Forecasting Output Growth Using a DSGE-Based Decomposition of the South African Yield Curve*

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Abstract

Evidence in favor of the ability of the term spread to forecast economic growth of the South African economy is non-existent. Presuming that this could be due to the term spread aggregating, and hence loosing out on important, information contained in the expected spread and the term premium, we: (i) Develop an estimable Small Open Economy New Keynesian Dynamic Stochastic General Equilibrium (SOENKDSGE) model of the inflation targeting South African economy; (ii) Use the SOENKDSGE model estimated using Bayesian methods, to decompose the term spread into an expected spread and the term premium over the quarterly period of 2000:01−2014:04, and; (iii) Use a linear predictive regression framework to analyze the out-of-sample forecasting ability of the aggregate term spread, as well as the expected spread and term premium. Our forecasting results fail to detect forecasting gains from the aggregate term spread and also the term premium, but the expected spread is found to contain important information in forecasting the output growth over short- to medium-run horizons, over the period of 2004:01−2014:04, using an in-sample period of 2000:01−2003:04. In other words, we confirm our presumption, and in the process highlight the importance of the forward looking component of the term spread, i.e., the expected spread, in forecasting output growth of South Africa.

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1 Introduction

Economists have been intrigued by the behaviour of interest rates at various maturities, more formally known as the yield curve, for more than a century.[1] Once Kessel (1965) pointed out that movements in the yield curve were driven by the business cycle, a substantial literature blossomed around the yield curve's predictive ability. The general consensus that has emerged from this literature – although varying over time and across countries – is that the yield spread (i.e., the difference between interest rates on long-term and short-term bonds) has the ability to predict the future level of output (see for example, Wheelock and Wohar (2009); Chinn and Kucko (2015), and references cited therein for a detailed literature review in this regard).[2]

The expectations hypothesis states that the yield of a given maturity should equal the average of expected short term rates over the period until maturity. In other words, bonds of different maturities are perfect substitutes which, in turn, implies that the slope of the yield curve is flat on average. Empirically, however, the yield curve tends to slope upwards on average (Mishkin, 2007). This empirical shortcoming of the expectations hypothesis in explaining the upward-sloping nature of the yield curve is addressed by the liquidity premium theory. It extends the expectations hypothesis by assuming that bonds of different maturities are not perfect substitutes, given that investors generally prefer to hold shorter-term bonds due to the increasing interest rate risk that they face when holding longer-term bonds. As a result, in order to be induced to hold longer-term bonds, investors require a liquidity or term premium that will compensate them for the additional risk. The term premium, which increases along with the maturity of the bond, explains the tendency of the yield curve to slope upwards. In sum, the yield spread is determined by the financial market's expectation of future short rates and a term premium (see Section 2 for further details).

At this stage, a relevant question that needs to be answered is: *Why might the spread predict GDP growth?* Given that the term spread can be decomposed into expected short rates and the term premium, the relationship between the yield spread and future economic activity could be explained through the role of either of these two components, as elegantly discussed in Hamilton and Kim (2002), and which we discuss briefly next. Suppose that the monetary authority decides to adopt a contractionary monetary policy, which will cause market agents to expect that short-term interest rates will rise temporarily. If the current short-term interest is higher than the expected future short-term rate, the long-term rate should rise as well, but less than the short-term rate, as predicted by the expectations hypothesis. Thus, the yield spread will be flattened. The tight

[1]See Mitchell (1913).

[2]Understandably, there is also a huge literature that analyses the ability of the term-spread to predict recession probabilities (see Estrella and Mishkin (1995, 1996, 1998) for detailed discussions in this regard).

monetary policy will eventually reduce spending in interest sensitive sectors of the economy, thus reducing economic growth. In the same vein, a loose monetary policy would result in a high yield spread, which, in turn, would signal faster future real economic growth. Alternatively, if market participants anticipate an economic boom and future higher rates of return to investment, then expected future short rates will exceed the current short rate, which will result in the yield on long-term bonds to rise relative to short-term yields according to the expectations hypothesis.

Note that, both of these interpretations of the yield spread's ability for forecasting economic growth operate through its role as a signal of future expected short rates. However, as outlined by the liquidity premium theory, the spread also contains a term premium. If, towards the end of a boom, interest rates become more volatile, then this could reduce the spread. This might cause long rates to fall relative to short rates towards the end of an expansion, because the cyclical volatility requires a change in the risk premium, but not because future short rates are expected to fall. Understandably, it is thus useful to decompose the spread's forecasting contribution into an expectations effect and a term premium effect.

Against this backdrop, the objectives of this current paper are twofold: First, it develops a small open economy New Keynesian Dynamic Stochastic General Equilibrium (SOENKDSGE) model for an emerging economy–South Africa–to decompose term spread into expected short spread and term premium, by allowing for imperfect asset substitutability (as in Andrés et al. (2004)) in an otherwise standard SOENKDSGE model. De Graeve et al. (2009) and Zagaglia (2013) argue that the rigorous specification of the macroeconomy within a DSGE framework allows for a more accurate modelling of the formation of expectations, as opposed to competing macro-finance models[3] (see for example, Ireland (2014) for a detailed discussion of affine structure models), and hence, our decision to rely on the former to decompose the term spread. As pointed out by Zagaglia (2013), the main problem of the macro-finance model is that the bond yields at different maturities are priced from adhoc stochastic discount factors, which in turn, do not arise from a microfounded structure of intertemporal utility maximization. And second, we analyse the ability of the term-spread as a whole, as well as its unobserved components (the expected short spread and term premium) separately in forecasting economic growth. This is done over an out-of-sample period of 2004:01−2014:04 using an in-sample period of 2000:01−2003:04. For our forecasting exercise, we use a linear predictive regression framework. Note that, the split between in- and out-of-samples is determined by the Bai and Perron (2003) test of multiple structural breaks applied to a first-order[4]

[3]The macro-finance models describe the evolution of macroeconomic variables, such as output and inflation, from reduced-form aggregate demand and Phillips curves, and hence are not microfounded (Zagaglia, 2013).

