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A Market-Based Assessment of the Outlook for Inflation Expectations and Monetary Policy in South Africa

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&

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Abstract

Using a novel arbitrage-free dynamic term structure model of nominal and real bond prices that accounts for bond-specific liquidity risk premia, this paper provides estimates of bond investors' inflation expectations and associated inflation risk premia in South African sovereign bonds. The results suggest that investors' long-term inflation expectations have gradually been declining towards the tolerance band adopted by the South African Reserve Bank in 2000. Although volatile, the estimated inflation risk premia have declined significantly since 2021, while a market-based estimate of the natural real rate has remained stable and slightly negative. A related measure of the stance of monetary policy is currently assessed to be mildly restrictive. Leveraging the estimated model's rich dynamics to assess the outlook for these key variables suggests that expected inflation is likely to gradually fall further, while monetary policy is projected to ease towards neutral in the context of a stable natural real rate.

JEL Classification: C32, E43, E52, E58, F41, F42, G12

Keywords: term structure modeling, inflation risk, liquidity risk, financial market frictions, emerging bond markets

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The views in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Federal Reserve Bank of San Francisco, the Federal Reserve System, or Codera Analytics.

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1 Introduction

The recent change in the inflation target in South Africa presents a unique opportunity to assess bond investors' expectations for future inflation and monetary policy. As background, the inflation targeting framework in South Africa has evolved over time. The Monetary Policy Committee (MPC) of the South African Reserve Bank (SARB) announced its original inflation target range on February 23, 2000, when it adopted a goal of achieving 3 to 6 percent inflation from 2002 onwards. Starting in 2017, the SARB began communicating a preference for the 4.5 percent midpoint of the tolerance band as its inflation target. Most recently, the Bank unilaterally made public that it would henceforth prefer a lower 3 percent interpretation of its inflation target. The change to a 3 percent target along with a 1 percent tolerance band was formally announced by the South African Finance Minister in the Medium Term Budget Policy Statement on November 12, 2025, and expected to be achieved within two years.[1]

To quantify potential costs and benefits of transitioning to the new lower 3 percent inflation target in South Africa, we focus on breakeven inflation (BEI)—the difference between yields on comparable-maturity nominal and real debt. This is a widely used indicator of inflation expectations. In particular, long-term BEI is frequently used to measure the credibility of the central bank's inflation objective, a key object of interest for our analysis given the recent inflation target change in South Africa.[2] However, BEI is a noisy measure of expected inflation because it contains both an inflation risk premium and differential liquidity premia. As a consequence, we could more accurately measure investors' underlying inflation expectations by subtracting both inflation risk premia and the differential liquidity premia in nominal and real yields from BEI rates. In South Africa, like in other emerging markets, frictions affect the secondary market trading and liquidity of both fixed-rate nominal and inflation-indexed real debt. Therefore, the adjustment for the differential liquidity premia in nominal and real bond prices is particularly important for the question at hand.

To decompose BEI rates as required, we use a novel dynamic term structure model of nominal and real yields that accounts for liquidity premia in nominal and real bond prices, taken from Christensen and Steenkamp (2025a). The model allows us to identify bond investors' underlying inflation expectations as in Christensen et al. (2010) and hence account for inflation risk premia. Furthermore, it offers a way to generate market-based measures of the natural real rate r_t^*, which we define as in Christensen and Rudebusch (2019).[3] Finally, the model accounts for bond-specific liquidity risk premia in the prices of both nominal

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[1] For details of the announcement, see https://www.treasury.gov.za/comm_media/press/2025/2025111201%20Announcement%20of%20the%20new%20inflation%20target%20for%20South%20Africa.pdf

[2] Provided the inflation objective is credible, it should be reflected in inflation expectations for the distant future as any current inflation shocks should be considered temporary and not affect long-run inflation expectations.

[3] Their definition focuses on the real short rates expected to prevail five to ten years in the future, once all current transitory shocks to the economy are expected to have faded and the economy is growing at its trend rate.

and inflation-indexed bonds as in Andreasen et al. (2021). The underlying mechanism rests on the assumption that, over time, a growing share of a bond's outstanding notional value becomes absorbed by buy-and-hold investors. Because investors are forward-looking, this lock-up effect implies that a bond's exposure to the market-wide bond-specific risk factor varies with its degree of seasoning and its proximity to maturity. In their detailed analysis of nominal U.S. Treasuries, Fontaine and Garcia (2012) document a pervasive bond-specific risk factor that influences prices across all maturities, with factor loadings that vary by both maturity and bond age. Exploiting time variation in the cross section of bond prices allows this bond-specific risk factor to be separately identified within each market.

We measure the historical evolution of not only long-term inflation expectations and how well anchored they are to the inflation target (past and present), but also the dynamics of the bond market liquidity premia. In the current context, the projection of long-term expected inflation helps to assess whether they are likely to become anchored or not. In addition, we quantify South African inflation risk premia that contribute to high interest rates and a steep yield curve. As such, the paper provides insights on the policy settings that affect the cost of capital in South Africa.

Consistent with estimates for Mexican bonds reported in Beauregard et al. (2024), we find that the liquidity premia of South African inflation-indexed government bonds are larger and more variable than those of nominal government bonds. Importantly, South African liquidity premium estimates are higher, on average, than those of other emerging markets for which similar estimates are available, such as Mexico. Moreover, our estimates imply that investors' long-term inflation expectations have gradually been approaching the tolerance band adopted by the SARB in 2000, although they have remained slightly higher than survey-based measures. Our estimate of the inflation risk premium peaked near 7 percent in early 2021 and has declined steadily since then, reaching 2 percent by the end of our sample. Finally, our estimates suggest that, at present, the stance of monetary policy is mildly restrictive, in line with the SARB's own assessment.

In a final exercise, we then leverage the estimated model's rich dynamics to assess the outlook for these key variables as of December 2025, pointing to a fairly imminent and somewhat quick monetary policy easing towards neutral, although the projections suggest that expected inflation will only very gradually fall towards the new 3 percent inflation target. A strict reading of our results suggests that there is only about a 0.5 percent chance of investors' long-term inflation expectations falling below 4 percent by the end of 2035. Thus, more guidance and communication by the SARB about its new target would seem warranted. This exercise also underscores the strength of our finance-based model approach as it can be used in real time to assess the progress made in getting investors' inflation expectations anchored near the new target, a key objective highlighted by the Finance Minister in his November 12, 2025, announcement of the new inflation target.

The analysis in this paper relates to several important strands of literature. Most directly, it speaks to the burgeoning literature on measurement of the neutral rate of interest, which is dominated by macroeconomic-based estimates starting with the seminal paper by Laubach and Williams (2003). In contrast, we provide a finance-based estimate for South Africa following the work of Christensen and Rudebusch (2019). Second, our estimates of the real yield curve that would prevail without trading frictions have implications for asset pricing analysis on the true slope of the real yield curve. Specifically, we are extending the U.S. evidence provided in Andreasen et al. (2021) to South Africa. Furthermore, our results relate to research on liquidity risk in emerging sovereign bond markets. Here, we extend evidence for Mexico and Colombia reported in Beauregard et al. (2024) and Cardozo and Christensen (2025) to include South Africa. Finally, this paper is different from previous studies estimating inflation and liquidity premia in South Africa because it uses individual bond characteristics in its estimation, allowing liquidity and inflation risk premia to be more accurately identified.[4]

The remainder of the paper is structured as follows. Section 2 details our South African bond data, while Section 3 provides a description of the no-arbitrage term structure model we use. Section 4 presents the empirical results, including an examination of the estimated bond-specific liquidity risk premia, while Section 5 describes the model's decomposition of breakeven inflation into inflation expectations and residual inflation risk premia. Section 6 examines the natural real rate and the related measure of the stance of monetary policy, including model projections of key variables. Finally, Section 7 concludes the paper.

2 South African Government Bond Data

This section describes the South African government bond data we use in the model estimation. We start with a description of the market for South African nominal fixed-coupon government bonds before we proceed to a description of the market for South African inflation-indexed bonds that reference the South African consumer price index.

Among emerging bond markets, the South African sovereign bond market counts as a major and very liquid market.[5] The South African National Treasury's issuance of debt has been at relatively long maturities compared with other major emerging markets. South Africa has extended the average term of its sovereign debt over time, from around 6 years in 2006 to over 12 years in 2020, a level comparable to those of Brazil and Russia. The weighted average term to maturity of fixed-rate bonds is currently about 10.6 years, at the lower end of the target range between 10 and 14 years.[6]

The South African nominal government bonds we consider are all marketable non-callable bonds denominated in South African rands that pay a fixed rate of interest semiannually.

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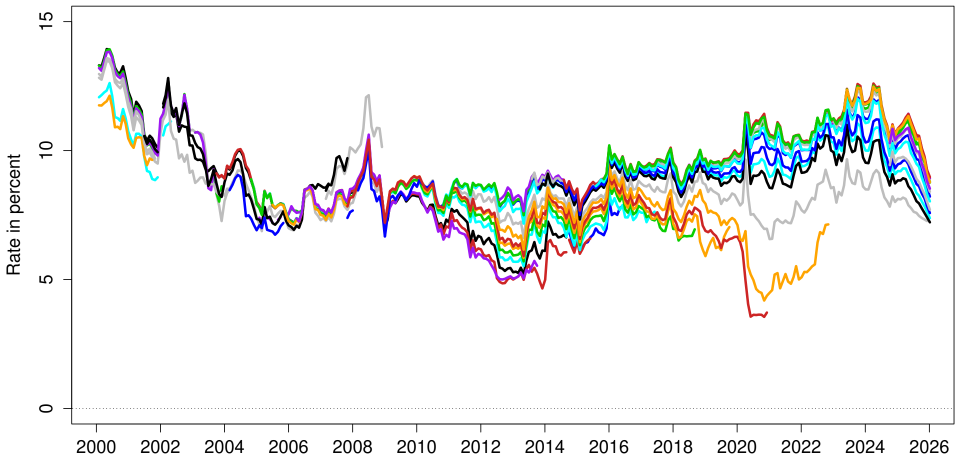
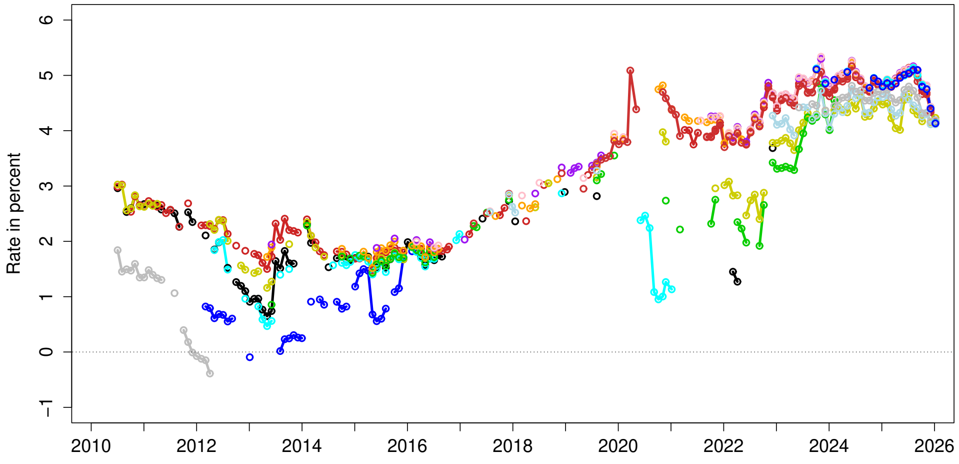
[4] For a South African example, see Reid (2009).

