Reaching for the (r)-stars: estimating South Africa's neutral real interest rate

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The global financial crisis pushed real interest rates to all-time lows and shifted neutral real interest rates for many economies. The neutral real interest rate – popularly referred to as r-star – plays a key role in gauging the appropriate stance of monetary policy. This paper applies the popular Laubach-Williams (LW) methodological framework to estimate r-star for South Africa, while simultaneously adapting it to the dynamics of a small open economy. This is achieved by adding the exchange rate channel and the impact of developments in the rest of the world on domestic growth and inflation. Additional drivers of the neutral rate, such as excess global savings and SA's country risk premium, are also included. The LW model is further modified by using Bayesian techniques to estimate the model parameters, instead of the maximum likelihood method utilised by LW. The results show that South Africa's r-star has fallen in line with r-star estimates for the United States, and other advanced economies, however not to the same extent. Although underlying potential growth has fallen further than in the US, other factors including SA's country risk premium aid in keeping the neutral real interest rate elevated.

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1 Introduction

The global financial crisis (GFC) and subsequent great recession took monetary policy into new terrain in many economies, requiring extraordinary policy action to stimulate economic activity. Part of this reflected a zero-lower bound of nominal policy rates, which created a nominal floor for policymakers. But more importantly, the GFC pushed the real interest rate to multi-decade lows as households deleveraged, demand for safe assets rose, emerging market savings rose, and advanced economy investment fell. These factors also affect the neutral real interest rate (henceforth r-star): the rate at which inflation is stable around the central bank's objective and output is operating at its equilibrium. The importance of r-star lies in its indication of the stance of monetary policy. If real interest rates are below the level of r-star, monetary policy is seen as supportive of economic activity, and *vice versa*. While the aftermath of the GFC required real rates to be exceptionally supportive, recent growth momentum in advanced economies, coupled with indications of rising inflation, have led some such as the United States to begin to normalise monetary policy back to sustainable levels – in line with their respective r-stars. Similarly, South Africa has been normalising monetary policy since 2014. For this normalisation process to succeed, it is vital that the dynamics of the neutral policy rate is well understood.

We build an open economy version of the Laubach and Williams (2003) model to measure r-star in South Africa. Laubach and Williams (2003) base r-star estimates on two factors: (1) the underlying potential growth rate of an economy, and (2) an unobservable factor z that captures other likely drivers of r-star, such as time preferences of households, in a closed economy model. We expand on this formulation by adding the exchange rate channel and allowing for the impact of developments in the rest of world on domestic growth and inflation. Unlike Laubach and Williams (2003) we use Bayesian techniques to estimate the model. In addition, following Pescatori and Turunen (2015) we define drivers of the unobserved component z, specifically a measure of global savings imbalances, and South Africa's country risk premium. Since this unobserved component forms a critical part of where the neutral r-star ends up, it provides some structure to this term by significantly improving the results.

The results show that r-star has fallen in South Africa since the GFC, in line with estimates of the United States and other advanced economies, however not at the same extent. The declining neutral real interest rate is mainly the result of slowing potential growth that is estimated to have declined from rates of four per cent in the mid-2000s to around 0.7 per cent in early 2017. The neutral rate, ending at 1.5 per cent in the first quarter of 2017, could have been even lower if there were not other factors keeping it elevated, such as rising domestic country risk and a narrowing savings glut in emerging markets (proxied by emerging market current account deficits).

The paper proceeds as follows: section 2 provides a brief literature review on the neutral real interest rate; section 3 describes the model; section 4 discusses the estimation, including the data used and posterior estimate; section 5 provides the estimation results; section 6 looks at the robustness of the results to certain estimation changes; before section 7 concludes.

2 Literature review

In the time of pre-Keynesian macroeconomics, Wicksell (1898) planted the seed of the r-star concept. According to Wicksell, the *natural* rate of interest was the rate which was consistent with stable prices. Further, he argued that the level of r-star may change over time depending, for example, on factor productivity and their availability (Beyer and Wieland, 2017). To this day, Wicksell's definition remains dominant, and many papers use it as a point of departure when estimating r-star.[1]

Laubach and Williams's (2003) (henceforth LW) more contemporary definition of the natural, or neutral, real interest rate is the real short-term rate that is consistent with stable inflation and output at potential. That is, the level of the interest rate that is expected to prevail once the economy has recovered from any cyclical distortions. The position of the real interest rate relative to r-star then determines the stance of monetary policy. Real interest rates below r-star would be expansionary, while rates above it would be contractionary.

LW build on the New Keynesian framework of an intertemporal investment-savings (IS) equation and a Phillips curve relationship. With the use of these two main equations, the dynamics of the output gap is described as a function of the real interest rate *gap*, and in turn, inflation as a function of the output gap.[2] They apply a Kalman filter to jointly estimate r-star, the level of potential output as well as its trend growth rate – ultimately linking r-star with the estimated trend growth rate. Furthermore, they use median-unbiased estimates from Stock (1994) and Stock and Watson (1998) on the coefficients of r-star and trend growth variations and estimate the remaining model parameters using maximum likelihood. Work based on LW include Holston et al. (2017) on the US, Canada, and Euro Area, and Beyer and Wieland (2017) for the US, Euro Area and Germany.

The method followed by LW to determine r-star is but one of a number of methods applied, including the Taylor rule (see Taylor and Wieland, 2016); consumption-based methods (see Hamilton et al., 2016 and Fuentes et al., 2007); the yield curve to determine market participants' beliefs of future short-rates (see Bomfim, 2001); and statistics-based methods including averaging and filters (see for example Hodrick and Prescott, 1997; and Cogley, 2002).

