. 2010).

Figure 3: SARB's repo rate and end of monetary policy cycles



Source: authors, based on data from the SARB.

4.2 Empirical results and interpretation

The relationships between the yield spread and inflation are estimated over varied time frames and horizons. This study tests for the predictive power of the yield spread over 4, 8, 12, 24, 30, and 32 quarters, which came as a consequence of the yield spread showing insignificant results prior to the 24th quarter and the predictive power dying out after the 32nd quarter across all the time sample periods. The results in between these quarters proved not to be different from those of the quarters chosen; for instance, the results obtained from lagging by 16 quarters did not give new insight to those produced by lagging by 12 quarters. The results broadly agree with international evidence, which shows that during the period of inflation targeting, the spread has substantial predictive power (Engsted and Tanggaard 1995). Results are reported in Tables 1–3. Table 1 shows results for the entire period (1990Q3–2016Q1); the sub-periods (1990Q1–1999Q4) and (2002Q1–2016Q1) are reported in Tables 2 and 3 respectively.

Panel B includes lagged inflation as one of the explanatory variables, as in the study by Kozicki (1997), which showed that past inflation rate does help in predicting current inflation. This exercise is done to see if the yield spread still explains future inflation over and above the inclusion of past inflation and also to improve the regression fit of the data. Estimation results indicate that the yield spread has predictive power in the South African data, particularly for the full sample period and for the inflation-targeting regime sub-period. The yield spread has a substantial predictive power between 2000Q1 and 2016Q1, as reported in Table 3. These results tend to support the rational expectations theory. The results for the period 1990Q3 to 1999Q4, however, do not show any predictive power of the spread in forecasting inflation.

Table 1: Estimates of inflation change

Panel A: $\pi_t^m = \propto_{m,n} + \beta_{m,n} \left[i_t^m - i_t^n \right]_{t-h} + \varepsilon_t^{m,n}$; period: September 1990 to March 2016

Spread		Horizon (in quarters)					
		4	8	12	24	30	32
91-day Treasury bill, ten-year bond	$\propto_{m,n}$	7.17	7.29	6.76	6.33	5.65	5.41
	SSE	(0.94)	(0.97)	(0.63)	(0.57)	(0.50)	(0.51)
	t-stat	7.63*	7.55*	10.66*	11.09*	11.20*	10.55*
	$\beta_{m,n}$	–0.20	–0.05	0.18	–0.10	0.49	0.72
	SSE	(0.37)	(0.35)	(0.24)	(0.21)	(0.20)	(0.22)
	t-stat	–0.53	–0.14	0.74	–0.50	**2.44****	**3.24***
	Adjusted R^2	0.01	0.00	0.01	0.01	0.12	0.26
	Wald test[a] $\beta_{m,n} = 0$	0.60	0.89	0.46	0.62	0.02	0.00
	Wald test[a] $\beta_{m,n} = 1$	0.00	0.00	0.00	0.00	0.01	0.21

Panel B: $\pi_t^m = \propto_{m,n} + \beta_{m,n}\left[i_t^m - i_t^n\right]_{t-h} + \pi_{t\ t-4}^m + \varepsilon_t^{m,n}$; period: September 1990 to March 2016

Spread		Horizon (in quarters)					
		4	8	12	24	30	32
	$\propto_{m,n}$	3.29	3.10	3.61	5.84	5.58	5.63
	SSE	(1.24)	(0.94)	(0.98)	(1.39)	(0.96)	(0.94)
	t-stat	2.66*	3.32*	3.67*	4.20*	5.80*	6.02*
	$\beta_{m,n}$	0.08	0.12	0.18	–0.07	0.49	0.72
	SSE	(0.33)	(0.21)	(0.19)	(0.23)	(0.20)	(0.23)
	t-stat	0.24	0.59	0.93	–0.30	**2.37****	**3.09***
	Inflation$_{t-4}$	0.50	0.53	0.43	0.07	0.01	–0.04
	SSE	(0.14)	(0.15)	(0.15)	(0.19)	(0.16)	(0.17)
	t-stat	3.56*	3.59*	2.84*	0.38	0.07	–0.22
	Adjusted R^2	0.27	0.31	0.23	0.01	0.12	0.26
91-day Treasury bill, ten-year bond	Wald test[a] $\beta_{m,n} = 0$	0.81	0.56	0.35	0.76	0.02	0.00
	Wald test[a] $\beta_{m,n} = 1$	0.01	0.00	0.00	0.00	0.01	0.24