[4]Both the Akaike Information Criterion and the Schwarz Information criterion chose a lag-length of one for the growth rate of GDP, allowing for a maximum lag of four.

autoregressive model of the growth rate of GDP. Five break points are identified, with the first being 2004:01, followed by 2008:03, 2009:02, 2011:02 and 2014:02.[5] With the forecasting exercise based on a recursive estimation scheme over the out-of-sample period, we are able to account for all possible parameter changes in the forecasting models due to these breaks. Note that the starting point of our sample coincides with the inflation targeting regime in South Africa (February, 2000), while the end point is purely driven by data availability at the time of writing this paper.

The decision to revisit the ability of the term spread to forecast economic growth in South Africa emanates from the non-existent out-of-sample evidence as observed by Gupta and Hartley (2013) and Thompson et al. (2015), even though, there exist some evidence of in-sample predictability as depicted in Nel (1996), Moolman (2004), Bonga-Bonga (2010), and du Plessis, Smit, and Steinbach (2015). Interestingly, the literature on the term spread in South Africa has primarily focussed on predicting (in-sample) recession probabilities, with some success, using probit-type models (see Mohapi and Botha (2013) for a detailed literature review in this regard) rather than predicting real GDP growth per se, barring the above exceptions. However, as stressed by Campbell (2008), the ultimate test of any predictive model is its out-of-sample performance, with in-sample predictive ability providing no guarantee in terms of forecasting. In addition, note that, none of the above-mentioned studies, barring du Plessis et al. (2015),[6] have made an attempt to analyse the predictive (in-sample or out-of-sample) ability (for recession probabilities or output growth) of the subcomponents of the term spread, i.e. the expected spread and the term premium. This neglect of the decomposition of the term structure could be a possible reason behind the weak performance of the term-spread when forecasting output growth, as the aggregate term spread could be compromising on important predictive content originating either from the expected short spread or the term premium. Given the above discussion, the primary contributions of our study are: (i) This is the first paper to develop a SOENKDSGE model for decomposing the term spread for any SOE, with all other existing studies on this decomposition concentrating on closed-economy DSGE models (see for example, Andrés et al. (2004), De Graeve et al. (2009), Doh (2008), Amisano and Tristani (2008), and Zagaglia (2013)) and; (ii) Use the decomposed term structure (besides the aggregate term spread) to forecast economic growth for South Africa - our case study, over an out-of-sample horizon based on a predictive regression framework.

The rest of the paper is organized as follows: Section 2 outlines the SOENKDSGE, with information on data used to estimate the model, the estimation results, and decomposition of the

[5] Complete details of the Bai and Perron (2003) test of multiple structural breaks are available upon request from the authors.

[6] du Plessis et al. (2015), like us, also used a SOENKDSGE to decompose the term-spread, but unlike us, only concentrated on in-sample predictability of the growth rate over the period of 2000:01−2010:04.

term-spread. Section 3 presents the forecasting results based on the linear predictive regression framework, while Section 4 concludes.

2 The SOENKDSGE model

The model used is essentially incorporating SOE features, based on the works of Gali and Monacelli (2005), Steinbach et al. (2009) Adolfson et al. (2007), Justiniano and Preston (2010), and Alpanda et al. (2010a) into the closed-economy DSGE model of imperfect asset substitutability as developed by Andrés et al. (2004). The setup is briefly discussed below.

2.1 Households

The asset portfolio of households consists of money, one-period domestic and foreign bonds, as well as L-period zero-coupon bonds $(B_{L,t})$.[7]

The one-period bond pays a gross return of R_t while, following Andrés et al. (2004) and it is assumed that households hold their long-term bonds until they mature in period $t + L$, at which point these bonds yield a gross return of $(R_{L,t})^L$.

In order to ensure positive holdings of both one-period and L-period bonds in equilibrium – irrespective of differences in yield – the model incorporates imperfect substitutability among assets, largely motivated by the work of Tobin (1958, 1969 and 1982). As a result, following **?**, it is assumed that bond trading is costly for the household, and hence, it pays the following quadratic adjustment cost when purchasing the long-term bond:

$$AC_t^b = \frac{\phi_L}{2} \left(\frac{b_{L,t}}{b_{L,t-1}} \right)^2 y_t. \tag{1}$$

The adjustment cost – measured in terms of stationary real bond holdings – may be interpreted as transaction costs on bond trading that are paid in terms of output.[8] This formulation allows variations in the spread between the one-period and long-term bond, both in equilibrium and over time. The magnitude of the adjustment cost parameter ϕ_L reflects the opportunity cost associated with holding a bond of longer maturity. As such, $\phi_L > 0$, and $R_L > R$.

Moreover, the household's money holdings are directly affected by its holding of long-term bonds. Andrés et al. (2004) argue that households experience a loss of liquidity when purchasing

[7]For the purposes of this paper, $L = 40$ such that the L-period bonds represent South African 10 year government bonds.

[8]Nominal bond holdings $B_{L,t}$ is deflated by the domestic price level P_t^d, and rendered stationary by removing the common trend as reflected by the permanent technology shock z_t, as follows: $b_{L,t} = B_{L,t}/(z_t P_t^d)$.

bonds of maturities in excess of one period. As a result, they compensate for this loss of liquidity by holding additional money. This friction can therefore be represented as an adjustment cost function between the relative holdings of money and the L-period bond, as follows:

$$AC_t^m = \frac{\nu_L}{2} \left(\frac{m_t}{b_{L,t}} \kappa_L - 1 \right)^2 y_t \tag{2}$$

where κ_L is the inverse of the steady state ratio m/b_L, such that the adjustment cost is zero in the steady state.