The last approach, although the simplest, is likely to be the most contentious. Simple statistical averages do not allow for the interest rate to be time varying over a long period and ignores structural breaks, something that has come to matter even more since the GFC. One alternative would be to apply moving averages of the real interest rate to allow for structural changes, however this is still proven to be a poor estimation technique over the long run, especially in periods where growth and inflation are not stable. The main advantage of semi-structural models like LW over a simplistic statistical approach, is that they are able to exploit information from other variables, most notably in inflation and output, when estimating r-star (Pescatori and Turunen, 2015).

While a more theoretically founded model such as a dynamic stochastic general equilibrium (DSGE) model may be seen as more appropriate than the semi-structural approach of LW, r-star estimates from DSGE models are found by Pescatori and Turunen (2015) to show more variability than is commonly attributed to equilibrium real interest rates. Additionally, given that the semi-structural model only imposes mild cross-equation restrictions, suffering the flaw of misspecification is less prone – especially in the presence of near non-stationarity in observed real rates (Barsky et al., 2014; Cúrdia et al., 2015; Pescatori and Turunen, 2015).

An alternative, but complimentary, definition of r-star, which arose due to the need to appropriately model small open economies is to use the uncovered interest parity condition. Indeed, small open economies are influenced by global factors, and the best way to explain this is through the exchange rate performance and risk premium. Bernhardsen and Gerdrup (2007) discuss the risk-adjusted uncovered interest rate parity whereby the domestic real interest rate is driven by its foreign counterpart, the expectation of the change in the real exchange rate and risk premiums. They find that interest rate parity

[1] See Laubach and Williams (2003), Laubach and Williams (2016), Pescatori and Turunen (2015), Orphanides and Williams (2002) and many others.

[2] The real interest rate gap is the difference between the real interest rate and r-star.

provides a reasonable explanation for why domestic interest rates may be influenced by the foreign interest rates, at least to avoid exchange rate depreciation. This is also true for global savings and investment behavior, whereby the global r-star will influence the r-star in a small open economy. However, depending on the economy's dynamics and functioning, the relationship between the global and domestic neutral rate may not be an easy task to model.

3 The model

We use a modified version of Laubach and Williams's (2003) simple macroeconomic model to estimate the neutral real interest rate, but make two important changes. First, since South Africa is an open economy reliant on commodity exports, we modify the model to include the exchange rate, commodity prices, and rest of world channels. These channels mean that the IS curve becomes:

$$\tilde{y}_t = \alpha_y \tilde{y}_{t-1} + \alpha_r (r_t - r_t^*) + \alpha_{y^f} \tilde{y}_t^f + \alpha_q (q_t - q_t^*) + \alpha_c com_t + \varepsilon_t^{\tilde{y}} \tag{1}$$

where $\tilde{y}$ is the difference between real GDP and its potential (i.e. $\tilde{y} = y - y^*$), $(r - r^*)$ is the gap between the real interest rate and its neutral rate, $\tilde{y}^f$ is the foreign output gap, $(q - q^*)$ is the gap between the real exchange rate from its equilibrium, and *com* is the export commodity price. For simplicity we do not use more than one autoregressive coefficient in the estimation step as there is not a significant difference in dynamics and is more appropriately linked to the theoretical foundations of intertemporal optimisation.

The Phillips curve is modified such that:

$$\pi_t = (1 - \beta_\pi)(\pi_e) + \beta_\pi \pi_{t-1} + \beta_y \tilde{y}_t + \beta_q (q_t - q_t^*) + \beta_o \pi_t^o + \varepsilon_t^\pi \tag{2}$$

where π is core inflation, and π^o is the oil price inflation in rand. Unlike Laubach and Williams (2003), we use the expectations Phillips curve. Since the model is semi-structural and not closed with a Taylor rule, we observe inflation expectations from the Bureau of Economic Research (BER) survey of inflation expectations π_e. Although we model core inflation, we use headline inflation expectations two-years ahead which should exclude relative prices, and hence equal core inflation. c, $(q - q^*)$, π^o, and $E(\pi_{t+1})$ are autoregressive functions.

Second, addressing criticisms in Beyer and Wieland (2017) and Pescatori and Turunen (2015), we modify the structure of the unobserved 'z' component, or 'headwinds' which create deviations of r-star from the underlying trend growth rate. As in Laubach and Williams (2003), the basic household intertemporal utility maximisation problem solves to:

$$r = \frac{1}{\sigma} g + \theta \tag{3}$$

where r is the real interest rate, g is the per capita growth in consumption, σ is the intertemporal elasticity of substitution in consumption, and θ is the rate of time preference. Laubach and Williams (2003) use this to show that the neutral (or natural) rate of interest will evolve as:

$$r_t^* = cg_t + z_t \tag{4}$$

where g_t is the underlying growth rate of output, and z is the unobserved component which may evolve as either a random walk or autoregressive function.

We modify z such that:

$$z_t = \gamma_z z_{t-1} + \gamma_p p_t - \gamma_s \Delta s_t - \gamma_e \Delta e_t - \gamma_u \Delta u_t + \varepsilon_t^z \tag{5}$$

where p is country risk premium (proxied by the South African 5-year CDS spread), s is global savings (proxied by emerging market current account balance to GDP), e is the equity risk premium as calculated by Damodaran (2016), and u is global policy uncertainty as measured by Baker et al. (2016). p, s, e, and u are modelled as autoregressive functions with a persistence term ρ_i with $i \in p, s, e, u$. The autoregressive term (γ_z) is set to 0.9.

As in Pescatori and Turunen (2015) the equity risk premium and policy uncertainty measures attempt to capture demand for safe assets. For an emerging market, however, the impact of the demand for safe assets is ambiguous. From a uncovered interest rate parity perspective, the falling global neutral real interest rate should decrease the domestic neutral as well, suggesting the sign on both should be negative. However, shifts in risk perceptions that accompany flight to safety may lead to significantly higher country risk premiums as capital outflows occur. Although in certain instances risk may dominate emerging market outcomes, evidence since the GFC suggests that low global yields also benefit emerging markets.