[5] The characteristics of South Africa's fixed-rate sovereign bonds is described in more detail in Christensen and Steenkamp (2025b).

[6] See National Treasury (2025) for further detail.



(a) Nominal bonds



(b) Inflation-indexed bonds

Figure 1: **Yield to Maturity of South African Nominal and Real Government Bonds** The top panel illustrates the yields to maturity implied by the South African nominal fixed-coupon government bond prices. The data are monthly covering the period from January 31, 2000, to December 31, 2025, and censors the last three months for each maturing bond. The bottom panel illustrates the yields to maturity implied by the South African real inflation-indexed government bond prices. The data are monthly covering the period from June 30, 2010, to December 31, 2025, and censors the last twelve months for each maturing bond. Note that these data are spotty due to frequent missing observations.

Similar to Christensen and Steenkamp (2025b), we track the entire universe of these bonds issued since January 2000. In addition, we include a few bonds outstanding at the start of our sample period. In general, the South African government has been issuing a diverse set of bonds, but with a clear preference for issuing long-term bonds with maturities of up to

35 years. For our analysis, the main thing to note is that there is a wide variety of bonds with different maturities and coupon rates in the data throughout our sample. This variation provides the foundation for the econometric identification of the factors in the yield curve model we use.

Figure 1(a) shows the yields to maturity for all South African nominal government bonds in our sample at a monthly frequency from January 31, 2000, to December 31, 2025. First, we note that the general yield level in South Africa trended down between 2000 and 2005 and remained fairly stable between then and the onset of the COVID-19 pandemic in early 2020. Yields rose dramatically after the COVID-19 pandemic, on withdrawal of foreign investors from the South African market (Havemann et al. 2022) and increased liquidity and credit risk premia (e.g., Soobyah and Steenkamp 2020a, 2020b, and Christensen and Steenkamp 2025b) as the government debt-to-GDP ratio steadily increased. Since then, there has been a notable reversal that has left South African long-term government bond yields by the end of our sample close to their average for our sample period. Second, as in U.S. Treasury yield data, there is notable variation in the shape of the yield curve. At times, like in early 2006, yields across maturities are relatively compressed. At other times, the yield curve is steep with long-term bonds trading at yields that are 400-500 basis points above those of shorter-term securities, as occurred in 2013 and again in 2021. Although these yield shape patterns typically reflect the variation in the monetary policy cycle, the South African sovereign yield curve has been one of the steepest in the world over recent history, as documented by Erasmus and Steenkamp (2022a). There are many possible explanations for South Africa's steep curve. It may, for example, reflect high perceived sovereign credit and inflation risk, which is expressed in crash risk that is priced into market expectations of the exchange rate. Rand options-implied variance estimates, which captures exchange rate uncertainty priced into foreign exchange options prices, is relatively high by international standards (Greenwood-Nimmo et al. 2022) and is highly correlated with the South African sovereign term premium over the last several years (Erasmus and Steenkamp 2022a). These characteristics are the practical motivation behind our choice of using a three-factor model for the frictionless part of the South African nominal yield curve, adopting an approach similar to Christensen and Steenkamp (2025b).

Turning to the South African inflaton-indexed government bond data, there are currently 10 inflation-linked bonds outstanding, with coupons paid out semiannually and maturities in excess of 30 years. The weighted average term to maturity of these inflation-indexed bonds is about 13.7 years. The secondary market liquidity of inflation-indexed bonds is lower than that of South African nominal bonds (Christensen and Steenkamp 2025a).

Figure 1(b) shows price-implied yields to maturity for the 15 inflation-indexed bonds in our sample at monthly frequency covering the period from June 30, 2010, to December 31, 2025. We note that for these bond prices we use a 12-month censoring before maturity to

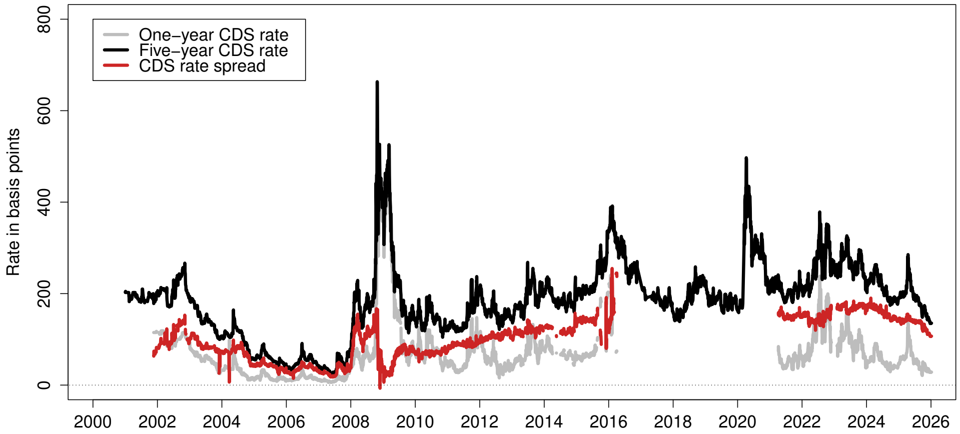


Figure 2: **South African CDS Rates**

minimize the effects of erratic prices close to maturity; see Gürkaynak et al. (2010). The spotty available data prior to 2022 is clearly visible and a sign of poor liquidity in the first decade of our sample. Importantly and comfortingly, all 10 currently outstanding bonds have complete data since 2023, and we anticipate this to continue going forward. Moreover, our model estimation based on the Kalman filter is designed to handle missing data like this. Thus, it does not pose an obstacle for the execution of our analysis.[7]

2.1 The Credit Risk of South African Government Bonds

To gauge whether there are any material credit risk issues to consider in modeling the South African government bond prices, we consider rates on so-called credit default swap (CDS) contracts. These rates reflect the annual rate investors are willing to pay to buy protection against default-related losses on South African government bonds over a fixed period of time stipulated in the contract. Such contracts have been used to price the credit risk of many countries, including South Africa, since the early 2000s.

In Figure 2, we plot the available series for the one- and five-year South African CDS rate with solid gray and black lines, respectively. Also shown with a solid red line is the spread between the two CDS rates. We note that the five-year CDS rate has fluctuated in a fairly narrow range between 100 and 200 basis points, except for a few brief episodes including the Global Financial Crisis in 2008-2009, when South African CDS rates temporarily spiked above 400 basis points, and the early stages of the COVID-19 pandemic. This is a level of credit risk on par with most investment-grade firms in the United States, and its variation is mostly very gradual. Still, we do see an upward trend in the data that correlates with the

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[7] Finlay and Wende (2012) examine prices from a limited number of Australian inflation-indexed bonds using an approach similar to ours.

increase in the amount of outstanding government debt, which stood at around 75 percent of nominal GDP by the end of our sample, a high level by emerging market standards.

Importantly, though, there are no differences in the credit risk of nominal and inflation-indexed bonds in the sense that they will receive the same treatment in case the South African government stops servicing its debt. Thus, using arguments similar to those made by Fleckenstein et al. (2014) for U.S. Treasuries and Treasury Inflation-Protected Securities (TIPS), there is no reason to believe that there are any differentials in the pricing of nominal and inflation-indexed bonds tied to credit risk. By implication, our measures and decompositions of South African BEI are unaffected by variation in the credit risk premia of South African government debt.[8] As a consequence, we will not be accounting for credit risk in our analysis.[9]

3 Model and Estimation

In this section, we first detail the model that serves as the benchmark in our analysis before we describe its estimation and the restrictions imposed to achieve econometric identification.

3.1 An Arbitrage-Free Model of Nominal and Real Yields with Bond-Specific Liquidity Risk Premia

To begin, let $X_t = (L_t^N, S_t, C_t, X_t^N, L_t^R, X_t^R)$ denote the state vector of our six-factor model. Here, L_t^N and L_t^R denote the level factor unique to the nominal and real yield curve, respectively, while S_t and C_t represent slope and curvature factors common to both yield curves. Finally, X_t^N and X_t^R represent the liquidity risk factors added to capture nominal and real bond-specific liquidity risk premia, respectively. We follow Christensen and Steenkamp (2025a) and refer to this six-factor Gaussian model as the $G^{X^N,X^R}(6)$ model.

The instantaneous nominal and real risk-free rates are defined as

$$r_t^N = L_t^N + S_t, \tag{1}$$
$$r_t^R = L_t^R + \alpha^R S_t. \tag{2}$$

Note that the differential scaling of the real rates to the common slope factor is captured by the parameter α^R as in Christensen et al. (2010).

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[8] We note that this view of equal treatment of nominal and real government debt in bankruptcy is not universally accepted. For an example, see Dittmar et al. (2026) for evidence and arguments in favor of an asymmetric impact on nominal and real sovereign debt as the government approaches the default threshold.

[9] See Christensen and Steenkamp (2025b) for a model that accounts for the credit risk in South African nominal government bond prices.

The risk-neutral $\mathbb{Q}$-dynamics of the state variables used for pricing are given by

$$\begin{pmatrix} dL_t^N \\ dS_t \\ dC_t \\ dX_t^N \\ dL_t^R \\ dX_t^R \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \lambda & -\lambda & 0 & 0 & 0 \\ 0 & 0 & \lambda & 0 & 0 & 0 \\ 0 & 0 & 0 & \kappa_N^{\mathbb{Q}} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \kappa_R^{\mathbb{Q}} \end{pmatrix} \left[\begin{pmatrix} 0 \\ 0 \\ 0 \\ \theta_N^{\mathbb{Q}} \\ 0 \\ \theta_R^{\mathbb{Q}} \end{pmatrix} - \begin{pmatrix} L_t^N \\ S_t \\ C_t \\ X_t^N \\ L_t^R \\ X_t^R \end{pmatrix} \right] dt + \Sigma \begin{pmatrix} dW_t^{L^N,\mathbb{Q}} \\ dW_t^{S,\mathbb{Q}} \\ dW_t^{C,\mathbb{Q}} \\ dW_t^{X^N,\mathbb{Q}} \\ dW_t^{L^R,\mathbb{Q}} \\ dW_t^{X^R,\mathbb{Q}} \end{pmatrix},$$

where W_t denotes a Brownian motion and Σ is the associated constant volatility matrix that is assumed to be a diagonal as per Christensen et al. (2011).

Based on the $\mathbb{Q}$-dynamics above, nominal and real frictionless zero-coupon bond yields preserve a Nelson and Siegel (1987) factor loading structure

$$\begin{aligned} y_t^N(\tau) &= L_t^N + \left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) S_t + \left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) C_t - \frac{A^N(\tau)}{\tau}, \qquad (3) \\ y_t^R(\tau) &= L_t^R + \alpha^R \left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) S_t + \alpha^R \left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) C_t - \frac{A^R(\tau)}{\tau}, \qquad (4) \end{aligned}$$

where $A^N(\tau)$ and $A^R(\tau)$ are convexity terms that adjust the functional form in Nelson and Siegel (1987) to ensure absence of arbitrage; see Christensen et al. (2011).