Note: *, **, and *** denote significance at the 1, 5, and 10 per cent critical level, respectively.

Standard errors calculated for Newey–West adjusted covariation matrices.

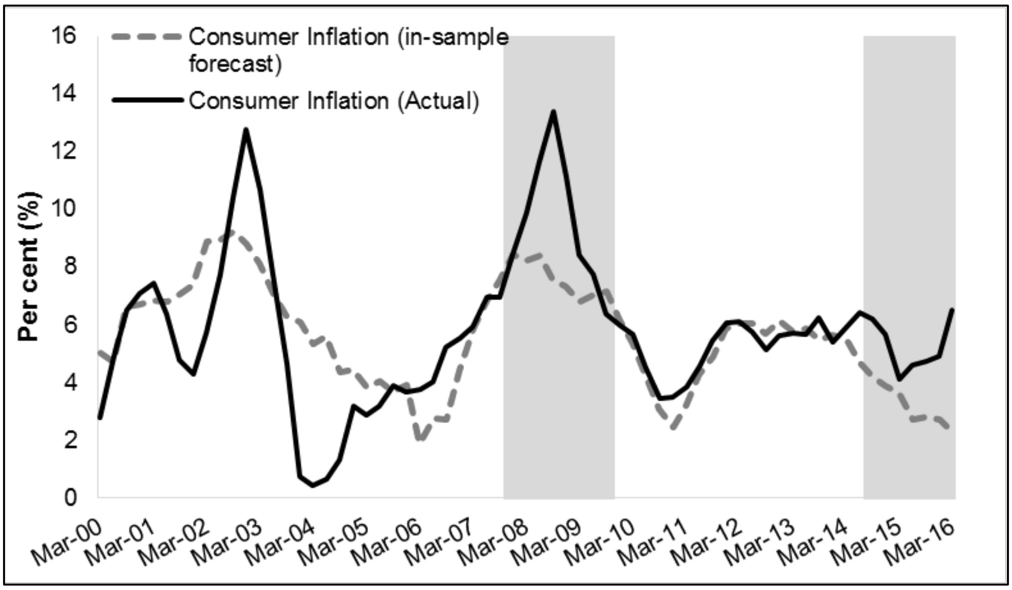
[a] Wald test: *p*-values of F-statistic reported

Source: authors, based on SARB data.

The results in Table 1 for both Panel A and B are roughly the same and show that the spread has no to little predictive power for the short to medium term (that is, for 4–24 quarters (1–6 years)). In most cases the $\beta_{m,n}$ coefficients have the wrong signs and are insignificant. However, for forecast horizons over 30 quarters (that is, 7.5 years), the coefficients of the yield spread are significant and close to 1. The fit of the regression is very poor, as shown by very low adjusted R^2, with Panel B's relatively better than those of Panel A. There is a significant improvement in the adjusted R^2 for forecast horizons of over 30 quarters. This study also presents results of the Wald test. This test assumes the null hypothesis of $\beta_{m,n} = 0$ or 1 and fails to reject at 1, 5, and 10 per cent significance levels. The results of the Wald test: $\beta_{m,n}$ coefficient being significantly different from 0 is not rejected for forecasts over 32 quarters. For quarter 30, however, the Wald test rejects both the cases that the $\beta_{m,n}$ coefficient is significantly different from 1 and 0; this is a borderline scenario.