Potential output and underlying potential growth are modelled as:

$$y_t^* = y_{t-1}^* + g_t/4 + \varepsilon_t^{y^*} \tag{6}$$

and

$$g_t \quad = \quad \rho_g g_{t-1} + (1-\rho_g) g^{ss} + \varepsilon_t^g, \quad \rho_g < 1 \tag{7}$$

where the (log) level of potential growth (y^*) evolves by the quarter-on-quarter annualised underlying potential growth rate, g. In turn, g evolves as an autoregrassive function, anchored by a steady state growth rate, g^{ss}, which represents the long-run growth potential of the economy and is set to 2.5 per cent. These equations allow for idiosyncratic factors such as droughts and strikes to affect the level of potential output, allowing for temporary deviations from the underlying potential growth process, g. This approach to modelling potential output first appeared in the literature when Clark (1987) applied it to US data within a highly parsimonious structure consisting of a minimal number of equations.

The rest of world in the model is proxied by the United States and modelled as in Laubach and Williams (2003) and Laubach and Williams (2016), with the only exception being that all autoregressive functions are resticted to AR(1). We calibrate this model to the results released by Laubach and Williams (2003) by observing g^*, $\tilde{y}^*$, π^*, and r^* and the coefficient values as estimated in Laubach and Williams (2016). Coefficient values on autoregressive functions of lags greater than one are summed and used as a single coefficient. Following Pescatori and Turunen (2015) we use an alternative output gap estimate to Laubach and Williams (2016) based on an in-house version of the Global Projection Model.[3]. This estimate is more in line with the production function approach implemented by CBO and Arnold (2001)

4 Estimation

We implement a Bayesian estimation procedure instead of the maximum likelihood approach in Laubach and Williams (2003). This approach has a number of advantages. It allows us to impose prior views on many well-studied coefficients including the slope of the Phillips curve, the persistence in inflation, and the impact of the foreign output gap on its domestic counterpart. Incorporating this prior information yields more plausible results, especially for the unobserved variables in the model.

Bayesian estimation re-weights the likelihoods of the parameters of interest using prior information, and maximises these re-weighted likelihoods such that:

$$P(\Omega|X^T) = \frac{P(\Omega)L(X^T|\Omega)}{P(X^T)} \tag{8}$$

where the posterior distribution of the unknown parameters conditional on the observed data over time T, $P(\Omega|X^T)$, is proportional to the product of the prior distribution, $P(\Omega)$, and the likelihood function of the observed data over time T conditional on the unknown parameters, $L(X^T|\Omega)$. $P(\cdot)$ is the probability density function which can take on any possible distribution.

We set out the specific prior used for each parameter in Table 2, describing its prior mean, probability distribution and standard error. The posterior distribution is then estimated through the integration of the likelihood function with the help of the Kalman filter over the parameter space using priors as weights. However, as pointed out by Rabanal and Rubio-Ramírez (2005), an analytical solution of the above problem is only available in a restrictive set of examples and therefore we require Monte Carlo methods such as the Metropolis-Hastings algorithm, specifically a Markov chain Monte Carlo method, in order to solve for the unknown posterior distributions. The specific type of algorithm used in this estimation is a rejection sampling algorithm. Essentially a jump distribution is used to sample specific values of the unknown parameters, where the posterior value is either accepted or rejected based on some acceptance rule. An initial burn-in phase is also taken to ensure that the posterior distribution is formed from the stable section of the Markov chain.

4.1 Data

Both foreign and domestic data are used in the estimation step and described in Table 1. The foreign economy is linked directly to the Laubach and Williams (2003) estimates including potential growth and the r-star. Given the lack of consensus on the appropriateness of the output gap generated by Laubach and Williams (2003), we use a US output gap estimated from an adapted version of the global model of Carabenciov et al. (2013). Other foreign variables include core personal consumption expenditure (PCE) inflation, the effective federal funds rate, brent crude oil prices, global savings proxied by emerging market current account balance to GDP (interpolated), global economic policy uncertainty, commodity prices weighted by SA exports, and an equity premium.

[3]see Carabenciov et al. (2013) for details of the model structure

Domestically, real GDP and consumer inflation excluding food and energy, or core inflation, data is obtained from Statistics South Africa (StatsSA). We also use inflation expectations from the Bureau of Economic Research (BER) survey of inflation expectations. Although we model core inflation, inflation expectations of headline two-years ahead should exclude relative prices, and hence equal core inflation. We observe real interest rates as the difference between the repurchase rate and the one-year ahead inflation forecast from the South African Reserve Bank's core econometric model. The country risk premium is proxied by the 5-year credit default swap (CDS) spread.

4.2 Posterior estimates

The model is estimated using a Matropolis-Hastings algorithm with 100 000 iterations on data from 2000Q1 to 2017Q1. The data and model structure ensure that almost all parameter likelihoods are well defined. The initial burn-in is 10 per cent of the iteration size and the acceptance ratio is 0.23. The priors and posteriors are provided for in table 2. The parameter values are based on gamma and beta distributions while the standard deviation of the residuals are inverse gamma. Priors for some of the parameters, such as the slope of the Phillips curve, are common place in the South African literature and based on work by Anvari et al. (2014) and Kabundi et al. (2016). Others more specific to the model used here are based on Pescatori and Turunen (2015) and Laubach and Williams (2016).

The prior on $\varepsilon_{\tilde{y}}$ is based on the standard deviation of the HP-filter output gap. Following Borio et al. (2013), we scale the prior on ε_g such that the signal-to-noise ratio of the Kalman filter is similar to that of the HP-filter[4]. We do not impose this signal-to-noise ratio on the posterior, however, the signal-to-noise ratio generated remains close to that of the HP-filter.