Consequently, the representative household maximises the following intertemporal utility function:

$$E_0^j \sum_{t=0}^{\infty} \beta^t \left[\xi_t^c \ln \left(C_t - bC_{t-1} \right) - \xi_t^h A_L \frac{(h_t)^{1+\sigma_L}}{1+\sigma_L} + A_m \frac{m_t^{1-\sigma_m}}{1-\sigma_m} \right] \tag{3}$$

subject to the budget constraint:

$$\begin{aligned} M_t(1 + AC_t^m) + \frac{B_t}{R_t} + \frac{B_{L,t}}{(R_{L,t})^L}(1 + AC_t^b) + \frac{S_t B_{j,t}^*}{R_t^* \Phi\left(\frac{A_t}{z_t}, S_t, \tilde{\phi}_t\right)} \\ + P_t^c C_t + P_t^i I_t + P_t^d \left[a(u_t) K_{t-1} + P_t^{k'} \Delta_t \right] \\ = M_{t-1} + B_{t-1} + B_{L,t-L} + S_t B_{t-1}^* + W_t h_t + R_t^k u_t K_t + \Pi_t - T_t, \end{aligned} \tag{4}$$

where C_t and h_t denote household consumption and labour supply, while $m_t = M_t/(z_t P_t^d)$ denotes its stationary real cash holdings. A_m and σ_m respectively pin down steady state money holdings and determine the curvature of money demand. Within the budget constraint of Equation (4), households purchase new money holdings, L-period bonds, one-period domestic and foreign bonds (where the bond prices are inversely proportional to their respective gross nominal interest rates), nominal consumption goods, nominal investment goods, they pay adjustment costs on capital utilisation and also purchase installed capital. The wealth households carry over from $t-1$ consists of cash holdings as well as their maturing domestic and foreign bond portfolio. Households are remunerated for the labour they supply and the capital services they rent to firms. In addition, they receive profits from firm ownership, Π_t, while they pay nominal lump-sum taxes to the government, T_t.

First-order conditions Optimising Equations (3) and (4) with respect to the two assets that are key to the term-structure extension of the model – money and L-period bonds – yields the following first-order conditions:

Money holdings, m_t

$$E_t\left[\frac{\beta\psi^z_{t+1}}{\pi_{t+1}\mu^z_{t+1}}\right]+A_m m_t^{-\sigma_m}-\psi^z_t\left\{1+AC^m_t+\left[\nu_L\kappa_L\left(\frac{m_t}{b_{L,t}}\kappa_L-1\right)\frac{m_t}{b_{L,t}}\right]y_t\right\}=0 \tag{5}$$

Holdings of L-period bonds, $b_{L,t}$

$$\begin{aligned}&E_t\left[\frac{\psi^z_{t+L}\left(\beta R_{L,t}\right)^L}{\prod_{k=1}^{L}\left(\pi_{t+k}\mu^z_{t+k}\right)}+\beta\phi_L\psi^z_{t+1}\left(\frac{R_{L,t}}{R_{L,t+1}}\right)^L\left(\frac{b_{L,t+1}}{b_{L,t}}\right)^3 y_{t+1}\right]\\&-\psi^z_t\left[1+\frac{3}{2}\phi_L\left(\frac{b_{L,t}}{b_{L,t-1}}\right)^2 y_t-\nu_L\kappa_L\left(R_{L,t}\right)^L\left(\frac{m_t}{b_{L,t}}\kappa_L-1\right)\left(\frac{m_t}{b_{L,t}}\right)^2 y_t\right]=0\end{aligned} \tag{6}$$

As the remainder of the model structure is similar to a standard SOENKDSGE model, further detail is to be found in du Plessis, Smit, and Steinbach (2014) and du Plessis et al. (2015).[9]

2.2 DSGE model estimation

We estimate the model with Bayesian techniques using eighteen domestic and international time series over the quarterly sample period of 2000:01−2014:04. The dataset purposely coincides with the inflation targeting regime of the South African Reserve Bank (SARB). Data for domestic interest rates and macro variables are obtained from the SARB Quarterly Bulletin, whereas domestic consumer and producer inflation data are obtained from Statistics South Africa (StatsSA). The foreign economy data for gross domestic product, inflation and the policy rate are calculated using a trade-weighted average based on the South African Revenue Service's Customs and Excise bilateral trade statistics. The data for South Africa's trading partners are obtained from the Global Projection Model (GPM).[10] All variables except inflation and interest rates are converted into real per capita terms and log-differenced prior to estimation. Table 1 summarizes the 18 observable variables as well as their sources.

[9]The small open economy model structure largely follows the lines of Adolfson et al. (2007), as it forms the backbone of an operational DSGE model that is used for policy analysis in an inflation-targeting central bank. Nevertheless, the model laid out below departs from Adolfson et al. (2007) in three key aspects. Firstly, allowance is made for the fact that on average, inflation in South Africa exceeds that of its trading partners. In the context of the model, this is achieved by assuming that South Africa has a higher steady state inflation rate. By implication, these differential inflation rates yield a nominal exchange rate depreciation in steady state, as predicted by purchasing parity theory. Secondly, it is assumed that there is no cost channel of monetary policy, hence firms do not borrow their wage bill. Finally, apart from lump-sum transfers, the role of taxes in the model is disregarded.

[10]The Centre for Economic Research and its Application (CEPREMAP), together with Douglas Laxton's team at the IMF in Washington DC, develop and support the GPM: a large-scale quarterly macroeconomic model of the world economy which consists of approximately 35 countries, aggregated into 6 regions.

Table 1

Observable variables

Variable	Series	Source
South Africa		
$\Delta \ln(\tilde{Y}_t)$	Real gross domestic product	South African Reserve Bank
$\Delta \ln(\tilde{C}_t)$	Private consumption	
$\Delta \ln(\tilde{I}_t)$	Total fixed investment	
$\Delta \ln(\tilde{X}_t)$	Total exports	
$\Delta \ln(\tilde{M}_t)$	Total imports	
$\Delta \ln(\tilde{S}_t)$	Nominal effective exchange rate	
$\Delta \ln(\tilde{E}_t)$	Non-agricultural employment	
$\Delta \ln(\tilde{W}_t)$	Compensation of employees	
$\tilde{\pi}_t^i$	Fixed investment deflator	
$\tilde{R}_t$	Repo rate	
$\tilde{R}_{L,t}$	10 year government bond yield	
$\Delta \ln(\tilde{M1}_t)$	M1 money supply	
$\tilde{\pi}_t^c$	Consumer price inflation	StatsSA
$\tilde{\pi}_t^d$	Producer price inflation, domestic manufacturing	
$\tilde{\bar{\pi}}_{t+1}^c$	Inflation target midpoint	Author's own calculations
Foreign economy		
$\Delta \ln(\tilde{Y}_t^*)$	Real gross domestic product (trade weighted)	GPM, CEPREMAP
$\tilde{\pi}_t^*$	Consumer price inflation (trade weighted)	
$\tilde{R}_t^*$	Policy interest rates (trade weighted)	