On a broader view, these results can be interpreted as follows. The yield spread for the South African data does contain useful information about the future path of inflation for forecast horizons above 30 quarters. Even though not precisely, the results of this paper broadly compare well with those of Mishkin (1990a, 1991), Miskin and Posen (1998), Campbell and Shiller (1991), Kozicki (1997), Estrella (2005), Ang et al. (2008), and Schich (1999) in that the term structure of interest rates provides little information on the short end of the yield curve about future changes of inflation. As noted by Kotlán (1999), this could be as a result of great variability of real interest rates in the short run, which could eclipse the inflation expectations component. Figure 4 shows how well the forecast according to 32 quarters tracks the actual data on inflation in South Africa.

Figure 4: Inflation forecasts according to an eight-year lag spread for the entire sample period



Note: grey shaded areas denote the downward phases of the business cycle as defined by the SARB.

Source: authors, based on SARB data.

Switching to the analysis of the regime switch effect, Table 2 presents results for regime 1 (1990Q1–1999Q4), in which the SARB did not formally target inflation. This analysis is aimed at uncovering the usefulness of the inflation-targeting regime in anchoring inflation expectations post-2000. Estrella (2005), Gurkaynak et al. (2006), and Reid (2009) all concurred that the relationship between the yield spread and the future inflation evolution are broadly influenced by the monetary policy regime. In Table 2 Panels A and B, we see that the $\beta_{m,n}$ coefficients are all insignificant across all forecast horizons, and most of them even carry wrong signs. Even though the adjusted R^2 are slightly higher compared to Table 1, the Wald test that hypothesized that the β coefficients significantly differ from 0 cannot be rejected for all forecast horizons. As such, these results are in agreement with those of Estrella, Gurkaynak et al., and Reid, that in the absence of an inflation-targeting regime, inflation expectations are not anchored and hence the yield spread tends to have weak or no predictive power about future inflation.

Table 2: Estimates of inflation change

Panel A: $\pi_t^m = \propto_{m,n} + \beta_{m,n}\left[i_t^m - i_t^n\right]_{t-h} + \varepsilon_t^{m,n}$; sub-period: September 1990 to December 1999 sample

Spread		Horizon (in quarters)					
		4	8	12	24	30	32
91-day Treasury bill, ten-year bond	$\propto_{m,n}$	10.06	10.12	9.49	7.63	7.02	7.18
	SSE	(1.32)	(1.33)	(0.93)	(0.59)	(0.71)	(0.86)
	t-stat	7.62*	7.61*	10.23*	13.00*	9.88*	8.32*
	$\beta_{m,n}$	–0.53	–0.42	–0.32	–0.11	–0.51	0.25
	SSE	(0.54)	(0.46)	(0.28)	(0.31)	(0.36)	(0.33)
	t-stat	–0.97	–0.90	–1.15	–0.34	–1.39	0.75
	Adjusted R^2	0.08	0.05	0.03	0.01	0.12	0.03
	Wald test[a] $\beta_{m,n} = 0$	0.34	0.37	0.26	0.73	0.19	0.47
	Wald test[a] $\beta_{m,n} = 1$	0.01	0.00	0.00	0.00	0.00	0.04

Panel B: $\pi_t^m = \propto_{m,n} + \beta_{m,n}\left[i_t^m - i_t^n\right]_{t-h} + \pi_{t\ t-4}^m + \varepsilon_t^{m,n}$; sub-period: September 1990 to December 1999 sample