Most posterior values are in line with expectations. The persistence on inflation is aligned to its prior at 0.65. The slope of the Phillips curve (β_y) has a posterior of 0.23. Contemporaneous impacts are as follows. A 10 per cent undervaluation of the real effective exchange rate raises inflation by 0.44 per cent. The standard error on inflation is 0.73 per cent. The output gap has a persistence of 0.56 and a standard error of 0.25. A one percentage point increase in the foreign output gap raises the SA output gap by 0.22 per cent, while a 10 per cent undervaluation of the currency raises the output gap by 0.1 per cent.

5 Results

By estimating r-star using a modified version of the LW paper, we generate appropriate outcomes for the South African economy. The unobserved z component now has a clearer interpretation, if still ad hoc in nature, by including the country risk premium, equity risk premium, global policy uncertainty and global savings. South Africa also suffers from a fall in the output gap and trend potential during the GFC, as was the experience of many economies at the time. Moreover, since the GFC, the South African r-star appears to be on a downward path, ending at close to 1.5 per cent in first quarter of 2017.

5.1 Neutral real interest rate

Figure 1 plots the decomposition of r-star into underlying potential growth (g_t) and z (figure 1a), from 2000Q1 to 2017Q1, and recursively solving z into its main driver (figure 1b). Potential growth in South

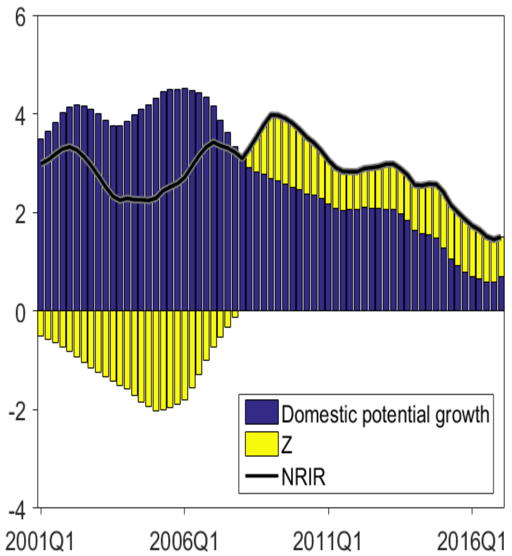
[4]See Borio et al. (2013) for an explanation of the reasoning behind this choice.

Africa rose sharply into the early- to mid-2000s, reaching a peak of 4.5 per cent in 2006Q1, as robust investment and credit growth, rising house prices, and a favorable global backdrop saw accelerating commodity prices and external demand. The neutral interest rate, however, did not reflect high potential growth as other factors in z, including a global savings glut and generally low and falling country risk premium put downward pressure on the domestic r-star. As a consequence, r-star averaged 3 per cent from 2000 to 2009, rising through most of this period from 2.5 per cent in the first quarter of 2000 to 4 per cent by the start of 2009.

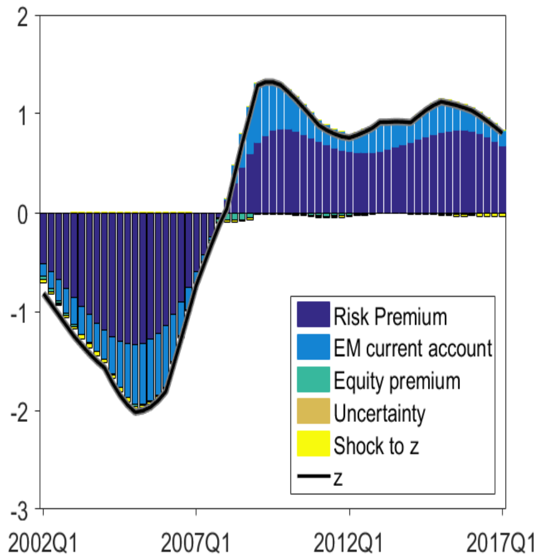
The year 2006 represented a turning point in the direction of South African potential growth, but also in the global savings glut with emerging market current account surplus reaching its own peak of almost 5 per cent of GDP, rising from 1.5 per cent of GDP in 2000. The global financial crisis of 2008 changed everything, leading to significant declines in global demand, ending the housing bubble in both South Africa as well as other advanced and emerging markets, and later in the next decade, the collapse of commodity prices.

Figure 1: Neutral real interest rate

(a) Decomposition of r-star



(b) Decomposition of Z



From 2006 onwards, potential growth in South Africa is estimated to have slowed from over 4 per cent to its current level of under 1 per cent. A number of factors contributed to this decline, including a significant slowdown in investment and hence accumulation of capital stock since 2009; falling domestic and international total factor productivity; worsening terms of trade due to falling export commodity prices; binding constraints in electricity; and falling global potential growth particularly due to the Chinese economy's shift away from exports and investment.