On the other hand, due to the bond-specific liquidity risk premia in the markets for nominal and real bonds, their pricing is not performed with the standard frictionless discount functions shown above, but rather with a discount function that accounts for the bond-specific liquidity risk:

$$\begin{aligned} \bar{r}^{N,i}(t,t_0^i) &= r_t^N + \beta^{N,i}(1-e^{-\delta^{N,i}(t-t_0^i)})X_t^N = L_t^N + S_t + \beta^{N,i}(1-e^{-\delta^{N,i}(t-t_0^i)})X_t^N, \qquad (5) \\ \bar{r}^{R,j}(t,t_0^i) &= r_t^R + \beta^{R,j}(1-e^{-\delta^{R,j}(t-t_0^j)})X_t^R = L_t^R + \alpha^R S_t + \beta^{R,j}(1-e^{-\delta^{R,j}(t-t_0^j)})X_t^R, \qquad (6) \end{aligned}$$

where t_0^i and t_0^j denote the dates of issuance of the specific nominal and real bonds, respectively, and $\beta^{N,i}$ and $\beta^{R,j}$ are their sensitivities to the variation in their respective bond-specific liquidity risk factors. Furthermore, the decay parameters $\delta^{N,i}$ and $\delta^{R,j}$ are assumed to vary across securities as well.

Christensen and Rudebusch (2019) show that the net present value of one unit of currency paid by nominal bond i at time $t+\tau^i$ has the following exponential-affine form

$$\begin{aligned} P_t^N(t_0^i,\tau^i) &= E^{\mathbb{Q}}\left[e^{-\int_t^{t+\tau^i} \bar{r}^{N,i}(s,t_0^i)ds}\right] \\ &= \exp\left(B_1^N(\tau^i)L_t^N + B_2^N(\tau^i)S_t + B_3^N(\tau^i)C_t + B_4^N(t,t_0^i,\tau^i)X_t^N + A^N(t,t_0^i,\tau^i)\right). \end{aligned}$$

Andreasen et al. (2021) show that the net present value of one consumption unit paid by real bond j at time $t+\tau^j$ has the following exponential-affine form

$$\begin{aligned} P_t^R(t_0^j,\tau^j) &= E_t^{\mathbb{Q}}\Big[e^{-\int_t^{t+\tau^j}\overline{r}^{R,j}(s,t_0^j)ds}\Big] \\ &= \exp\Big(B_1^R(\tau^j)S_t + B_2^R(\tau^j)C_t + B_3^R(\tau^j)L_t^R + B_4^R(t,t_0^j,\tau^j)X_t^R + A^R(t,t_0^j,\tau^j)\Big). \end{aligned}$$

These formulas imply that the model belongs to the class of Gaussian affine term structure models. Note also that, by fixing $\beta^{N,i}=0$ for all i and $\beta^{R,j}=0$ for all j, we recover the model originally analyzed in Christensen et al. (2010) and denoted the $G(4)$ model.

Now, consider the whole value of the nominal bond i issued at time t_0^i with maturity at $t+\tau^i$ that pays a coupon C^i semiannually. Its price is given by[10]

$$\begin{aligned} \overline{P}_t^{N,i}(t_0^i,\tau^i,C^i) &= C^i(t_1-t)E^{\mathbb{Q}}\Big[e^{-\int_t^{t_1}\overline{r}^{N,i}(s,t_0^i)ds}\Big] + \sum_{k=2}^{n}\frac{C^i}{2}E^{\mathbb{Q}}\Big[e^{-\int_t^{t_k}\overline{r}^{N,i}(s,t_0^i)ds}\Big] \\ &\quad + E^{\mathbb{Q}}\Big[e^{-\int_t^{t+\tau^i}\overline{r}^{N,i}(s,t_0^i)ds}\Big]. \end{aligned}$$

Similarly, the price of the real bond j issued at time t_0^j with maturity at $t+\tau^j$ that pays a coupon C^j semiannually is given by

$$\begin{aligned} \overline{P}_t^{R,j}(t_0^j,\tau^j,C^j) &= C^j(t_1-t)E^{\mathbb{Q}}\Big[e^{-\int_t^{t_1}\overline{r}^{R,j}(s,t_0^j)ds}\Big] + \sum_{k=2}^{n}\frac{C^j}{2}E^{\mathbb{Q}}\Big[e^{-\int_t^{t_k}\overline{r}^{R,j}(s,t_0^j)ds}\Big] \\ &\quad + E^{\mathbb{Q}}\Big[e^{-\int_t^{t+\tau^j}\overline{r}^{R,j}(s,t_0^j)ds}\Big]. \end{aligned}$$

There are only two minor omissions in the real bond price formula above. First, it does not account for the lag in the inflation indexation of the real bond payoff, but the potential error should be modest in most cases thanks to the long maturities of our South African inflation-indexed bonds; see Grishchenko and Huang (2013) and D'Amico et al. (2018) for evidence in the case of the U.S. TIPS market. Second, we do not account for the value of deflation protection offered by the inflation-indexed bonds. However, given the generally elevated level of inflation in South Africa, the value of this protection is likely to be entirely negligible.

So far, the description of the $G^{X^N,X^R}(6)$ model has relied solely on the dynamics of the state variables under the $\mathbb{Q}$-measure used for pricing. However, to complete the description of the model and to implement it empirically, we will need to specify the risk premia that connect the factor dynamics under the $\mathbb{Q}$-measure to the dynamics under the real-world (or historical) $\mathbb{P}$-measure. It is important to note that there are no restrictions on the dynamic drift components under the empirical $\mathbb{P}$-measure beyond the requirement of constant volatility. To facilitate empirical implementation, we use the essentially affine risk premium specification

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[10] This is the clean nominal bond price that does not account for any accrued interest and maps to our observed nominal bond prices. The same applies to the real bond price formula.

introduced in Duffee (2002). In the Gaussian framework, this specification implies that the risk premia Γ_t depend on the state variables; that is,

$$\Gamma_t = \gamma^0 + \gamma^1 X_t,$$

where $\gamma^0 \in \mathbf{R}^6$ and $\gamma^1 \in \mathbf{R}^{6\times 6}$ contain unrestricted parameters.

Thus, the resulting unrestricted six-factor $G^{X^N,X^R}(6)$ model has $\mathbb{P}$-dynamics given by

$$dX_t = K^{\mathbb{P}}(\theta^{\mathbb{P}} - X_t) + \Sigma dW_t^{\mathbb{P}},$$

where $K^{\mathbb{P}}$ is an unrestricted 6×6 mean-reversion matrix, $\theta^{\mathbb{P}}$ is a 6×1 vector of mean levels, and Σ is a 6×6 diagonal triangular volatility matrix. This is the transition equation in the extended Kalman filter estimation of this model.

3.2 Model Estimation and Econometric Identification

Due to the nonlinearity of the bond pricing formulas, the model cannot be estimated with the standard Kalman filter. Instead, we use the extended Kalman filter, as in Kim and Singleton (2012); see Christensen and Rudebusch (2019) for details. To make the fitted errors comparable across bonds of various maturities, we scale each bond price by its duration. Thus, the measurement equation for the nominal bond prices takes the following form:

$$\frac{\overline{P}_t^N(t_0^i, \tau^i)}{D_t^N(\tau^i)} = \frac{\widehat{P}_t^N(t_0^i, \tau^i)}{D_t^N(\tau^i)} + \varepsilon_t^{N,i},$$

where $\widehat{P}_t^N(t_0^i, \tau^i)$ is the model-implied price of nominal bond i and $D_t^N(\tau^i)$ is its duration, which is fixed and calculated before estimation. Similarly, the measurement equation for the real bond prices takes the following form:

$$\frac{\overline{P}_t^R(t_0^j, \tau^j)}{D_t^R(\tau^j)} = \frac{\widehat{P}_t^R(t_0^j, \tau^j)}{D_t^R(\tau^j)} + \varepsilon_t^{R,j},$$

where $\widehat{P}_t^R(t_0^j, \tau^j)$ is the model-implied price of real bond j and $D_t^R(\tau^j)$ is its duration, which is again fixed and calculated before estimation. See Andreasen et al. (2019) for evidence supporting this formulation of the measurement equations.

Since the bond-specific liquidity risk factors are latent factors that we do not observe, their level is not identified without imposing an identifying restriction on each. As a consequence, we let the ninth standard fixed-coupon bond in our sample have a unit loading on the nominal bond-specific risk factor X_t^N, that is, the fixed-coupon bond issued on May 21, 1998, with maturity on December 21, 2026, and a coupon rate of 10.5 percent has $\beta^i = 1$. As for the real liquidity risk factor X_t^R, we let the first 30-year inflation-indexed bond in our sample—the third bond in the data—issued on August 20, 2003, with maturity on December 7, 2033, and a coupon rate of 3.45 percent have a unit loading on this factor. Note that these two restrictions are imposed purely for econometric reasons and do not matter for our reported results.

Furthermore, we note that the $\delta^{N,i}$ and $\delta^{R,j}$ parameters can be hard to identify if their values are too large or too small. As a consequence, we impose the restriction that they fall within the range from 0.0001 to 10, which is without practical consequences for our results, as also noted by Cardozo and Christensen (2025). Also, for numerical stability during the model optimization, we impose the restriction that the $\beta^{N,i}$ and $\beta^{R,j}$ parameters fall within the range from 0 to 250.

In addition, we assume that all nominal bond price measurement equations have *i.i.d.* fitted errors with zero mean and standard deviation σ_ε^N. Similarly, all real bond price measurement equations have fitted errors that are assumed to be *i.i.d.* with zero mean and standard deviation σ_ε^R.

Finally, we assume that the state variables are stationary, which is standard in the finance literature. As a consequence, we start the Kalman filter at the unconditional mean and covariance matrix.

4 Results

In this section, we briefly summarize the main estimation results for the specific version of the $G^{X^N,X^R}(6)$ model we use throughout. This specification was first identified by Christensen and Steenkamp (2025a) based on a careful model selection process and is characterized by a mean-reversion $K^{\mathbb{P}}$ matrix given by[11]

$$K^{\mathbb{P}} = \begin{pmatrix} \kappa_{11}^{\mathbb{P}} & \kappa_{12}^{\mathbb{P}} & 0 & \kappa_{14}^{\mathbb{P}} & 0 & \kappa_{16}^{\mathbb{P}} \\ 0 & \kappa_{22}^{\mathbb{P}} & 0 & 0 & 0 & 0 \\ 0 & 0 & \kappa_{33}^{\mathbb{P}} & \kappa_{34}^{\mathbb{P}} & \kappa_{35}^{\mathbb{P}} & 0 \\ \kappa_{41}^{\mathbb{P}} & \kappa_{42}^{\mathbb{P}} & 0 & \kappa_{44}^{\mathbb{P}} & 0 & \kappa_{46}^{\mathbb{P}} \\ \kappa_{51}^{\mathbb{P}} & 0 & \kappa_{53}^{\mathbb{P}} & \kappa_{54}^{\mathbb{P}} & \kappa_{55}^{\mathbb{P}} & 0 \\ \kappa_{61}^{\mathbb{P}} & \kappa_{62}^{\mathbb{P}} & 0 & \kappa_{64}^{\mathbb{P}} & 0 & \kappa_{66}^{\mathbb{P}} \end{pmatrix},$$

while it has a diagonal Σ volatility matrix.

The estimated parameters of this preferred specification are reported in Table 1. The estimated $\mathbb{Q}$-dynamics used for pricing and determined by (Σ, λ, α^R, $\kappa_N^{\mathbb{Q}}$, $\theta_N^{\mathbb{Q}}$, $\kappa_R^{\mathbb{Q}}$, $\theta_R^{\mathbb{Q}}$) are close to those reported in Christensen and Steenkamp (2025a). This implies that our model

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[11] To select the best fitting specification of the $G^{X^N,X^R}(6)$ model's real-world dynamics, Christensen and Steenkamp (2025a) use a general-to-specific modeling strategy in which the least significant off-diagonal parameter of $K^{\mathbb{P}}$ is restricted to zero and the model is re-estimated. This strategy of eliminating the least significant parameter is carried out down to the most parsimonious specification, which has a diagonal $K^{\mathbb{P}}$ matrix. The final specification choice is based on the value of the Bayesian information criterion (BIC) as in Christensen et al. (2014).