2.3 Calibrated parameters

Table 2 lists the parameters that are calibrated prior to estimation. Where appropriate, the steady state values are fixed such that the model matches the sample means of the observed variables. For example, concerning the yield curve, we calibrate the L-period bond adjustment cost parameter, ϕ_L, and the ratio of L-period bonds to money, κ_L, to match the sample mean for government bond data. That is, $\phi_L = 0.09$ implies a 9.35% annualized 10-year government bond yield in steady-state, whereas $\kappa_L = 0.2861$ is the ratio of long term bonds to the total quantity of outstanding government bonds. Furthermore, to ensure a low short-term rate in steady-state, it is necessary to have a high discount factor. We therefore set β to 0.9985. Given that $R = (\pi\mu^z)/\beta$ is the steady state nominal interest rate, a steady state quarterly inflation rate (π) equal to 1.0114 and steady state trend growth (μ^z) equal to 1.0085 implies an annualized rate for R of 8.9%.

Ten parameters are calibrated from the literature. Following Martínez-García et al. (2012), we set the inverse of the Frisch elasticity σ_L to 5, with $A_L = 7.5$ implying that households spend approximately a two-thirds of their time in leisure. The parameter governing capital utilisation costs is likely to be weakly identified. Based on preliminary estimates we fix σ_a to 10, in line with the estimate of Smets and Wouters (2007).[11] We follow the extant literate and assume that

[11]That is, the rate of return on capital has a slightly less than one-to-one relationship with variable capital utiliza-

wages are re-optimized approximately every 4 quarters ($1-\theta_w$), with 50% indexation (κ_w) to past inflation (e.g., Adolfson et al., 2007; Medina and Soto, 2014). Similarly, the steady state domestic price and wage setting markups equal 10 and 5% respectively. Finally, the elasticities of substitution for consumption, investment and foreign goods are 1.5, 1.5, and 1.25, respectively (e.g., Adolfson et al., 2007, 2008). Third, the elasticity of substitution between money and bonds is estimated to be 0.874, and therefore represents a slightly higher adjustment cost between money holdings and L-period bonds.

Table 2

Calibrated parameters

β	Discount factor	0.9975	δ	Depreciation rate	0.025
A_L	Labour disutility constant	7.5	σ_L	Labour supply elasticity	5
σ_a	Capital utilisation cost	10	α	Capital share in production	0.23
ϑ_c	Consumption imports share	0.36	ϑ_i	Investment imports share	0.48
θ_w	Calvo: wage setting	0.69	κ_w	Indexation: wage setting	0.5
λ_w	Wage setting markup	1.05	λ_d	Domestic price markup	1.1
η_c	Subst. elasticity: consumption	1.5	η_i	Subst. elasticity: investment	1.5
η_f	Subst. elasticity: foreign	1.25	μ^z	Permanent technology growth	1.0085
π	Inflation	1.0114	g_y	Government spending persistence	0.815
ρ_g	Government spending to GDP	0.197	π^*	Foreign inflation	1.005
Yield curve					
ϕ_L	Long bond adjustment cost	0.09	κ_L	Steady state ratio: L-period bonds/money	0.2861

2.4 Prior distributions and posterior estimates

We estimate the remaining 19 parameters in the model that govern real and nominal frictions as well as those for the 13 exogenous shock processes. Prior distributions of the structural parameters are reported in columns 3−5 in Table 3. Parameters for adjustment costs, habit formation, Calvo pricing and indexation, the Taylor rule and shock processes all conform well within literature standards (Smets and Wouters, 2003, 2007; Adolfson et al., 2007; Medina and Soto, 2007, 2014). Parameter distributions governing the exchange rate, however, are more difficult to specify. For the elasticity of the risk premium, we follow Alpanda et al. (2010b) and set ϕ_a a prior mean of 0.01 with an inverse gamma distribution. Whereas we assume a uniform distribution between zero and one for ϕ_s. Finally, we assume an elasticity of substitution between money and L-period bonds to have a mean of 0.2 and a standard deviation of 0.05.

The estimated posterior statistics for the structural parameters are reported in columns 6−8 in Table 3. Given the standard structure of the model, the estimated parameters conform well within the literature consensus. Three points are worth noting though. Firstly, the estimated parameters

tion.

for the Taylor rule indicate a high degree of persistence with the lagged policy rate. Together with the larger weights on inflation, the Taylor rule estimates suggest a policy preference toward gradual (dovish) price stability. Secondly, although ϕ_a and ϕ_s are estimated to be slightly lower than their priors, we still find evidence for carry trade risk. That is, exchange rate movements present a form of endogenous risk between foreign and domestic bonds.

2.5 The expectations hypothesis and the term premium

An attractive feature of the DSGE approach, as compared to its affine counterpart, allows for the term spread (yield curve) to be decomposed into its *unobserved* components. On the one hand, we have the 'expected spread' based on the expectations hypothesis. That is, for an L-period bond, the yield-to-maturity equals the weighted average of expected short-term rates over that period:

$$R^E_{L,t} = \frac{1}{L} E_t[R_t + R_{t+1} + R_{t+2} + ... + R_{t+L-1}]. \tag{7}$$