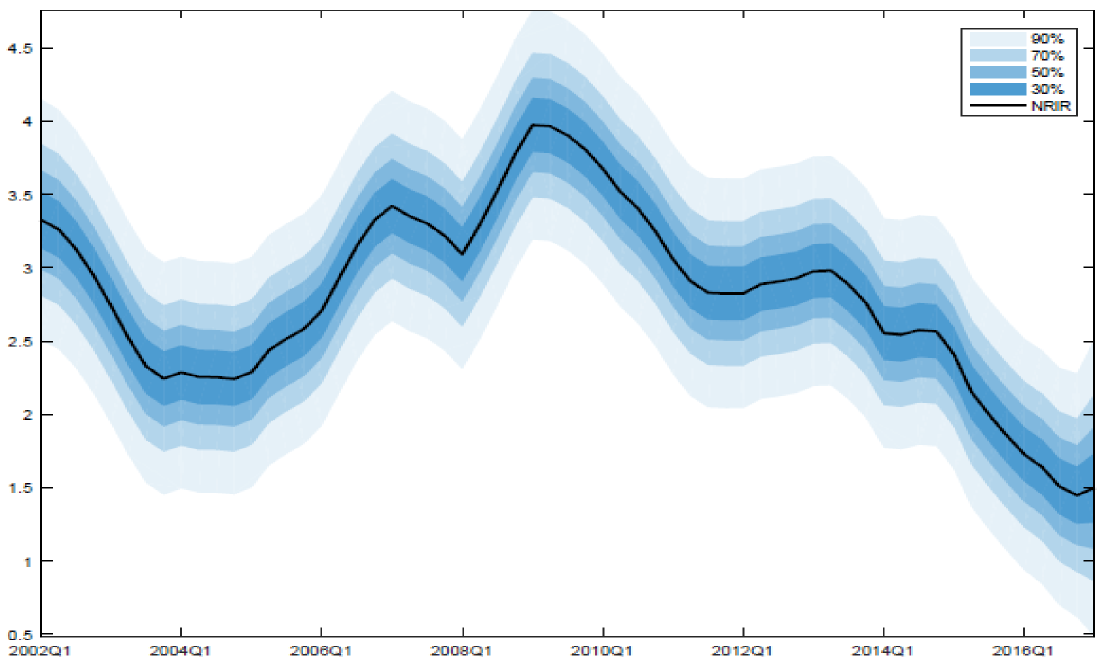
The r-star fell in line with the collapse in South Africa's potential growth, however, other factors have contributed to raising its level. The most significant global factor contributing to a more elevated r-star is the dwindling global savings, with emerging markets current account surplus turning to deficit by 2015. Total gross savings, as a per cent of GDP, are at their lowest level since 2010. Domestic factors have also contributed to a higher r-star. The country risk premium, proxied by the 5-year CDS spread, has risen from an average of 1.3 per cent from 2000 to 2008 to 2 per cent since 2009. The higher country risk premium represents deteriorating growth outcomes and fiscal balances, and rising policy and political uncertainty. Z has placed an average 1.0 percentage point wedge in the r-star since 2009. As a consequence, r-star is estimated at 1.5 per cent in 2017Q1, its lowest level in post-democracy South Africa.

To better understand the drivers of the unobserved component z, figure 1b decomposes z recursively into its main drivers, including country risk premium, global savings, equity risk premium, and economic policy uncertainty. Country risk premium and global savings play the biggest role in driving z, while equity premium and economic policy uncertainty contribute significantly less. There are two distinct periods highlighting the role of global savings on z including pre-GFC, where global savings was large and peaked, and its aftermath, where global savings started to decline and emerging market current account surplus turned to deficit. The post-GFC period sees the demand for safe assets only marginally contributing to a lower z. The dominant contribution from global savings on z is likely due to the stronger impact on SA due to the economy being largely dependent on global savings and trade.

These two distinct periods are also reflected in the impact that the country risk premium has on z. Prior to the great recession, country risk premiums in South Africa were comparatively low – reflecting strong growth outcomes and fiscal surpluses. Subsequently, a deterioration in both economic growth and fiscal balances, compounded by rising policy and political uncertainty, have resulted in a rising country risk premium.

Estimates of an unobserved variable such as r-star are surrounded by uncertainty. Figure 2 plots the estimated 90 per cent uncertainty bands around r-star from 2000Q1 to 2017Q1. The estimated standard deviation around r-star is 0.4 per cent. This means at a 30 per cent confidence band we could expect the neutral to be between 1.4 and 1.9 per cent in 2017Q1. While the bounds for a 90 per cent confidence is a lot wider (by 2 percentage points) starting from 0.6 to 2.6 per cent in 2017Q1.

Figure 2: Uncertainty around the neutral real interest rate



5.2 Comparisons of the r-stars to other economies

Owing to the diverse idiosyncratic influences across economies, estimation of the neutral real interest is likely to differ from one methodology to the next, and also from economy to economy. However, across the majority of r-star literature, two noticeable phases of sustained declines can be seen in the developed and developing economies' r-star estimations.

Most developed countries' r-star estimates display a moderate secular decline pre-GFC; and a predominant decline post-GFC. This is true for papers such as Beyer and Wieland (2017) and Holston et al. (2017). On the other hand, Vilmi et al. (2016) estimate the Euro Area's r-star as being relatively stable around 2 per cent pre-GFC, before falling immediately over the GFC period, whereafter is has been moderately recovering, albeit at a lower level than at the start of the sample period.

While it is important to consider the performance of the developed economies, it is noteworthy to assess the r-star performance across emerging market economies with respect to our own estimate. Behera et al. (2017) found that through their three differently estimated models, the r-star for India has declined since GFC. While studying the most comparable model to ours, (model version 1) by the naked eye, the path is virtually the same for both emerging economies, keeping in mind that the impacts and magnitude may differ due to the idiosyncratic differences between the two models. A key difference here, is that the r-star estimate for India declined at a faster pace pre-GFC than post-GFC. For example, r-star from 2001 to 2002/2003 declined by close to 3 percentage points, only to reverse it's decline by an equal increase in 2007; and then a more moderate decline from 3 per cent to around 2 per cent in 2015. Interestingly we find the opposite rates of decline to our model, whereby the rate of decline pre-GFC is more moderate than India's and more in-line with Beyer and Wieland (2017) and Holston et al. 's (2017) estimates for developed economies. Post-GFC, our rate of decline is a lot faster than that found in India, and again in line with the developed economies' paths.