$K^{\mathbb{P}}$	$K^{\mathbb{P}}_{\cdot,1}$	$K^{\mathbb{P}}_{\cdot,2}$	$K^{\mathbb{P}}_{\cdot,3}$	$K^{\mathbb{P}}_{\cdot,4}$	$K^{\mathbb{P}}_{\cdot,5}$	$K^{\mathbb{P}}_{\cdot,6}$	$\theta^{\mathbb{P}}$		Σ
$K^{\mathbb{P}}_{1,\cdot}$	0.8578	1.2770	0	2.3308	0	-0.5268	0.1548	σ_{11}	0.0105
	(0.1960)	(0.2075)		(0.4284)		(0.1449)	(0.0128)		(0.0005)
$K^{\mathbb{P}}_{2,\cdot}$	0	0.1366	0	0	0	0	-0.0976	σ_{22}	0.0236
		(0.1258)					(0.0249)		(0.0009)
$K^{\mathbb{P}}_{3,\cdot}$	0	0	0.7024	-2.9258	3.3467	0	0.0336	σ_{33}	0.0578
			(0.2656)	(0.8247)	(0.8877)		(0.0529)		(0.0029)
$K^{\mathbb{P}}_{4,\cdot}$	1.3725	3.3663	0	6.3489	0	-1.6123	0.0259	σ_{44}	0.0232
	(0.4935)	(0.4500)		(0.6846)		(0.3518)	(0.0130)		(0.0014)
$K^{\mathbb{P}}_{5,\cdot}$	-0.9094	0	-0.2728	0.5619	1.1472	0	0.0125	σ_{55}	0.0055
	(0.2519)		(0.0759)	(0.2315)	(0.3804)		(0.0086)		(0.0006)
$K^{\mathbb{P}}_{6,\cdot}$	-1.6550	-3.0888	0	-4.6150	0	1.2385	0.1562	σ_{66}	0.0244
	(0.5262)	(0.4194)		(0.6878)		(0.2499)	(0.0258)		(0.0039)

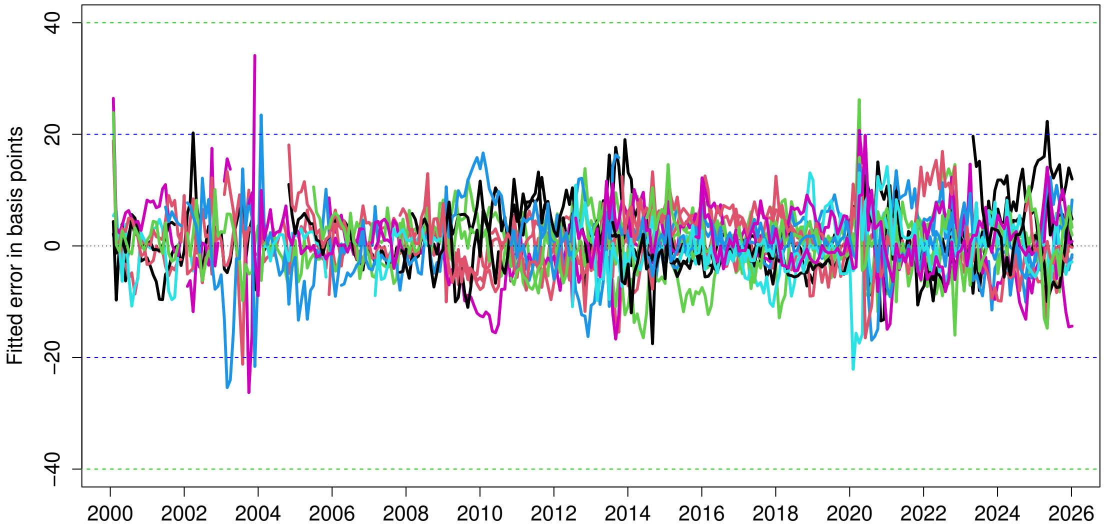
Table 1: **Estimated Dynamic Parameters of the Preferred $G^{X^N,X^R}(6)$ Model**
The table shows the estimated parameters of the $K^{\mathbb{P}}$ matrix, $\theta^{\mathbb{P}}$ vector, and diagonal Σ matrix for the $G^{X^N,X^R}(6)$ model preferred by Christensen and Steenkamp (2025a). The estimated value of λ is 0.1800 (0.0037), while $\alpha^R = 0.1746$ (0.0205), $\kappa_N^{\mathbb{Q}} = 0.9891$ (0.0415), $\theta_N^{\mathbb{Q}} = 0.0045$ (0.0004), $\kappa_R^{\mathbb{Q}} = 0.5975$ (0.0535), and $\theta_R^{\mathbb{Q}} = 0.0443$ (0.0044). The maximum log likelihood value is 23,255.93. The numbers in parentheses are the estimated parameter standard deviations.

fit and the estimated bond-specific parameters are very similar to theirs and therefore not reported. Furthermore, the estimated objective $\mathbb{P}$-dynamics in terms of $\theta^{\mathbb{P}}$ and Σ are also qualitatively similar to their reported estimates.

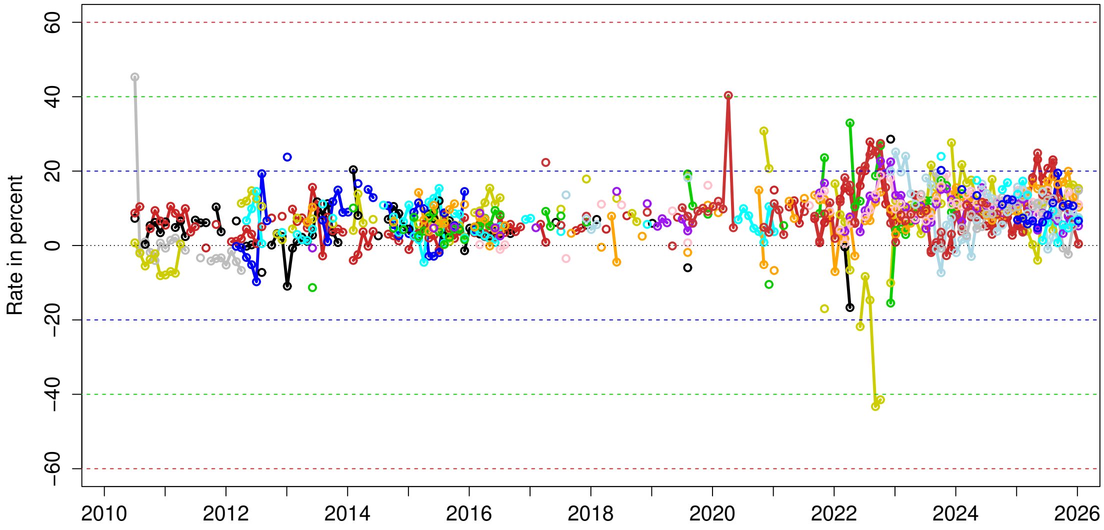
To examine the model fit, pricing errors are computed based on the implied yield on each coupon bond to make these errors comparable across securities. That is, for the price on the ith coupon bond $P_t^i(\tau, C^i)$, we find the value of $y_t^{i,c}$ that solves

$$P_t^i(\tau^i, C^i) = C^i(t_1 - t)\exp\left\{-y_t^{i,c}(t_1 - t)\right\} + \sum_{j=2}^{N}\frac{C^i}{2}\exp\left\{-y_t^{i,c}(t_j - t)\right\} + \exp\left\{-y_t^{i,c}(t_N - t)\right\}. \quad (7)$$

For the model-implied estimate of this bond price, denoted $\hat{P}_t^i(\tau, C^i)$, we find the corresponding implied yield $\hat{y}_t^{i,c}$ and report the pricing error as $y_t^{i,c} - \hat{y}_t^{i,c}$. Figure 3 shows the fitted error series for each bond price calculated this way. The top panel shows the results for the 33 nominal bonds in our sample, while the bottom panel shows the results for the 15 inflation-indexed bonds in the sample. For the nominal bonds, the root mean-squared error (RMSE) for all bonds combined is 5.46 basis points, while the corresponding statistics for the real bonds is 10.67 basis points. Thus, the $G^{X^N,X^R}(6)$ model provides a really tight fit to the cross section of nominal bond prices, while it is facing some challenges in fitting the inflation-indexed bond prices, but it still delivers a satisfying fit to that data. In part, the better fit to the nominal bonds reflect the fact that the $G^{X^N,X^R}(6)$ model is fitting those with four factors, while the inflation-indexed bond prices are only fitted using three factors.



(a) Nominal bonds



(b) Inflation-indexed bonds

Figure 3: **Fitted Errors of South African Nominal and Real Government Bonds**

4.1 The Estimated Bond-Specific Liquidity Risk Premia

We now use the estimated $G^{X^N,X^R}(6)$ model described in the previous section to extract the bond-specific liquidity risk premia in the South African government bond market. To compute these premia, we first use the estimated parameters and the filtered states $\left\{X_{t|t}\right\}_{t=1}^{T}$ to calculate the fitted bond prices $\left\{\hat{P}_t^i\right\}_{t=1}^{T}$ for all outstanding securities in our sample. These

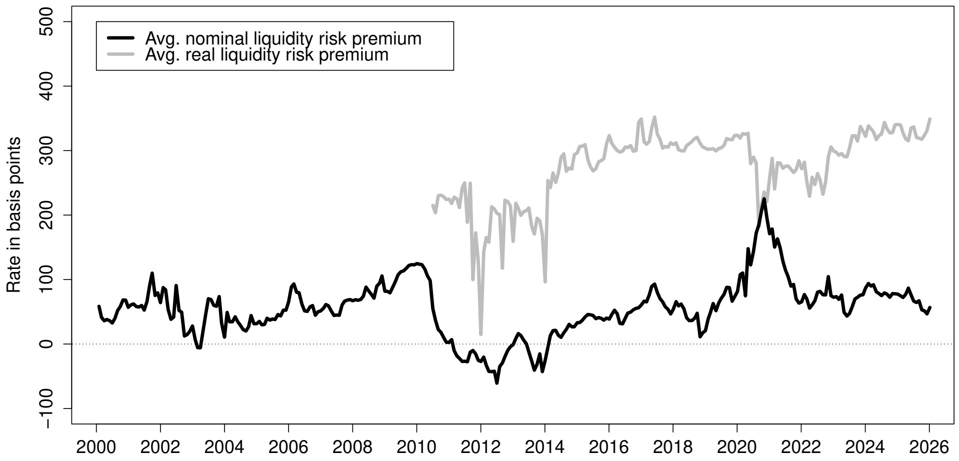


Figure 4: **Average Estimated Liquidity Risk Premia**
Illustration of the average estimated bond-specific liquidity risk premia of South African nominal and inflation-indexed bonds for each observation date implied by the $G^{X^N,X^R}(6)$ model. The nominal bond price data cover the period from January 31, 2000, to December 31, 2025, while the real bond price data cover the period from June 30, 2010, to December 31, 2025.

bond prices are then converted into yields to maturity $\left\{\hat{y}_t^{c,i}\right\}_{t=1}^{T}$ by solving the fixed-point problem in equation (7) for $i = 1, 2, ..., n$, meaning that $\left\{\hat{y}_t^{c,i}\right\}_{t=1}^{T}$ is approximately the rate of return on the ith bond if held until maturity (see Sack and Elsasser 2004). To obtain the corresponding yields corrected for the bond-specific liquidity risk premia, we compute a new set of model-implied bond prices from the estimated $G^{X^N,X^R}(6)$ model using only its frictionless part, i.e., using the constraints that $X_{t|t}^N = 0$ for all t as well as $\sigma_{44} = 0$ and $\theta_N^Q = 0$, and $X_{t|t}^R = 0$ for all t as well as $\sigma_{66} = 0$ and $\theta_R^Q = 0$. These prices are denoted $\left\{\tilde{P}_t^i\right\}_{t=1}^{T}$ and converted into yields to maturity $\tilde{y}_t^{c,i}$ using equation (7) as well. They represent estimates of the prices that would prevail in a world without any financial frictions or convenience premia. The bond-specific liquidity risk premium for the ith bond is then defined as

$$\Psi_t^i \equiv \hat{y}_t^{c,i} - \tilde{y}_t^{c,i}. \tag{8}$$

Figure 4 shows the average bond-specific risk premia in the nominal and inflation-indexed bond market across the outstanding set of bonds in each market at each point in time, denoted $\overline{\Psi}_t^N$ and $\overline{\Psi}_t^R$, respectively.