Under the assumption of rational expectations and zero adjustment costs, bonds are perfect substitutes and the yield curve is on average flat. On the other hand, we have the 'term (liquidity) premium' by which bonds of different maturities are not perfect substitutes. As such, investors must be compensated for the interest rate risk of holding longer term maturities. On average, it is the term premium that accounts for the tendency of yield curves to be upward sloping. This term premium ($\zeta^{TP}_{L,t}$) therefore captures the deviation of realized bond yields from its expectations counterpart, expressed as:

$$R_{L,t} = R^E_{L,t} + \zeta^{TP}_{L,t}. \tag{8}$$

We can re-write this equation in terms of the yield spread as

$$R_{L,t} - R_t = (R^E_{L,t} - R_t) + \zeta^{TP}_{L,t}, \tag{9}$$

which describes the current period t difference between the long rate $R_{L,t}$ and the short rate R_t. Here, we clearly see that term spread (TS) variability arises from both changes in the expected spread ($ES = R^E_{L,t} - R_t$) and the term premium ($TP = \zeta^{TP}_{L,t}$).[12]

Figure 1 shows the model decomposition of the term spread (the difference between the 10-year government bond yield and the repo rate) as well as the growth rate for the South African economy

[12]Note that, for the sake of consistency with the estimation of the SOENKDSGE based on the observable variables, we use the Repo rate as the measure of the short-term rate of interest instead of the three-months Treasury Bill rate, while decomposing the term spread. We do not expect our results to be affected by such a choice, given that the Repo rate and the three-months Treasury bill rate virtually comoves, and shares a (positive) correlation of 0.94, which is significant at 1% level of significance.

Table 3

Priors and posterior estimation results

Parameter description		Prior			Posterior	
		Density[a]	Mean	Std. Dev.	Mean	90% interval
Adjustment costs						
ϕ_i	Investment	N	7.694	1.5	10.081	[8.074 ; 11.94]
Consumption						
b	Habit formation	B	0.65	0.1	0.839	[0.784 ; 0.898]
Calvo parameters						
θ_d	Domestic prices	B	0.715	0.05	0.867	[0.832 ; 0.900]
θ_{mc}	Imported consumption prices	B	0.675	0.1	0.828	[0.765 ; 0.894]
θ_{mi}	Imported investment prices	B	0.675	0.1	0.833	[0.786 ; 0.887]
θ_x	Export prices	B	0.675	0.1	0.638	[0.547 ; 0.740]
θ_E	Employment	B	0.675	0.1	0.730	[0.660 ; 0.802]
Indexation						
κ_d	Domestic prices	B	0.5	0.15	0.069	[0.022 ; 0.111]
κ_{mc}	Imported consumption prices	B	0.5	0.15	0.259	[0.094 ; 0.408]
κ_{mi}	Imported investment prices	B	0.5	0.15	0.305	[0.120 ; 0.484]
Exchange rate						
ϕ_a	Risk premium	IG	0.01	Inf	0.007	[0.003 ; 0.011]
ϕ_s	Modified UIP	U	0.5	[0,1]	0.277	[0.155 ; 0.403]
Taylor Rule						
ρ_R	Smoothing	B	0.8	0.05	0.918	[0.892 ; 0.945]
ϕ_π	Inflation	G	1.7	0.15	1.744	[1.509 ; 1.997]
$\phi_{\Delta\pi}$	Inflation (change)	G	0.3	0.1	0.323	[0.166 ; 0.494]
ϕ_y	Output gap	G	0.25	0.05	0.339	[0.237 ; 0.428]
$\phi_{\Delta y}$	Output gap (change)	G	0.125	0.05	0.136	[0.046 ; 0.214]
$\phi_{\Delta m}$	Money growth	G	1.38	0.27	0.850	[0.775 ; 0.928]
L-period bond						
ν_l	Money/bonds substitution elasticity	G	0.2	0.05	0.874	[0.807 ; 0.942]
Persistence parameters						
ρ_{μ^z}	Permanent technology	B	0.75	0.1	0.739	[0.634 ; 0.846]
ρ_ε	Transitory technology	B	0.75	0.1	0.902	[0.776 ; 0.988]
ρ_i	Investment technology	B	0.75	0.1	0.772	[0.639 ; 0.989]
$\rho_{\tilde{z}^*}$	Asymmetric technology	B	0.75	0.1	0.423	[0.288 ; 0.548]
ρ_c	Consumption preference	B	0.75	0.1	0.654	[0.502 ; 0.807]
ρ_H	Labour supply	B	0.75	0.1	0.199	[0.127 ; 0.262]
ρ_a	Risk premium	B	0.75	0.1	0.700	[0.540 ; 0.866]
ρ_{λ^d}	Domestic price markup	B	0.75	0.1	0.756	[0.592 ; 0.907]
$\rho_{\lambda^{mc}}$	Imported cons. price markup	B	0.75	0.1	0.646	[0.457 ; 0.860]
$\rho_{\lambda^{mi}}$	Imported invest. price markup	B	0.75	0.1	0.864	[0.774 ; 0.961]
ρ_{λ^x}	Export price markup	B	0.75	0.1	0.247	[0.144 ; 0.340]
ρ_{b^L}	L-period bond supply	IG	0.75	0.1	0.481	[0.283 ; 0.648]
Structural shocks						
σ_{μ^z}	Permanent technology	IG	0.4	Inf	0.317	[0.202 ; 0.424]
σ_ε	Transitory technology	IG	0.7	Inf	2.670	[1.566 ; 3.832]
σ_i	Investment technology	IG	0.4	Inf	0.415	[0.311 ; 0.525]
$\sigma_{\tilde{z}^*}$	Asymmetric technology	IG	0.4	Inf	0.438	[0.077 ; 0.651]
σ_c	Consumption preference	IG	0.4	Inf	0.123	[0.085 ; 0.159]
σ_H	Labour supply	IG	0.2	Inf	0.307	[0.223 ; 0.388]
σ_a	Risk premium	IG	0.5	Inf	1.536	[1.022 ; 2.051]
σ_d	Domestic price markup	IG	0.3	Inf	1.224	[1.006 ; 1.457]
σ_{mc}	Imported cons. price markup	IG	0.3	Inf	0.872	[0.641 ; 1.090]
σ_{mi}	Imported invest. price markup	IG	0.3	Inf	0.316	[0.131 ; 0.496]
σ_x	Export price markup	IG	0.3	Inf	1.542	[1.056 ; 2.006]
σ_R	Monetary policy	IG	0.15	Inf	0.157	[0.125 ; 0.186]
σ_{b^L}	L-period bond supply	IG	1.65	Inf	3.238	[2.471 ; 3.979]