Spread		Horizon (in quarters)					
		4	8	12	24	30	32
91-day Treasury bill, ten-year bond	$\propto_{m,n}$	2.98	1.30	2.84	12.19	12.60	14.56
	SSE	(2.14)	(2.11)	(2.81)	(2.12)	(2.00)	(2.58)
	t-stat	1.39	0.62	1.01	5.76*	6.29*	5.65*
	$\beta_{m,n}$	–0.31	0.28	0.11	–0.22	–0.35	–0.01
	SSE	(0.37)	(0.33)	(0.40)	(0.35)	(0.41)	(0.29)
	t-stat	–0.83	0.85	0.29	–0.62	–0.86	–0.03
	Inflation_{t-4}	0.65	0.76	0.60	–0.55	–0.71	–0.98
	SSE	(0.18)	(0.19)	(0.27)	(0.29)	(0.24)	(0.35)
	t-stat	3.54*	3.92*	2.25**	–1.90*	–2.89**	–2.82**
	Adjusted R^2	0.45	0.44	0.33	0.16	0.40	0.39
	Wald test[a] $\beta_{m,n} = 0$	0.41	0.40	0.77	0.54	0.40	0.98
	Wald test[a] $\beta_{m,n} = 1$	0.00	0.04	0.03	0.00	0.01	0.01

Note: *, **, and *** denote significance at the 1, 5, and 10 per cent critical level respectively.

Standard errors calculated for Newey–West adjusted covariation matrices.

[a]Wald test: *p*-values of F-statistic reported.

Source: authors, based on SARB data.

Table 3 presents the results of the inflation-targeting regime employed by the SARB in February 2000. In Panel B we lag inflation by two instead of four; this is because current inflation within an inflation-targeting regime is more forward-looking and hence if lagged by four quarters it fails to explain current inflation and is insignificant. The results for Panel A and B differ slightly from each other in that the inclusion of the inflation component means the spread has a predictive power as early as from quarter 24 going forward. The results of Table 3 also prove to be more robust relative to the previous results.

Table 3: Estimates of inflation change

Panel A: $\pi_t^m = \propto_{m,n} + \beta_{m,n}\left[i_t^m - i_t^n\right]_{t-h} + \varepsilon_t^{m,n}$; sub-period: February 2000 to March 2016 sample

Spread		Horizon (in quarters)					
		4	8	12	24	30	32
91-day Treasury bill, ten-year bond	$\propto_{m,n}$	5.84	5.58	5.49	5.87	5.05	4.76
	SSE	(1.04)	(0.64)	(0.47)	(0.70)	(0.42)	(0.46)
	t-stat	5.60*	8.72*	11.80*	8.36*	11.93*	10.36*
	$\beta_{m,n}$	–0.03	0.20	0.34	–0.08	0.74	0.94
	SSE	(0.42)	(0.21)	(0.22)	(0.24)	(0.17)	(0.22)
	t-stat	–0.07	0.95	1.57	–0.35	**4.26***	**4.20***
	Adjusted R^2	0.00	0.02	0.06	0.00	0.29	0.44
	Wald test[a] $\beta_{m,n} = 0$	0.95	0.35	0.12	0.73	0.00	0.00
	Wald test[a] $\beta_{m,n} = 1$	0.02	0.00	0.00	0.00	0.14	0.79

Panel B: $\pi_t^m = \propto_{m,n} + \beta_{m,n}\left[i_t^m - i_t^n\right]_{t-h} + \pi_{t\ t-2}^m + \varepsilon_t^{m,n}$; sub-period: February 2000 to March 2016 sample

Spread		Horizon (in quarters)					
		4	8	12	24	30	32
91-day Treasury bill, ten-year bond	$\propto_{m,n}$	1.86	2.30	2.40	1.92	2.36	3.05
	SSE	(0.61)	(0.58)	(0.62)	(0.54)	(0.48)	(0.66)
	t-stat	3.07*	3.96*	3.88*	3.57*	4.94*	4.61*
	$\beta_{m,n}$	0.23	0.12	0.10	0.21	0.57	0.67
	SSE	(0.26)	(0.18)	(0.21)	(0.12)	(0.14)	(0.22)
	t-stat	0.88	0.66	0.48	**1.80*****	**4.08***	**3.01***
	Inflation$_{t-2}$	0.64	0.59	0.58	0.65	0.50	0.35
	SSE	(0.10)	(0.12)	(0.12)	(0.12)	(0.10)	(0.13)
	t-stat	6.12*	4.85*	4.64*	5.48*	4.96*	2.74*
	Adjusted R^2	0.40	0.38	0.38	0.40	0.53	0.53
	Wald test[a] $\beta_{m,n} = 0$	0.38	0.51	0.63	0.08	0.00	0.00
	Wald test[a] $\beta_{m,n} = 1$	0.00	0.00	0.00	0.00	0.00	0.14

Note: *, **, and *** denote significance at the 1, 5, and 10 per cent critical level respectively.