The average liquidity risk premium of the nominal bonds has a mean equal to 55 basis points with a standard deviation of 44 basis points, while the average liquidity risk premium of the indexed bonds has a significantly higher mean equal to 275 basis points with a standard deviation of 57 basis points.[12] Hence, according to our model, the liquidity risk in the inflation-indexed market is an order of magnitude above that in the standard bond market. Furthermore, their correlation in levels is 50 percent, while it is 15 percent in first differences. Thus, the liquidity risk in the two markets is mildly positively correlated and higher than the estimates reported in Beauregard et al. (2024) for the Mexican government bond market or in Ceballos et al. (2024) for Brazil, Chile, and Mexico. Overall, these estimates suggest that liquidity premia are an important contributor to the elevated level of interest rates in South Africa.

5 Empirical BEI Decomposition

In this section, we first briefly describe how we decompose BEI into the model-implied expected inflation and the associated inflation risk premium that investors in nominal bonds demand to assume their inflation risk. We then examine the properties of the BEI decomposition implied by the $G^{X^N,X^R}(6)$ model with a particular emphasis on both the model-implied expected inflation and the associated inflation risk premium.

5.1 Decomposing BEI

Christensen et al. (2010) show that the price of a nominal zero-coupon bond with maturity in τ years can be written as

$$P_t^N(\tau) = P_t^R(\tau) \times E_t^{\mathbb{P}}\left[\frac{\Pi_t}{\Pi_{t+\tau}}\right] \times \left(1 + \frac{cov_t^{\mathbb{P}}\left[\frac{M_{t+\tau}^R}{M_t^R}, \frac{\Pi_t}{\Pi_{t+\tau}}\right]}{E_t^{\mathbb{P}}\left[\frac{M_{t+\tau}^R}{M_t^R}\right] \times E_t^{\mathbb{P}}\left[\frac{\Pi_t}{\Pi_{t+\tau}}\right]}\right),$$

where $P_t^R(\tau)$ is the price of a real zero-coupon bond that pays one consumption unit in τ years, M_t^R is the real stochastic discount factor, and Π_t is the price level.[13]

By taking logarithms, this can be converted into

$$y_t^N(\tau) = y_t^R(\tau) + \pi_t^e(\tau) + \phi_t(\tau),$$

where $y_t^N(\tau)$ and $y_t^R(\tau)$ are nominal and real *frictionless* zero-coupon yields adjusted for the embedded liquidity risk premia, while the market-implied average rate of inflation expected at time t for the period from t to $t+\tau$ is

$$\pi_t^e(\tau) = -\frac{1}{\tau}\ln E_t^{\mathbb{P}}\left[\frac{\Pi_t}{\Pi_{t+\tau}}\right] = -\frac{1}{\tau}\ln E_t^{\mathbb{P}}\left[e^{-\int_t^{t+\tau}(r_s^N - r_s^R)ds}\right] \tag{9}$$

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[12] These estimates are consistent with the liquidity premia of Olds and Steenkamp (2021) and Christensen and Steenkamp (2025a). An important contributor to the increase in sovereign liquidity premia has been the declining role of foreign investors in the domestic bond market since the market share of foreign investors peaked in 2018; see South African Reserve Bank (2023) and Christensen and Steenkamp (2025a).

[13] The full details of the decomposition can be found in Beauregard et al. (2024).

and the associated inflation risk premium for the same time period is

$$\phi_t(\tau) = -\frac{1}{\tau}\ln\left(1+\frac{cov_t^{\mathbb{P}}\left[\frac{M_{t+\tau}^R}{M_t^R},\frac{\Pi_t}{\Pi_{t+\tau}}\right]}{E_t^{\mathbb{P}}\left[\frac{M_{t+\tau}^R}{M_t^R}\right]\times E_t^{\mathbb{P}}\left[\frac{\Pi_t}{\Pi_{t+\tau}}\right]}\right). \tag{10}$$

Equation (10) demonstrates that the inflation risk premium can be positive or negative. It is positive if and only if

$$cov_t^{\mathbb{P}}\left[\frac{M_{t+\tau}^R}{M_t^R},\frac{\Pi_t}{\Pi_{t+\tau}}\right] < 0. \tag{11}$$

That is, the riskiness of nominal bonds relative to real bonds depends on the covariance between the real stochastic discount factor and inflation and is ultimately determined by investor preferences, as in, for example, Rudebusch and Swanson (2012).

Now, the BEI rate is defined as

$$BEI_t(\tau) \equiv y_t^N(\tau) - y_t^R(\tau) = \pi_t^e(\tau) + \phi_t(\tau),$$

that is, the difference between nominal and real yields of the same maturity. Note that it can be decomposed into the sum of expected inflation and the inflation risk premium.

5.2 BEI Decomposition

The formulas for decomposing BEI provided in the previous section are valid for any maturity τ. However, to be consistent with the existing literature, we focus on a horizon long enough into the future that most transitory shocks to the economy can be expected to have vanished. At the same time, the horizon must be practically relevant and covered by the available maturities in the underlying bond data. Balancing these considerations, we limit our analysis to the five-year forward BEI rate that starts five years ahead, denoted 5yr5yr BEI. Our measure controls for liquidity premia embedded in nominal and inflation-indexed bond prices, as well as an expected inflation component and a residual inflation risk component.

The result of decomposing 5yr5yr BEI based on the $G^{X^N,X^R}(6)$ model is shown in Figure 5. The solid gray line shows the fitted 5yr5yr BEI obtained by estimating the standard $G(4)$ model using nominal and real bond prices. This can be compared to the estimated 5yr5yr frictionless BEI implied by the $G^{X^N,X^R}(6)$ model, which is shown with a solid black line in Figure 5. The difference between these two measures of 5yr5yr BEI represents the net liquidity premium or distortion of the observed BEI series due to bond-specific liquidity risk premia in both nominal and real bond prices. The fact that the 5yr5yr frictionless BEI is entirely above the 5yr5yr fitted BEI implies that the distortions due to liquidity risk are systematically larger in the real yields compared to those in the nominal yields at the 5yr5yr horizon, consistent with the evidence in Figure 4.

Due to its theoretical consistency, the $G^{X^N,X^R}(6)$ model allows us to break down the

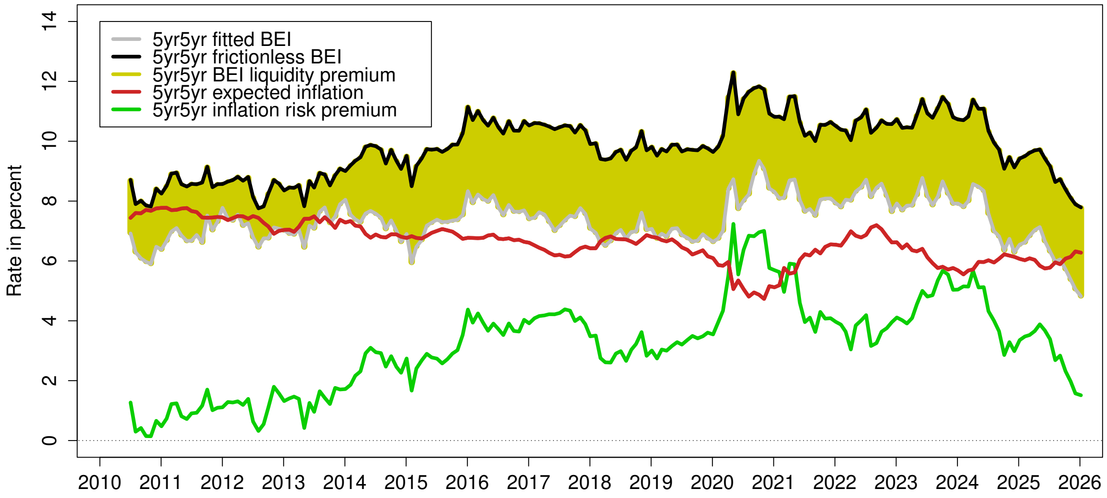

Figure 5: **Decomposition of 5yr5yr BEI**
Illustration of the fitted 5yr5yr BEI obtained by fitting the G(4) model to South African nominal and real bond prices jointly and its decomposition based on the $G^{X^N,X^R}(6)$ model estimated with the preferred specification of $K^{\mathbb{P}}$ and a diagonal specification of Σ into: (1) the estimated frictionless BEI, (2) expected inflation, and (3) the residual inflation risk premium. The difference between the fitted and frictionless 5yr5yr BEI is highlighted in yellow and represents the net liquidity premium of the observed 5yr5yr BEI. The shown data cover the period from June 30, 2010, to December 31, 2025.

5yr5yr frictionless BEI into an expected inflation component, shown with a solid red line in Figure 5, and the residual inflation risk premium, shown with a solid green line.

First, we note that long-term inflation expectations are variable, reaching a highest value of 8 percent and dropping to almost 4 percent over the course of a relatively short ten-year period. Moreover, at a technical level, these significant fluctuations in the estimated 5yr5yr expected inflation suggest that the $G^{X^N,X^R}(6)$ model's estimated factor dynamics reflect a reasonable level of persistence and are not overly plagued by the finite-sample bias challenges discussed in Bauer et al. (2012) despite the relatively short sample of real yields. More importantly, there is a persistent mild downward trend in 5yr5yr expected inflation. Thus, investors' long-term inflation expectations appear to gradually be approaching the 3 to 6 percent tolerance band adopted by the SARB in 2000. Second, thanks to the varying 5yr5yr expected inflation, the residual 5yr5yr inflation risk premium series is also quite variable, reaching its lowest value near zero in fall 2010 and assuming its maximum close to 7 percent in spring 2020. Since then, it has declined steadily to reach 2 percent by the end of our sample. Hence, the sharp drop in inflation risk premia since 2024 is a key factor behind the decline in nominal yields during the most recent period.