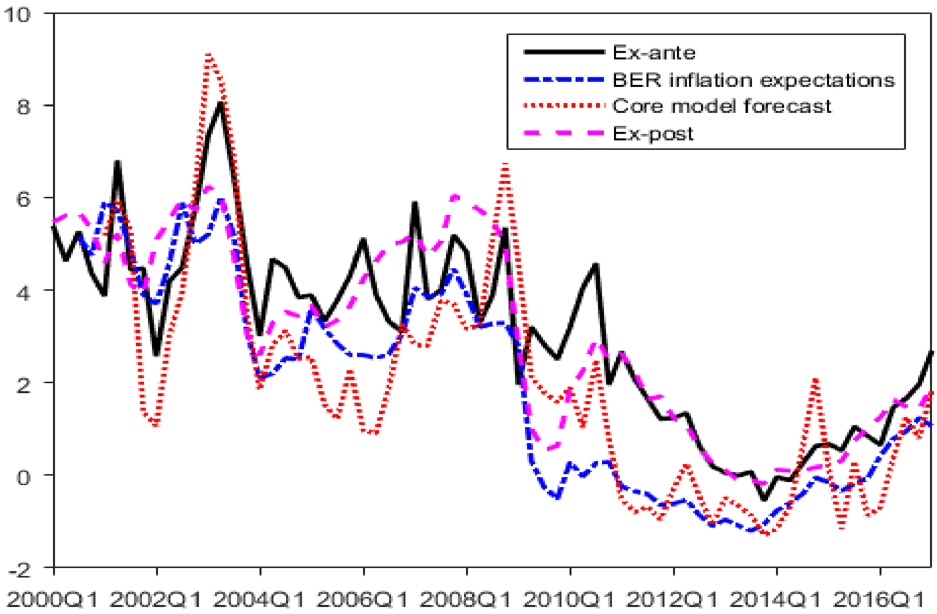
Perhaps an alternative emerging market r-star performance to consider would be estimations for Asian economies (Guimaraes-Filho et al., 2015). The authors used a range of methodologies, but for consistency purposes, their semi-structural model estimates, based on the LW methodology, produced the best comparable results. In fact,the average r-star estimates post GFC was significantly less than the average r-star pre-GFC. This holds for China, India, Australia, New Zealand, Korea and Thailand. Alternatively, r-star estimates for the Philippines, Malaysia and Indonesia were either the same or higher post GFC, largely due to higher trend growth rates.

Overall, while the rate of the declines may differ across economies, we find that post GFC, the r-star estimates are somewhat lower than the average pre-GFC r-star estimates. This brings to question whether the global recovery from the GFC is the "new normal", with lower global growth trends and real interest rates. As Zhu (2016) explains, the lower growth trends may be attributed to a secular deficiency in aggregate demand, significant financial frictions, unfavorable demographic trends, ebbing innovations, debt overhang, and insufficient structural policies.

5.3 Comparisons of real interest rates

We observe real interest rates in the model, using the one-year ahead inflation forecast from the SARBs core econometric model. This is done to ensure that the real interest rate aligns to the forecasts announced by the MPC and the implicit real rate that it implies. The real interest rate, however, can differ depending on which measure of inflation expectations are used. Figure 3 compares the real interest rate we use in the model (labelled 'core model forecast') to other estimates, including inflation expectations from the BER's inflation expectations survey, using current inflation (labelled 'Ex-post'), and the model consistent real interest rates (labelled 'Ex-ante'). All measures generally follow the same path and co-move well, with correlations above 0.75.

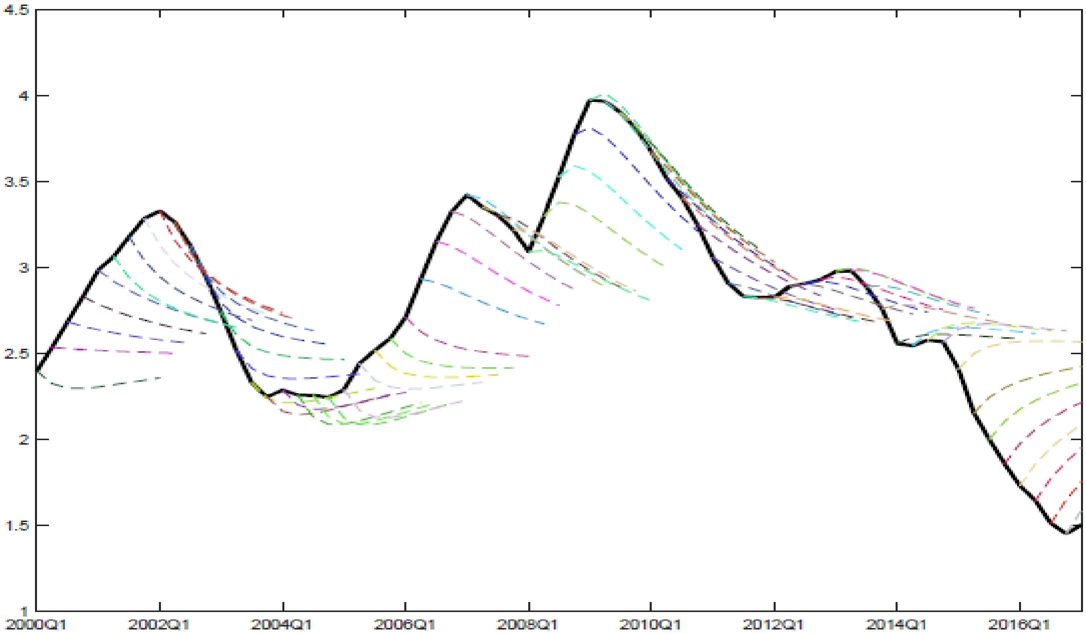
Figure 3: Real interest rate: Inflation expectation comparisons



5.4 Forecasting r-star

Having a measure of r-star over history is immensely valuable for a central bank, however, the forward looking nature of policy requires an appropriate assessment of the stance of monetary policy over the policy horizon. To understand the forecasting properties of the estimated model, Figure 4 plots 8-step-ahead pseudo out-of-sample forecasts of r-star from 2000 to 2017. The model generates root mean squared forecast errors (RMSFE) of 0.15 per cent at one-step-ahead rising to 0.62 at 8-steps-ahead. Despite the small RMSFE, forecasts of r-star only outperform a random walk (RW) from 6-quarters-ahead, by a maximum of 7 per cent at 8-steps-ahead; i.e. the ratio of the RMSFE to a RW is 0.93 at that horizon. Forecasts of r-star also show no clear upward or downward bias, with a small mean error at all horizons.