Standard errors calculated for Newey–West adjusted covariation matrices.

[a]Wald test: *p*-values of F-statistic reported

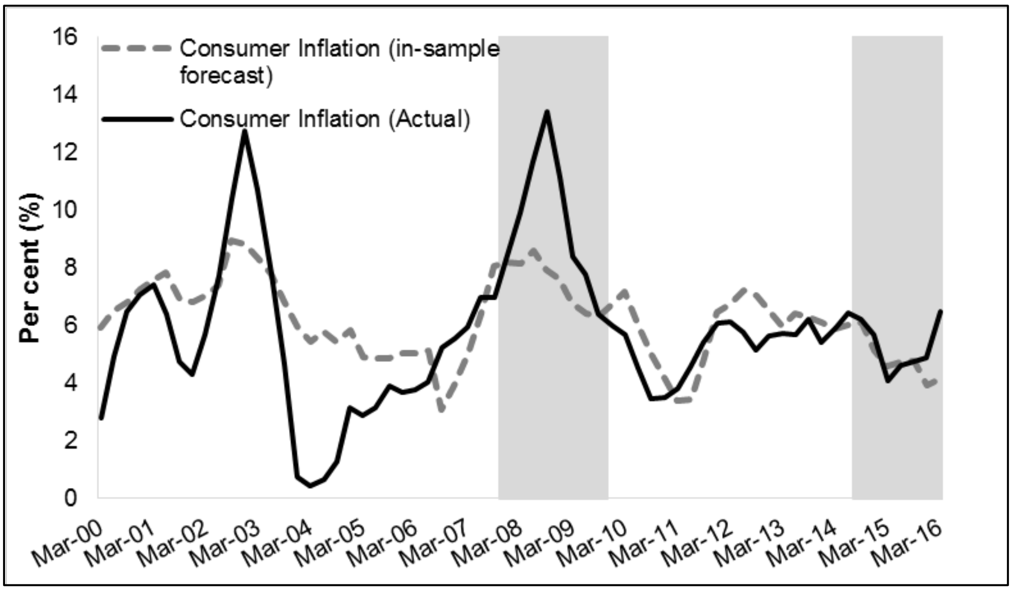
Source: authors, based on SARB data.

The $\beta_{m,n}$ coefficients of Table 3 Panel A are insignificant up to quarter 26 (6.5 years); however, from quarter 27, the yield spread coefficient is significant and thus explains the future changes of inflation. Interestingly, including a two-lag inflation term, the spread starts becoming significant as early as quarter 24 (six years) and has correct signs across all forecast horizons. The adjusted R^2

are very low for Panel A prior to quarter 30, indicating a poor fit of the regressions. There is, however, a slight improvement from quarter 30 going forward. Panel B, on the other hand, shows relatively higher adjusted R^2 across all horizons; this shows that including a lagged inflation term as one of the regressors significantly improves the fit. In Panel A, the hypothesis that $\beta_{m,n}$ significantly differs from 0 is not rejected from quarter 30 onwards. For Panel B, we can conclude that since we cannot reject the null ($\beta_{m,n}$ = 0) for quarters 4, 8, and 12, the slope of the real yield curve is not constant over time and hence the nominal yield spread is not an optimal predictor of future inflation.