[a] B – Beta, G – Gamma, IG – Inverse Gamma, N – Normal, U – Uniform

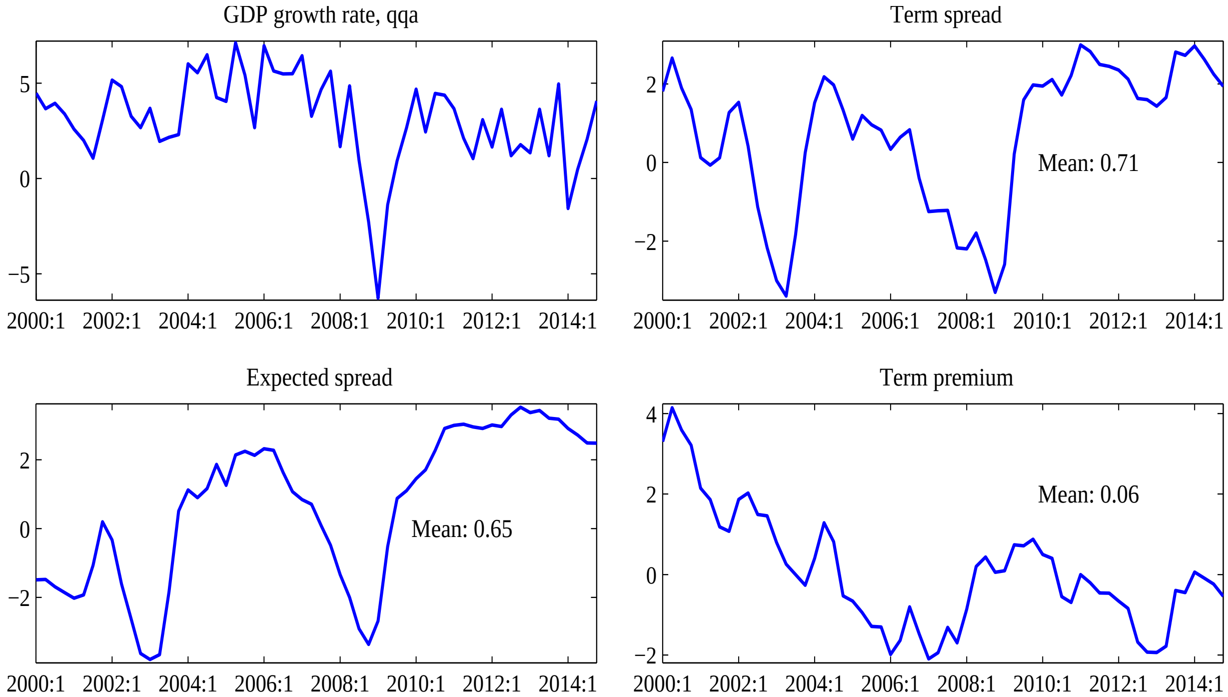

Figure 1: Growth and the structural decomposition of the yield curve

for the period 2000:01−2014:04.

Firstly, the 'expected spread' over our sample is not zero on average as expected. Nevertheless, at 0.65 basis points its mean confirms prior expectations of being lower than the aggregate term spread's mean of 0.71 basis points. Absent any interest rate risk, this spread represents the model-generated expected 10-year repo rate spread. It also makes up the largest component of the term spread. The extent of the positive relationship between the term spread and real growth therefore depends on the monetary policy reaction function (e.g., Eijffinger et al., 2000; Estrella, 2005). The 'term premium' implied from the model setup (Eq. 9) shows a steady decline in the compensation of interest rate risk from 2000 to 2007. In fact, the premium becomes negative in the three years leading up to the 2008 global financial crisis. This considerable narrowing of the term premium can, in part, be attributed to the introduction of the SARB's inflation targeting regime. Over the 2008/09 period the term premium increased markedly, peaking towards the end of 2009. More recently, the 2014:01 dip in growth was foreshadowed by the 2013 rise in the premium. This pattern (in Fig.1) is consistent with the view that the term premium varies inversely with expected GDP growth (e.g., Rosenberg and Maurer, 2008; Rudebusch et al., 2007).[13]

[13]Bernanke (2006), in his 2006 address to The Economic Club of New York, cited the narrowing of the term premium as having a stimulative impact on economic activity rather than indicative of an expected decline in economic activity. While both practitioners and academics hold true to the negative correlation between the term premium and economic activity, there is more ambiguity on its *predictive* power for forecasting economic activity.

3 Out-of-sample forecasting of the South African growth rate

We adopt a predictive regression framework to study the forecasting power of the term spread and its subcomponents for the growth rate of the South African economy. The model is of the following standard form:

$$y_{t+1}^{k} = \alpha + \beta_j \cdot z_{j,t} + \gamma \cdot y_t + u_{t+1}^{k} \ , \tag{10}$$

where y_t is the real growth rate of the economy from period $t-1$ to t and $y_{t+1}^{k} = y_{t+1} + ... + y_{t+k}$ is the real growth rate from period t to $t+k$. $z_{j,t}$ therefore represents the macro variable (TS, ES, or TP individually) used to predict economic growth at the k^{th} horizon, with u_{t+1}^{k} being the error term. As discussed in the introduction, given that lag-length tests choose an optimal lag of one, the benchmark is an AR(1) model for the growth rate, which in turn, is the restricted model, obtained by setting $\beta_j = 0$.