Our inflation risk premium estimates are broadly in line with comparable estimates for

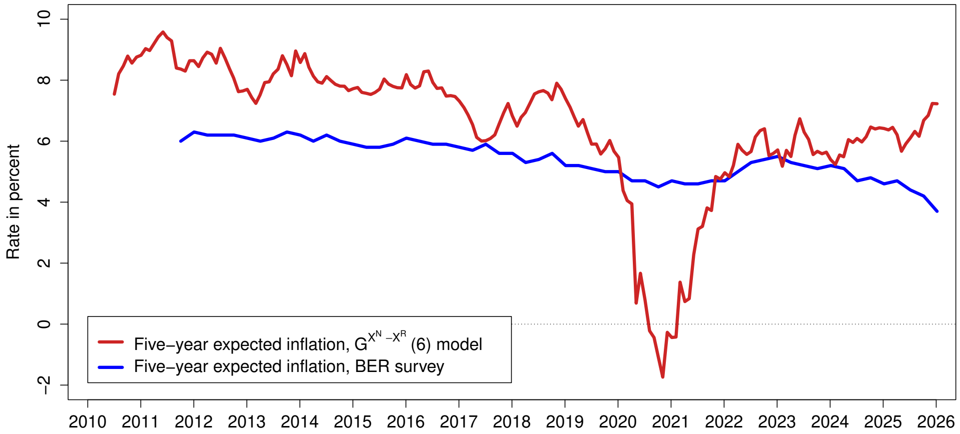

Figure 6: **Comparison of Five-Year Inflation Expectations**

Colombia, but higher than available estimates for Mexico, Canada or the United States, though more volatile than those of Colombia; see Cardozo and Christensen (2025).

Although our results are consistent with a gradual improvement in the anchoring of inflation expectations in South Africa, we will more formally assess in Section 6 whether the recent decline in market rates reflects a fall in the equilibrium real borrowing costs.

5.2.1 Comparison with Survey Forecasts

To validate the BEI decomposition implied by the $G^{X^N,X^R}(6)$ model, we compare its expected inflation with the inflation forecasts collected by the Bureau of Economic Research (BER) through its quarterly survey of financial market analysts, businesses, and trade unions.[14] Although responses are reported for each group, we focus on the average, or consensus, forecast across all surveyed groups. Moreover, while one- and two-year inflation forecasts are available back to the early 2000s, we limit our comparison to the medium-term five-year inflation forecasts collected since the third quarter of 2011. The main reason is that the short end of the inflation-indexed yield curve is very sparsely populated during our sample period. As a result, we consider the model's short-term one- and two-year expected inflation to be less reliable than its medium- and long-term expected inflation.

Figure 6 compares the estimated five-year expected inflation from the $G^{X^N,X^R}(6)$ model with the corresponding survey five-year inflation forecasts. Although our estimates have been slightly higher on average than the survey-based measure of inflation expectations, two main things stand out in the comparison. First and most importantly, the two series have followed a very similar downward trend since 2011. Thus, both surveys and our model are in agreement

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[14] For details about the survey, see https://www.ber.ac.za/Methodologies/InflationExpectationSurvey

that medium-term expected inflation in South Africa has declined about 2 percentage points on net the past 15 years. Second, the model-implied series exhibits a sharp temporary drop in the 2020-2021 period that is barely detectable in the survey forecasts. This can be traced back to variation in the yield data. As shown in Figure 1, short-term nominal and real yields experienced sharp declines in this period. Technically, this implies that the launch point for the path of $r_t^N - r_t^R$, which is integrated to produce the model-implied expected inflation, was unusually low during that brief extraordinary window. Moreover, the estimated factor dynamics within our model imply that the process for the nominal short rate r_t^N is notably more persistent than the process for the real short rate r_t^R. As a consequence, r_t^R is expected to revert back towards its mean much faster than r_t^N. Mechanically, this forces the formula in equation (9) to produce very low expected inflation up to a certain horizon into the future, by which time r_t^N is expected to have reverted back towards its mean sufficiently so as to produce expected inflation near its historical average. Hence, it is a combination of unique variation in the yield data and notable differences in factor persistence across the nominal and inflation-indexed bond markets that gives rise to the sizable temporary gyration in the model-implied expected inflation during this period.

Overall, aside from this short-lived episode, we take the presented evidence to demonstrate that our $G^{X^N,X^R}(6)$ model is able to produce realistic medium- and long-term expected inflation that share key characteristics with matching inflation forecasts from surveys of analysts, businesses, and trade unions, which represent key economic actors in the South African economy. Therefore, we feel comfortable in relying on the model for our assessment of the stance of monetary policy in South Africa, the task we turn to in the next section.

Before assessing the stance of policy, it is worth evaluating the impact of the 2025 change in the inflation target on market-based inflation expectations. Figure 7 plots the model's decomposition of the five-year BEI, the relevant maturity compared in Figure 6. This shows that the five-year observed BEI has steadily declined since early 2024. However, our model shows that five-year frictionless BEI (the one observed after adjustment for the net liquidity distortions in both nominal and real yields) has been flat over the past 6 months due to a widening in the real bond liquidity premium. The model interprets recent data as implying a continued drop in the five-year inflation risk premium, matched by a similar-sized uptick in five-year expected inflation. This comes from the specific change in the entire shape of the nominal and real yield curve and underscores the value of modelling both yield curves jointly as opposed to just looking at a single point like the five-year BEI series in isolation.

The credibility of the inflation target can best be judged by looking at the 5yr5yr horizon, that is, the horizon beyond the nearest 5 years that is the focus of Figure 6. At that horizon, one observes greater stability in inflation expectations over recent months in Figure 5 than in Figure 6. These estimates suggest that market expectations have not yet re-anchored to a lower inflation target. In the section that follows, however, we present forecasts that suggest

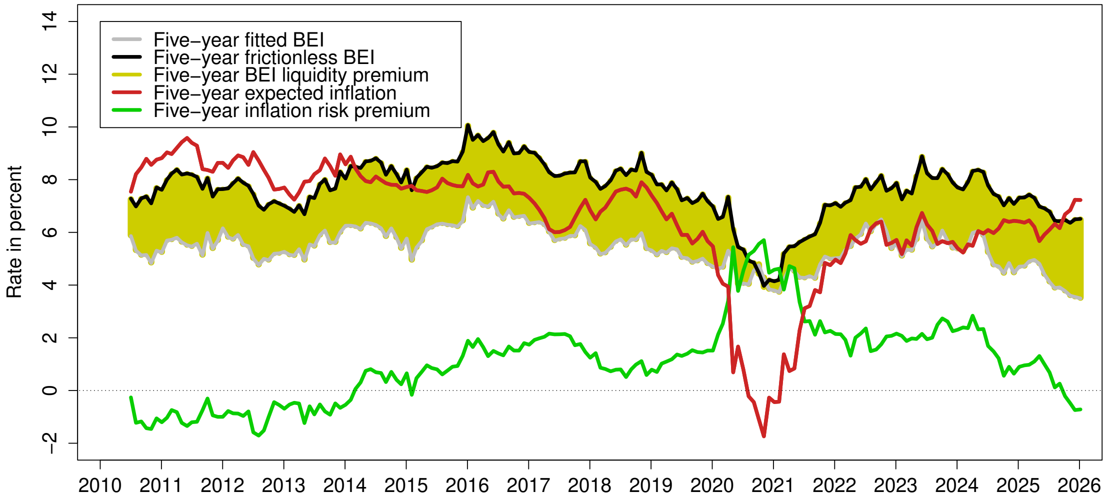

Figure 7: **Decomposition of Five-Year BEI**
Illustration of the fitted five-year BEI obtained by fitting the G(4) model to South African nominal and real bond prices jointly and its decomposition based on the $G^{X^N,X^R}(6)$ model estimated with the preferred specification of $K^{\mathbb{P}}$ and a diagonal specification of Σ into: (1) the estimated frictionless BEI, (2) expected inflation, and (3) the residual inflation risk premium. The difference between the fitted and frictionless five-year BEI is highlighted in yellow and represents the net liquidity premium of the observed five-year BEI. The shown data cover the period from June 30, 2010, to December 31, 2025.

that expected inflation is most likely to continue its gradual decline in the decade ahead.

6 The Natural Real Rate and the Stance of Monetary Policy

In this section, we leverage the $G^{X^N,X^R}(6)$ model to examine the level of the natural real rate of interest, widely known as r_t^*, and an associated measure of the stance of monetary policy in South Africa. As a matter of background, Christensen and Rudebusch (2019) pioneered models of market-based estimates of the natural real rate, while Christensen and Mouabbi (2024) originated an innovative method using those estimates to measure the stance of monetary policy.

6.1 Estimate of r_t^*

To begin, we follow Christensen and Rudebusch (2019) and define the natural real rate of interest r_t^* as

$$r_t^* = \frac{1}{5}\int_{t+5}^{t+10} E_t^{\mathbb{P}}[r_s^R]ds, \tag{12}$$

that is, the average expected real short rate over a five-year period starting five years ahead, where the expectation is with respect to the objective $\mathbb{P}$-probability measure. We note that this 5yr5yr forward average expected real short rate should be little affected by short-term transitory shocks. Alternatively, r_t^* could be defined as the expected real short rate at an infinite horizon, as discussed in Christensen and Rudebusch (2019). However, this quantity will depend crucially on whether the factor dynamics exhibit a unit root. The typical spans of the available time series data do not distinguish strongly between highly persistent stationary processes and nonstationary ones. Our model follows the finance literature and adopts the former structure, so strictly speaking, our infinite-horizon steady-state expected real rate is constant. However, our data sample likely has insufficient information in the ten-year to infinite horizon to definitively pin down that steady state.

To illustrate the decomposition underlying our definition of r_t^*, recall that the real term premium is defined as

$$TP_t^R(\tau) = y_t^R(\tau) - \frac{1}{\tau}\int_t^{t+\tau} E_t^{\mathbb{P}}[r_s^R]ds,$$

where $y_t^R(\tau)$ is the *frictionless* real yield with maturity at $t+\tau$. That is, the real term premium is the difference in expected real returns between a buy-and-hold strategy for a τ-year real bond and an instantaneous rollover strategy at the risk-free real rate r_t^R. Figure 8 shows the $G^{X^N,X^R}(6)$ model decomposition of the 5yr5yr forward frictionless real yield based on this equation. The solid green line is the 5yr5yr forward real term premium, which, although volatile, has fluctuated around a fairly stable level since 2010. Theory suggests that this premium should be countercyclical and elevated during economic recessions, and our estimate broadly aligns with these characteristics. Similarly, the estimate of the natural rate of interest implied by the $G^{X^N,X^R}(6)$ model—the blue line—shows a very stable pattern centered slightly below zero with very modest variation. By the end of the sample, our estimate of r_t^* in South Africa stands at -0.36 percent.[15]

Equally importantly, note the sizable inflation-indexed bond liquidity premia that drive a large wedge between the observed 5yr5yr real yield shown with a solid black line in Figure 8 and the lower 5yr5yr frictionless real yield shown with a solid gray line in Figure 8. Thus, without the liquidity premium adjustment, one might be led to believe that real yields are much higher than are actually the case, a point also made by Andreasen and Christensen (2016) in the context of U.S. TIPS.[16]

As we show in the next section, a negative natural rate does not imply that monetary policy is accommodative, as high liquidity and term premia keep real market yields high, requiring the central bank to set positive real policy rates to compensate investors for factors such as inflation uncertainty or sovereign credit risk. The SARB's real neutral estimate that

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[15] For comparison, in a dynamic stochastic general equilibrium model, Havemann and Hollander (2025) estimate the natural real short rate associated with a flexible-price equilibrium for South Africa and obtain a negative estimate between 2010:Q2 and 2023:Q4.

[16] This is indeed the case for the commonly used approach of Adrian et al. (2013). Updated estimates from Erasmus and Steenkamp (2022b) for South Africa, which do not account for liquidity premia, produce an estimate of the nominal neutral 5yr5yr rate of 7.5 percent over our sample, or a 3 percent real rate if one assumes a 4.5 percent inflation rate.