The results of Table 3 can therefore be broadly interpreted as follows. The South African yield spread contains useful information about the future evolution of inflation only for forecast horizons from 24 quarters ahead. Figure 5 shows that the forecast using quarter 30 tracks the actual data on inflation more closely than the one showed in Figure 2, which confirms and complements the findings of Estrella, Gürkaynak et al., and Reid. Table 3 further shows that inflation expectations are well anchored under the inflation-targeting regime, which implies that long-term yields provide useful information about the future of inflation.

Figure 5: Forecast of 30-quarter yield spread compared to actual inflation



Note: grey shaded areas denote the downward phases of the business cycle as defined by the SARB.

Source: authors, based on SARB data.

Table 4 shows the fit of forecast according to 32 quarters; the forecast tracks the actual data of inflation in South Africa quite closely. In Table 4 the comparison of the forecast equation estimates using 30 quarters (7.5 years) spread lag for both the entire period and the inflation-targeting regime. The results for the inflation-targeting regime are more robust compared to those of the entire period. For instance, the adjusted R^2 for the entire period regression (0.12) is much lower than that of the inflation-targeting regime (0.51). This shows that the regression for the inflation-targeting regime is a better fit and produces better results. Table A1 shows the estimates for all the lags, and the results for the inflation-targeting regime tend to outperform those of the entire period across horizons.

Table 4: Forecast comparison between the entire sample and the inflation-targeting regime

Estimates	30-quarter lag	
	2000Q1–2016Q1	1991Q1–2016Q1
$\beta_{m,n}$	0.57	0.49
t-stat	**4.08***	**2.37****
Adjusted R^2	0.53	0.12
AIC	4.19	4.67
SIC	4.13	4.76

Note: *, **, and *** denote significance at the 1, 5, and 10 per cent critical level respectively.

Source: authors, based on SARB data.

5 Conclusion

The evidence provided in this paper suggests that the slope of the yield curve is useful in forecasting the future path of inflation. These results put forward that the yield spread should not be used to forecast the near-term inflation rate (that is, 23 quarters or less). The yield spread is, however, useful for predicting changes in future inflation over 24 quarters in the South African case. The results are much stronger for the inflation-targeting regime, confirming the credibility of monetary policy in anchoring long-term inflation. These findings are in harmony with those of Reid (2009), affirming that the SARB has been able to stabilize and manage inflation expectations through its transparent and credible monetary policy. The results of this paper are consistent with the theory that monetary policy has direct effects on the short end (real interest rates) of the yield curve because of price stickiness. Long-term yields, however, more closely mimic the behaviour of inflation expectations than do short-term rates as prices are fully flexible in the long run. Berk (1988), however, points out that caution should be exercised by policy makers when using the yield spread as a tool to forecast inflation. This is because many factors can shift the ends of the yield curve and at face value may prompt monetary authorities to respond inappropriately.

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Appendix

Table A1: Forecast comparison between the entire sample and the inflation-targeting regime: comparing the entire period and the inflation-targeting period

Period		Horizon (in quarters)					
		4	8	12	24	30	32
2000Q1–2016Q1	$\beta_{m,n}$	0.23	0.12	0.10	0.21	0.57	0.67
	t-stat	0.88	0.66	0.48	**1.80*** **	**4.08***	**3.01***
	Adjusted R^2	0.40	0.38	0.38	0.40	0.53	0.53
	AIC	4.35	4.37	4.48	4.35	4.19	4.09
	SIC	4.45	4.47	4.42	4.45	4.13	4.20
1991Q1–2016Q1	$\beta_{m,n}$	0.08	0.12	0.18	–0.07	0.49	0.72
	t-stat	0.24	0.59	0.93	–0.30	**2.37** **	**3.09***
	Adjusted R^2	0.27	0.31	0.23	0.01	0.12	0.26
	AIC	5.04	5.04	5.08	4.82	4.67	4.62
	SIC	5.12	5.12	5.03	4.91	4.76	4.56

Note: *, ** and *** denotes significance at the 1, 5, and 10 per cent critical level respectively.

Source: authors, based on SARB data.