Given the existence of five structural breaks (2004:01, 2008:03, 2009:02, 2011:02 and 2014:02) in the AR(1) model for the growth rate, we divide our total sample into an in-sample period R (2000:01−2003:04, i.e., 16 observations) and an out-of-sample period ($T-R$) (2004:01−2014:04, i.e., 44 observations), and perform a recursive estimation procedure, comprising of two-steps, to produce forecasts over the out-of-sample period. In stage one, we obtain the OLS regression results over period R for Eq. 10 when $\beta_j \neq 0$ (i.e., the unrestricted model). We use these estimates to construct an initial forecast for growth y_{R+1}^{k} at the k^{th} horizon, which in our case is eight-quarters-ahead. The unrestricted regression model (represented by subscript 1) can be specified as

$$\hat{y}_{1,R+1}^{k} = \hat{\alpha}_{1,R} + \hat{\beta}_{1j,R} \cdot z_{j,R} + \hat{\gamma}_{1,R} \cdot y_R \ , \tag{11}$$

where estimated parameters and forecast growth are now represented by hats. The forecast error, $\hat{u}_{1,R+1}^{k} = y_{R+1}^{k} - \hat{y}_{1,R+1}^{k}$, then captures the distance of the forecast for growth in $R+1$ from the actual observed value. The above estimation is repeated sequentially to give a set of $T-R-k+1$ unrestricted recursive forecast errors: $\{\hat{u}_{1,t+1}^{k}\}_{t=R}^{T-k}$. The second stage follows in the same manner as just described. Only now, the above estimation is repeated to give a set of $T-R-k+1$ recursive forecast errors for the restricted model ($\beta_j = 0 \ \forall \ j$): $\{\hat{u}_{0,t+1}^{k}\}_{t=R}^{T-k}$.

For the out-of-sample forecasts, we report Theil's U: a basic measure for forecast outperformance, and two test statistics for forecast superiority: the $MSE-F$ statistic (McCracken, 2004) and the $ENC-NEW$ statistic (Clark and McCracken, 2001). Theil's U gives the ratio of the unrestricted model forecast root-mean-squared error to the restricted model root-mean-squared error (RMSE). If U<1 then the unrestricted model outperforms the restricted model and $z_{j,t}$ improves the out-of-sample forecast of growth relative to the benchmark model. The $MSE-F$ statistic tests for equal predictive ability based on a standardized mean-squared-error differential,

$$\frac{\sum_{t=R}^{T-k}(\hat{u}_{0,t+1}^{k})^{2}-(\hat{u}_{1,t+1}^{k})^{2}}{M\hat{S}E_{1}} ,$$

where $M\hat{S}E_1 = (T-R-k+1)^{-1}\sum_{t=R}^{T-k}(\hat{u}_{1,t+1}^{k})^2$. A rejection of the null hypothesis (i.e., a positive and significant $MSE-F$ statistic) means that the unrestricted model has forecast superiority over the restricted model. Finally, the $ENC-NEW$ statistic tests whether the restricted forecast results encompass the unrestricted forecast results. If so, $z_{j,t}$ provides no further predictive power than the benchmark AR(1) model. The $ENC-NEW$ statistic incorporates a composite forecast given by

$$\frac{\sum_{t=R}^{T-k}(\hat{u}_{0,t+1}^{k})^{2}-(\hat{u}_{0,t+1}^{k}\cdot\hat{u}_{1,t+1}^{k})}{M\hat{S}E_{1}} .$$

As above, a rejection of the null hypothesis (i.e., a positive and significant ENC-NEW statistic) means that the unrestricted model forecasts are not encompassed by the restricted results.

Given that Eq. 11 is nested and that for $k > 1$, the limiting distributions of both out-of-sample test statistics are non-standard and non-pivotal (Clark and McCracken, 2004), we base our inferences on the bootstrap procedure as discussed in Rapach et al. (2005).

Table 4 reports Theil's U, the $MSE-F$, and the $ENC-NEW$ statistics to evaluate the out-of-sample forecasting ability of TS, ES or TP by turn over k = 1, 2,..., 8. Note that, in the discussion that follows, given the short out-of-sample sizes, we rely on the 10% level of significance (instead of the standard 5% level), to make our inferences on statistical significance of the $MSE-F$ and $ENC-NEW$ test statistics. As can be seen, in line with the studies of Gupta and Hartley (2013) and Thompson et al. (2015), there is no evidence of out-of-sample predictability emanating from the TS. While TP also shows no sign of out-of-sample predictability, ES is found to contain important and significant forecasting information for the growth rate of the South African economy over the first- and second-quarters-ahead, relative to the $AR(1)$ model.[14]

In line with the suggestion of Rudebusch et al. (2007), we conducted the Ng and Perron (NP, 2001) unit root test (widely acknowledged as the most powerful unit root test amongst the available alternative standard linear unit root tests) to check for the stationarity of our three predictors. The NP test could not reject the null of unit root, and hence, we used first differences of the predictors (which ensured stationarity)[15] to re-evaluate their respective forecasting performances. Table 5)

[14]Similar results were also obtained from the in-sample analysis, with only ES showing predictive power. Complete details of these results are available upon request from the authors.

[15]Complete details of the NP unit root tests are available upon request from the authors.

reports the results for the out-of-sample forecast of the growth rate based on the first-differenced predictors. Some evidence of out-of-sample predictive ability is now observed for TS (for one-quarter-ahead forecasts) and TP (for six-quarter-ahead forecasts). However, while the $MSE-F$ test is significant, the $ENC-NEW$ test, considered to be more powerful than the former, is not significant at 10% level of significance. So, this evidence of out-of-sample predictability for TS and TP can, at best, be considered as weak. Interestingly however, for ES, while no predictability is observed at horizon one, as was observed in Table 4, significant forecasting gains (as both the $MSE-F$ and $ENC-NEW$ test statistics are significant) over the $AR(1)$ model is observed from two-quarter-ahead till six-quarter-ahead.[16]

So overall, our results highlight the importance of the expected spread component of the term spread in forecasting output growth of the South African economy. Hence, our study elaborates the need to decompose the term spread into its components when it comes to forecasting the South African growth rate, since using the aggregate term spread (as the sum of the expected spread and the term premium) misses out on important information contained, especially, in the expected spread.[17] In other words, while the term spread on its own might not be helpful in forecasting the output growth, as also witnessed in the South African literature, its forward-looking component, i.e., the expected spread, is of tremendous value, especially when used in its stationary-form.