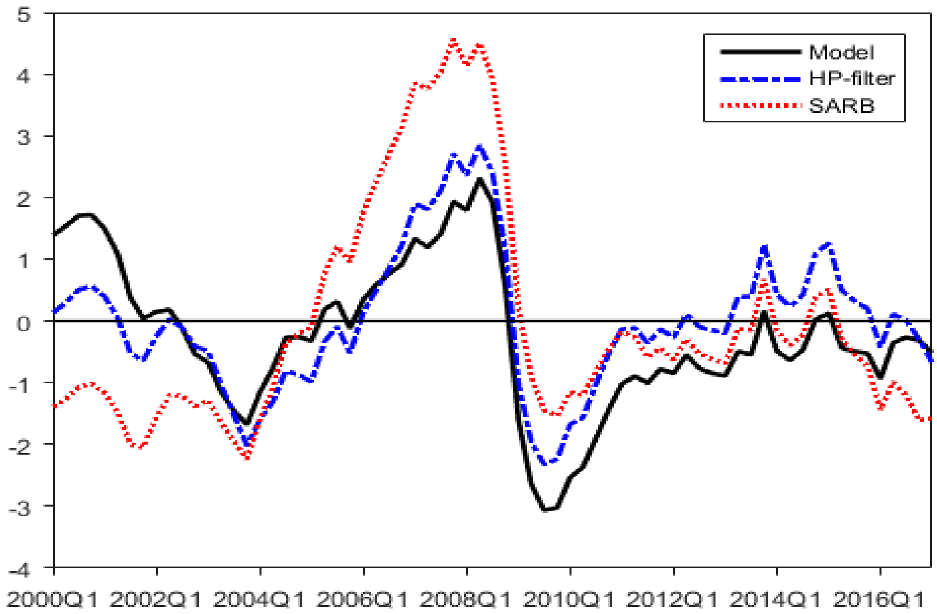
Figure 4: 8-quarter-ahead r-star forecasts



5.5 Output gap

Estimating the neutral real interest rate using the Laubach and Williams (2003) methodology also generates an output gap measure that is consistent with inflation pressures and potential growth outcomes. Figure 5 plots the output gap that is estimated in the model against the current methodology used by the SARB, as well as, a simple HP-filter estimate. The model's output gap is well correlated with other estimates of the gap. The boom years of 2005 to 2008 are similar to that of an HP-filter but lower, compared with the SARBs method. One driver of this may be the role of finance-neutral potential in the Bank's methodology (see Anvari et al., 2014). During the great recession, the model suggests a significantly larger output gap compared with the other methods. Despite this, all methods suggest that the gap is closed by 2014. The model-consistent output gap shows that the gap is -0.5 per cent in the first quarter of 2017, compared with -0.7 per cent for the HP-filter and -1.6 per cent using the Bank's method.

Figure 5: Output gap comparisons



6 Robustness

In this section we look at some of the properties of the model, and its estimation, to provide evidence of its sensitivity to certain choices. Two robustness tests are undertaken. First, we look at the sensitivity of the results of z and r-star to the variance of the residual of z ($\varepsilon_{\tilde{z}}$). Second, we show results from some alternative model estimation strategies including maximum likelihood and the numerical solution to our iterative approach.

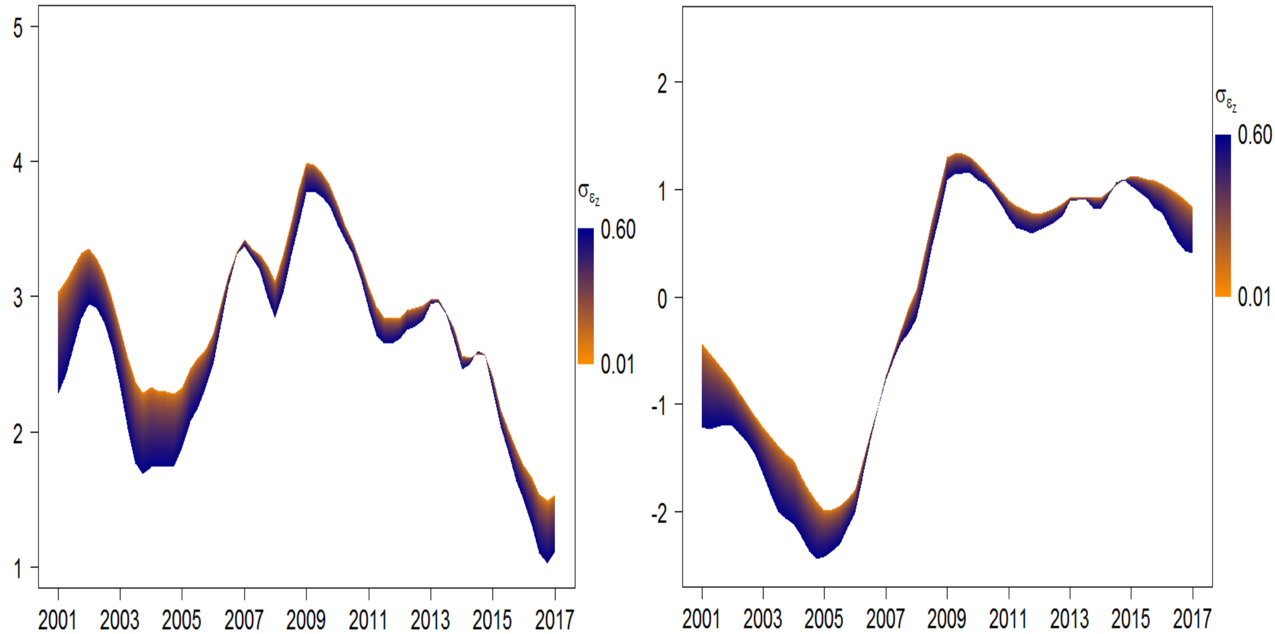
6.1 Sensitivity to changes to the variance of z