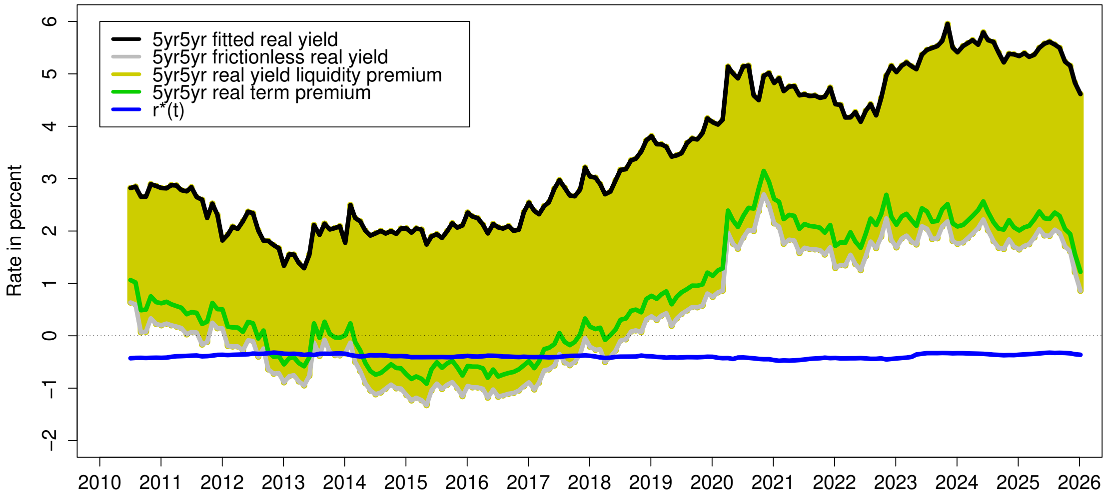

Figure 8: $G^{X^N,X^R}(6)$ **Model 5yr5yr Real Yield Decomposition**
Illustration of the 5yr5yr fitted real yield calculated based on the $G(4)$ model estimated using the sample of nominal and inflation-indexed government bond prices examined in this paper. Also shown is the estimated 5yr5yr frictionless real yield implied by the preferred $G^{X^N,X^R}(6)$ model and its decomposition into the 5yr5yr expected real short rates, which is equivalent to our definition of r_t^*, and the residual 5yr5yr real term premium. Note that the difference between the fitted 5yr5yr real yield and the estimated 5yr5yr frictionless real yield equals the estimated 5yr5yr real yield liquidity premium. The data cover the period from June 30, 2010, to December 31, 2025.

includes such premia has averaged 2.1 percent between 2014 and 2025 (the period for which estimates are available), rising from 1.6 percent in 2014 to 2.8 percent by late 2025.[17]

6.2 Estimated Stance of Monetary Policy

In constructing the related measure of the stance of monetary policy, we follow Christensen and Mouabbi (2024) and define it as

$$\zeta_t = \widehat{y}_t^R(1) - r_t^*,$$

where $\widehat{y}_t^R(1)$ is the *frictionless* one-year yield implied by our preferred $G^{X^N,X^R}(6)$ model.

We note that, in theory, the stance of monetary policy should be defined as $\zeta_t = r_t^R - r_t^*$, where r_t^R is the instantaneous real short rate. However, our sample of inflation-indexed bonds

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[17] In 2025, the SARB generally assumed that 4.5 percentage points of the South African long rate is "inflation compensation and 2.75 percentage points is attributed to global rates plus country risk;" see https://www.resbank.co.za/content/dam/sarb/publications/speeches/speeches-by-governors/2025/kganyago-price-stability.pdf. The Governor of the SARB has previously stated that the SARB expects that the inflation target reduction from the 4.5 percent midpoint to the new 3 percent midpoint would take 1.5 percentage points off this inflation risk premium and reduce the country risk component by a further 0.5 percentage points.

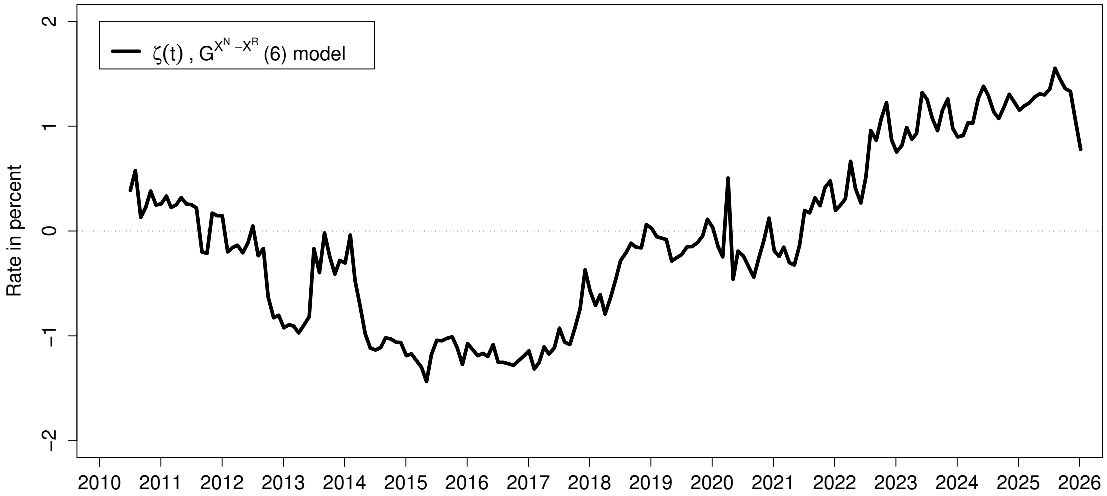


Figure 9: **Market-Based Estimate of the Stance of Monetary Policy**

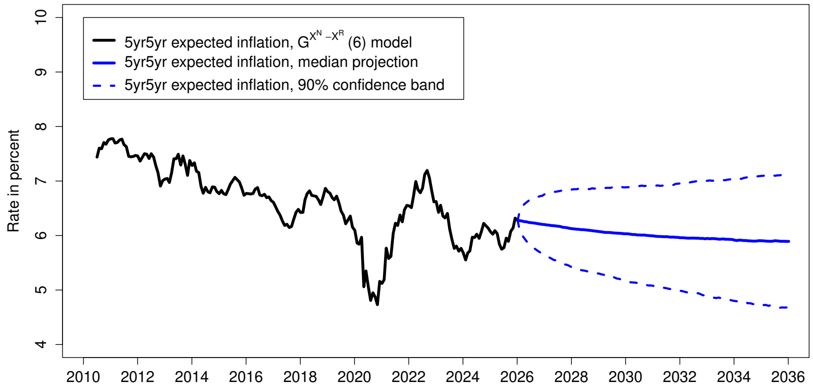
is very sparsely populated in the short end of the maturity space most of the time. Moreover, we censor inflation-indexed bonds when they have less than one year remaining to maturity to minimize the impact of noise in the prices of bonds close to maturity; see Gürkaynak et al. (2010). By using one-year fitted real yields, we aim to strike a reasonable balance between minimizing noise and staying true to the textbook formula for the stance of monetary policy.

The intuition behind the definition above is straightforward. When the current real short rate is above its neutral level, interest rates of all kinds are likely to be above their steady-state level and will provide some headwind for new economic activity through higher borrowing costs and help slow down the economy. And vice versa, when the current real short rate is below its neutral level, the general interest rate level is likely to be below what is needed to maintain trend growth, and businesses and households may take advantage of that by making investments in new projects or housing at cheap financing rates, which will help boost economic activity.

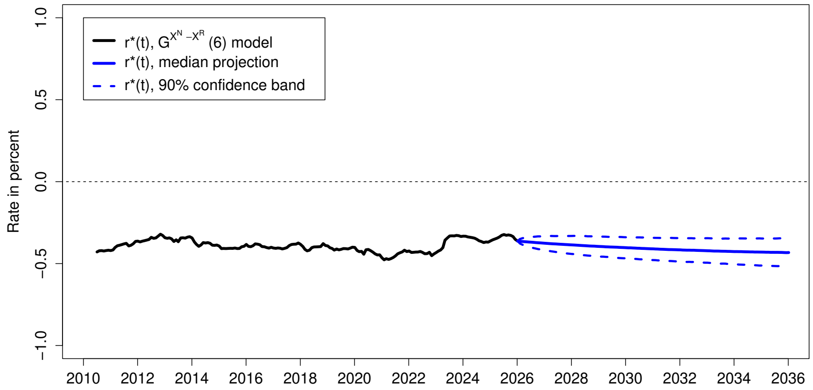
Figure 9 shows our market-based measure of ζ_t. It suggests that monetary policy was accommodative between 2014 and 2019, but barely so during the COVID-19 pandemic. Moreover, monetary policy has become increasingly contractionary since 2022. This is broadly in line with the SARB's own assessments of its policy stance.

6.3 Outlook for π_t^e, r_t^* and ζ_t

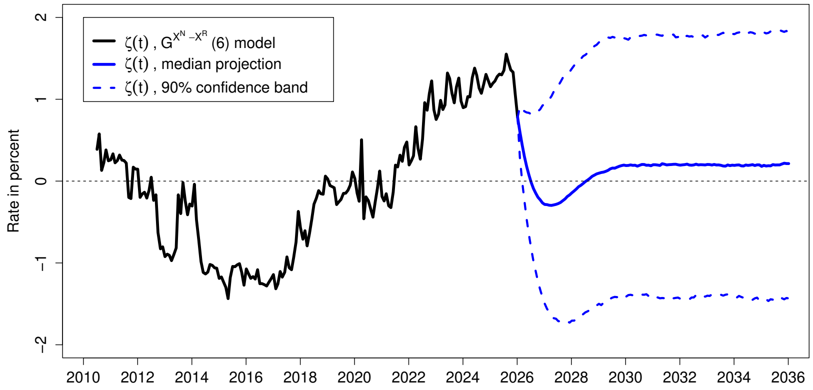
Given the debate among researchers, investors, and policymakers in South Africa about the persistence of the recent decline in interest rates and its ties to the adoption of the new lower inflation target, we analyze the outlook for long-term inflation expectations and the natural



(a) 5yr5yr expected inflation



(b) r^*_t



(c) ζ_t

Figure 10: **Ten-Year Projections**

rate based on our preferred $G^{X^N,X^R}(6)$ model. We follow the approach of Christensen et al. (2015) and simulate 10,000 factor paths over a ten-year horizon conditioned on the shapes of the nominal and real yield curves and investors' embedded forward-looking expectations as of the end of our sample (that is, using estimated state variables and factor dynamics as of December 31, 2025). The simulated factor paths are then converted into forecasts of 5yr5yr expected inflation, r_t^*, and ζ_t. Figure 10 shows the median projection and the 5th and 95th percentile values for the simulated outcomes of these three key variables over a ten-year forecast horizon.[18]

The median projection of the 5yr5yr expected inflation shows a continuation of its gradual decline since the start of our sample in 2010. Specifically, it is expected to fall from its current value of 6.28 percent to around 5.80 percent by the end of the ten-year projection. With a 5 percent chance, 5yr5yr expected inflation will fall notably faster and drop below 4.50 percent in less than ten years. On the upside, there is a 5 percent chance of long-term inflation expectations in South Africa re-anchoring near its original 7 percent level. This range of outcomes is consistent with the high volatility of the inflation process itself in South Africa.