4 Conclusion

There is widespread international evidence that the term spread can not only predict, but also forecast economic activity (output growth). However, this does not seem to hold true for the South African economy, especially in terms of out-of-sample forecasting of the growth rate, even though there is ample evidence of in-sample predictability. Presuming that such an observation could be due to the term spread aggregating, and hence loosing out on important, information contained in the expected spread and the term premium, the objectives of our study are threefold: First, we develop an estimable Small Open Economy New Keynesian Dynamic Stochastic General Equilibrium (SOENKDSGE) model of the inflation targeting South African economy characterized by imperfect asset substitutability; Second, using the SOENKDSGE structural model estimated using Bayesian methods, we decompose the term spread into an expected spread and the term premium over the quarterly period of 2000:01−2014:04, and; Third, we use a linear predictive regression framework

[16] As far as the in-sample is concerned, we observed predictability for all the three first-difference predictors, with ES producing the strongest prediction, followed by TS and TP.

[17] This line of thinking was further vindicated when we could not detect out-of-sample forecasting gains from the predictive regression model which contained both the expected spread and term premium simultaneously. Complete details of these results are available upon request from the authors.

Table 4

Out-of-sample predictability test results for growth forecasts with predictors in levels

Horizon	1	2	3	4	5	6	7	8
	Term spread (TS)							
Theil's U	1.02	1.04	1.05	1.08	1.11	1.11	1.14	1.20
MSE-F	-1.65	-3.36	-4.01	-5.46	-7.13	-7.03	-8.51	-11.03
	[0.455]	[0.495]	[0.496]	[0.539]	[0.65]	[0.65]	[0.72]	[0.814]
ENC-NEW	-0.48	-0.71	-0.35	-0.31	-0.50	-0.36	-1.39	-2.77
	[0.606]	[0.567]	[0.476]	[0.429]	[0.472]	[0.511]	[0.668]	[0.811]
	Expected spread (ES)							
Theil's U	0.95	0.97	1.02	1.04	1.04	1.03	1.01	1.02
MSE-F	**4.61**	**2.83**	-1.86	-2.73	-3.22	-2.45	-1.03	-1.19
	[0.008]	[0.04]	[0.254]	[0.295]	[0.37]	[0.338]	[0.253]	[0.276]
ENC-NEW	**4.80**	**5.13**	1.40	-0.48	-1.22	-1.02	-0.18	-0.09
	[0.022]	[0.052]	[0.253]	[0.44]	[0.632]	[0.584]	[0.46]	[0.466]
	Term premium (TP)							
Theil's U	1.02	1.03	1.04	1.07	1.10	1.11	1.15	1.22
MSE-F	-1.73	-2.71	-3.18	-4.82	-6.77	-7.06	-9.02	-11.80
	[0.452]	[0.40]	[0.354]	[0.448]	[0.582]	[0.611]	[0.691]	[0.816]
ENC-NEW	-0.06	0.82	1.67	1.56	1.08	0.75	-0.93	-2.63
	[0.42]	[0.268]	[0.217]	[0.243]	[0.326]	[0.35]	[0.548]	[0.812]

Notes: p-values are given in brackets; bold values indicate significance at the 10% level. out-of-sample tests are one-sided (upper-tailed), and therefore significant if p-value ≤ 0.10.

Table 5

Out-of-sample predictability test results for growth forecasts with predictors in first-differences

Horizon	1	2	3	4	5	6	7	8
	Term spread (TS)							
Theil's U	0.99	1.04	1.07	1.06	1.04	1.00	1.00	0.99
MSE-F	**0.98**	-3.01	-5.25	-4.50	-2.62	-0.10	0.32	0.53
	[0.058]	[0.769]	[0.911]	[0.91]	[0.782]	[0.264]	[0.207]	[0.179]
ENC-NEW	1.5842	-0.6076	-2.0597	-1.8876	-1.1766	0.0315	0.2705	0.3211
	[0.11]	[0.659]	[0.967]	[0.962]	[0.892]	[0.419]	[0.32]	[0.301]
	Expected spread (ES)							
Theil's U	1.02	0.99	0.95	0.97	0.97	0.97	0.99	1.02
MSE-F	-1.65	**0.76**	**4.41**	**2.61**	**2.46**	**2.25**	0.81	-1.14
	[0.579]	[0.096]	[0.011]	[0.045]	[0.048]	[0.062]	[0.149]	[0.53]
ENC-NEW	-0.27	**3.07**	**6.10**	**4.17**	**2.93**	**2.07**	0.91	-0.24
	[0.52]	[0.047]	[0.011]	[0.02]	[0.048]	[0.082]	[0.179]	[0.57]
	Term premium (TP)							
Theil's U	1.00	1.05	1.07	1.06	1.02	0.98	0.99	0.99
MSE-F	-0.21	-4.19	-5.49	-4.11	-1.40	**1.73**	1.05	0.53
	[0.172]	[0.887]	[0.922]	[0.853]	[0.54]	[0.093]	[0.14]	[0.205]
ENC-NEW	1.03	-1.27	-1.93	-1.37	-0.29	1.36	0.95	0.50
	[0.156]	[0.906]	[0.952]	[0.886]	[0.571]	[0.15]	[0.197]	[0.278]

Notes: p-values are given in brackets; bold values indicate significance at the 10% level. out-of-sample tests are one-sided (upper-tailed), and therefore significant if p-value ≤ 0.10.

to analyze the out-of-sample forecasting ability of the term spread, the expected spread and the term premium in turn. Our forecasting results confirm our presumption, in the sense that, while we fail to detect forecasting gains from the aggregate term spread (and also the term premium), the expected spread is found to contain important information in forecasting the output growth of South Africa over short- to medium-run horizons, over the period of 2004:01−2014:04, using an in-sample period of 2000:01−2003:04. In general, our paper contributes to the sparse literature on structural decomposition of the term spread, primarily based on closed-economy DSGE model, by developing a SOENKDSGE model for the first time. And, in addition, our study also highlights the importance of the forward looking component of the term spread, namely the expected spread, in forecasting output growth of an inflation targeting emerging economy like South Africa, thus providing a solution to the puzzling observation of the lack of out-of-sample predictability of the term spread for the South African growth rate.

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