In contrast, the estimated natural real rate r_t^* has followed a very stable path since 2010 and, accordingly, the simulations produce a very narrow band of outcomes for r_t^*. Hence, r_t^* can be expected to remain near its current mildly negative level in the decade ahead.

Finally, the median projection of the stance of monetary policy ζ_t suggests a fairly quick easing of policy back to a neutral stance within a year. However, these projections are associated with notable uncertainty. With a 5 percent chance, monetary policy will be eased quite significantly and reach a very accommodative stance. At the same time, there is a 5 percent chance that monetary policy will be tightened a notch from its already restrictive stance.

Although these simulation-based model projections point to an easing of monetary policy within a two- to three-year horizon, this is much more modest than projected in the SARB's latest November 2025 forecasts, which assume faster re-anchoring of inflation expectations to the new 3 percent inflation target. These simulations suggest that expected inflation will only gradually fall towards the new target. Taken together, our estimates suggest that sustainably reducing inflation to the new target would likely require monetary policy to remain tight to re-anchor inflation expectations to a permanently lower level.

7 Conclusion

In this paper, we estimate a flexible joint model of nominal and real yields taken from Christensen and Steenkamp (2025a) on the complete sample of nominal and real government bond prices from South Africa. The novel feature of the model is that it accounts for liquidity risk premia in both nominal and real bond prices. As a consequence, it provides us with estimates of the liquidity-adjusted frictionless BEI along with its decomposition into investors' underly-

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[18] Note that the lines do not represent paths from a single simulation run over the forecast horizon; instead, they delineate the distribution of all simulation outcomes at a given point in time.

ing inflation expectations and associated inflation risk premia. This work brings to light the varying components that are distorting readings of BEI rates in South Africa. In particular, using BEI rates for readings of investors' inflation expectations seems ill advised, based on our novel findings, thanks to large and time-varying liquidity and inflation risk premia.

Our examination of the model-implied inflation dynamics reveals fairly stable long-term inflation expectations in South Africa, although with a persistent downward trend. Thus, although mostly located outside the tolerance band adopted by the SARB as a guide to achieving its inflation target, investors' long-term inflation expectations seem gradually to be approaching the tolerance band. Moreover, simulation-based model projections suggest this mild downward trend is likely to continue in the coming decade. The estimated inflation risk premium, on the other hand, has been relatively large, although it has declined significantly since 2021.

Another contribution of our paper is to provide a market-based forward-looking measure of the natural rate of interest that can be extracted from inflation-indexed bonds and used to guide assessment of the real-time monetary policy stance. Our market-based estimate of the natural real rate implies that monetary policy has shifted to a contractionary stance since mid-2021.

Our simulation-based model projections point to a notable easing of monetary policy within a two- to three-year horizon and that expected inflation will only very gradually fall towards the new target. Taken together, our estimates suggest that sustainably reducing inflation to the new target would require monetary policy to remain tight to re-anchor inflation expectations to a permanently lower level.

Finally, while it is worth emphasizing that our findings and results for South Africa may not extend to other large and medium-sized emerging economies, we feel compelled to stress that our model framework and analysis can be applied to other emerging market economies with established nominal and real bond markets such as Brazil, Chile, and Peru, among many others. However, we leave those applications for future research.

References

Adrian, Tobias, Richard K. Crump, and Emanuel Moench, 2013, "Pricing the Term Structure with Linear Regressions," *Journal of Financial Economics*, Vol. 110, 110-138.

Andreasen, Martin M. and Jens H. E. Christensen, 2016, "TIPS Liquidity and the Outlook for Inflation," *FRBSF Economic Letter* 2016-35, 1-5.

Andreasen, Martin M., Jens H. E. Christensen, and Simon Riddell, 2021, "The TIPS Liquidity Premium," *Review of Finance*, Vol. 25, No. 6, 1639-1675.

Andreasen, Martin M., Jens H. E. Christensen, and Glenn D. Rudebusch, 2019, "Term Structure Analysis with Big Data: One-Step Estimation Using Bond Prices," *Journal of Econometrics*, Vol. 212, 26-46.

Bauer, Michael D., Glenn D. Rudebusch, and Jing (Cynthia) Wu, 2012, "Correcting Estimation Bias in Dynamic Term Structure Models," *Journal of Business and Economic Statistics*, Vol. 30, No. 3, 454-467.

Beauregard, Remy, Jens H. E. Christensen, Eric Fischer, and Simon Zhu, 2024, "Inflation Expectations and Risk Premia in Emerging Bond Markets: Evidence from Mexico," *Journal of International Economics*, Vol. 151, 103961.

Cardozo, Cristhian H. R. and Jens H. E. Christensen, 2025, "The Benefit of Inflation-Indexed Debt: Evidence from an Emerging Bond Market," Working Paper 2023-04, Federal Reserve Bank of San Francisco.

Ceballos, Luis, Jens H. E. Christensen, and Damian Romero, 2024, "Market-Based Estimates of the Natural Real Rate: Evidence from Latin American Bond Markets," Working Paper 2024-01, Federal Reserve Bank of San Francisco.

Christensen, Jens H. E., Francis X. Diebold, and Glenn D. Rudebusch, 2011, "The Affine Arbitrage-Free Class of Nelson-Siegel Term Structure Models," *Journal of Econometrics*, Vol. 164, No. 1, 4-20.

Christensen, Jens H. E., Jose A. Lopez, and Glenn D. Rudebusch, 2010, "Inflation Expectations and Risk Premiums in an Arbitrage-Free Model of Nominal and Real Bond Yields," *Journal of Money, Credit and Banking*, Supplement to Vol. 42, No. 6, 143-178.

Christensen, Jens H. E., Jose A. Lopez, and Glenn D. Rudebusch, 2014, "Do Central Bank Liquidity Facilities Affect Interbank Lending Rates?," *Journal of Business and Economic Statistics*, Vol. 32, No. 1, 136-151.

Christensen, Jens H. E., Jose A. Lopez, and Glenn D. Rudebusch, 2015, "A Probability-Based Stress Test of Federal Reserve Assets and Income," *Journal of Monetary Economics*, Vol. 73, 26-43.

Christensen, Jens H. E. and Sarah Mouabbi, 2024, "The Natural Rate of Interest in the Euro Area: Evidence from Inflation-Indexed Bonds," Working Paper 2024-08, Federal Reserve Bank of San Francisco.

Christensen, Jens H. E. and Glenn D. Rudebusch, 2019, "A New Normal for Interest Rates? Evidence from Inflation-Indexed Debt," *Review of Economics and Statistics*, Vol. 101, No. 5, 933-949.

Christensen, Jens H. E. and Daan Steenkamp, 2025a, "Do Inflation Target Changes Affect Bond Prices? Evidence from South Africa," Unpublished manuscript.

Christensen, Jens H. E. and Daan Steenkamp, 2025b, "Joint Estimation of Liquidity and Credit Risk Premia in Bond Prices with an Application," South African Reserve Bank Working Paper Series WP/25/01.

D'Amico, Stefania, Don H. Kim, and Min Wei, 2018, "Tips from TIPS: The Informational Content of Treasury Inflation-Protected Security Prices," *Journal of Financial and Quantitative Analysis*, Vol. 53, No. 1, 243-268.

Dittmar, Robert F., Alex Hsu, Guillaume Roussellet, and Peter Simasek, 2026, "Default Risk and the Pricing of U.S. Sovereign Bonds," forthcoming *Journal of Finance.*

Duffee, Gregory R., 2002, "Term Premia and Interest Rate Forecasts in Affine Models," *Journal of Finance*, Vol. 57, No. 1, 405-443.

Erasmus, Ruan and Daan Steenkamp, 2022a, "South Africa's Yield Curve Conundrum," *Economic Research South Africa*, Discussion Document 07.

Erasmus, Ruan and Daan Steenkamp, 2022b, "Term Premium Estimation for South Africa," *Journal of Applied Economic Sciences*, Vol. 78, No. 4.

Finlay, Richard and Sebastian Wende, 2012, "Estimating Inflation Expectations with a Limited Number of Inflation-Indexed Bonds," *International Journal of Central Banking*, Vol. 8, No. 2, 111-142.

Fleckenstein, Mathias, Francis A. Longstaff, and Hanno Lustig, 2014, "The TIPS-Treasury Bond Puzzle," *Journal of Finance*, Vol. 69, No. 5, 2151-2197.

Fontaine, Jean-Sébastien and René Garcia, 2012, "Bond Liquidity Premia," *Review of Financial Studies*, Vol. 25, No. 4, 1207-1254.

Greenwood-Nimmo, Matthew, Daan Steenkamp, and Rossouw van Jaarsveld, 2022, "Can Information on the Distribution of ZAR Returns be used to Improve SARB's ZAR forecasts," *South African Reserve Bank Working Papers* 11035.

Grishchenko, Olesya V. and Jing-Zhi Huang, 2013, "Inflation Risk Premium: Evidence from the TIPS Market," *Journal of Fixed Income*, Vol. 22, No. 4, 5-30.

Gürkaynak, Refet S., Brian Sack, and Jonathan H. Wright, 2010, "The TIPS Yield Curve and Inflation Compensation," *American Economic Journal: Macroeconomics*, Vol. 2, No. 1, 70-92.

Havemann, Roy, Henk Janse van Vuuren, Daan Steenkamp, and Rossouw van Jaarsveld, 2022, "The Bond Market Impact of the South African Reserve Bank Bond Purchase Programme," *South African Reserve Bank Working Papers* 11024.

Havemann, Roy and Hylton Hollander, 2025, "Monetary-Fiscal Ccordination in South Africa: Aligning the Stars," forthcoming *Economic Research South Africa.*

Olds, Tim and Daan Steenkamp 2021, "Estimates of Bank-Level Funding Costs in South Africa," *South African Reserve Bank Working Papers* 11005.

Kim, Don H. and Kenneth J. Singleton, 2012, "Term Structure Models and the Zero Bound: An Empirical Investigation of Japanese Yields," *Journal of Econometrics*, Vol. 170, No. 1, 32-49.

Laubach, Thomas and John C. Williams, 2003, "Measuring the Natural Rate of Interest," *Review of Economics and Statistics*, Vol. 85, No. 4, 1063-1070.

National Treasury, 2025, "Debt Management Report 2023/24," *National Treasury website.*

Nelson, Charles R. and Andrew F. Siegel, 1987, "Parsimonious Modeling of Yield Curves," *Journal of Business*, Vol. 60, No. 4, 473-489.

Reid, Monique, 2009, "Isolating a Measure of Inflation Expectations for the South African Financial Market using Forward Interest Rates," *South African Journal of Economics*, Vol. 77, 399-413.

Rudebusch, Glenn D. and Eric Swanson, 2012, "The Bond Premium in a DSGE Model with Long-Run Real and Nominal Risks," *American Economic Journals: Macroeconomics*, Vol. 4, No. 1, 105-143.

Sack, Brian and Robert Elsasser, 2004, "Treasury Inflation-Indexed Debt: A Review of the U.S. Experience," *Federal Reserve Bank of New York Economic Policy Review*, Vol. 10, No. 1, 47-63.

Soobyah, Luchelle and Daan Steenkamp, 2020a, “Term Premium and Rate Expectation Estimates from the South African Yield Curve,” *South African Reserve Bank Working Papers* 9998.

Soobyah, Luchelle and Daan Steenkamp, 2020b, “A Measure of South African Risk,” *South African Reserve Bank Occasional Bulletin of Economic Notes* 10009.

South African Reserve Bank, 2023, “Financial Stability Review,” May.