One possible criticism of the Laubach and Williams (2003) approach is the fact that a significant proportion of the neutral real interest rate is explained by the unobserved component 'z' and the r-star outcome's sensitivity to its variance. Pescatori and Turunen (2015) highlights three shortcomings with the Laubach and Williams (2003) approach to the unobserved component, including output gaps that do not relate to current estimates of the output gap over history, no formal accounting for the zero lower bound, and insufficient information to determine z. We have addressed part of this criticism by providing a structure to z with drivers that are observable. However, it is important to still determine the sensitivity of the z process to changes to its variance.

Figure 6a and 6b display the sensitivity of the neutral real interest rate and z to changes in the variance of z. We plot heat maps which show the standard deviation of z between 0.01 and 0.6 in increments of 0.01. The r-star (in 6a) deviates at most by 0.8 percentage points between the smallest and largest standard deviation, with larger deviations during periods including the 2001 depreciation episode, GFC, and periods of global uncertainty including during the fiscal crisis in Europe. On average, over the entire sample the difference between the largest and smallest standard deviation outcome is 0.6 percentage points. The deviations in r-star are entirely the result of changes to the shape and size of the unobserved components (figure 6b).

Figure 6: Sensitivity of r-star and z to changes to the variance of z

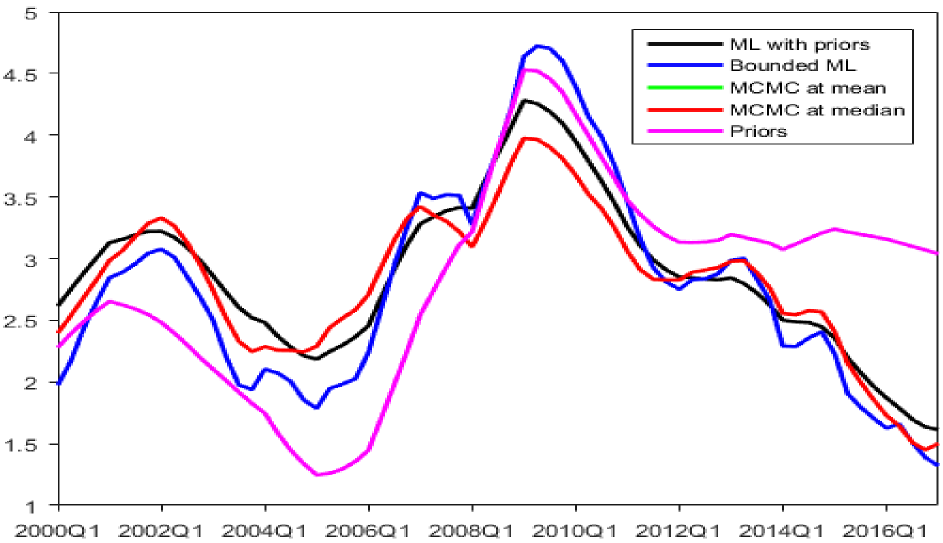
(a) Neutral real interest rate **(b)** z



6.2 Sensitivity to model estimation techniques

In this section we look at the impact of different estimation techniques including maximum likelihood with our priors, Bounded maximum likelihood where we apply bounds around coefficients, MCMC using the mean and median of the distribution, and a model version where our priors are directly applied. Figure 7 plots the neutral real interest rates from the five alternative estimations. A number of observations are worth mentioning. First, the 'priors' provide a baseline through which to gauge the impact of the data on the estimation. From 2000 to 2009, the data suggests that the r-star is higher than what we would have predicted given our prior view of the structure of the economy. From 2009 onwards, this reverses. Second, maximum likelihood methods with priors yield similar results to our MCMC methods. Third, the use of the mean or median of the distribution does not change the neutral real interest rate. Finally, bounded maximum likelihood generates similar but more volatile results.

Figure 7: Sensitivity to estimation method



7 Conclusion

The neutral real interest rate is an important benchmark for monetary policy. It indicates to the policy-maker whether the current stance, at least in real terms, supports or constrains growth, which in turn, either fuels or moderates inflation. In this paper, we adapt the popular Laubach and Williams (2003) methodology for estimating neutral real interest rates – or r-star – to the small-open economy characteristics of South Africa. This is done by expanding the Laubach and Williams (2003) semi-structural model to account for the impacts that the exchange rate, international commodity prices and developments in the global economy have on South Africa. In essence, Laubach and Williams (2003) model r-star as a function of the trend growth rate in an economy, and some unobservable factor. The dynamics of this unobservable factor can have far reaching consequences for the estimate of r-star. We follow recent research by identifying some of the likely drivers of this unobservable factor, thereby making its outcome easier to interpret. These factors include South Africa's country risk premium, a measure of excess global savings, policy uncertainty and the global equity premium.

Our estimate of r-star rises in the buildup to the global financial crisis, and peaks at 4 per cent by the start of 2009. While this rise mostly reflects rising domestic potential growth, excessive global savings and a low country risk premium over this build-up period serve to moderate the level of r-star. In the aftermath of the global financial crisis, South Africa's potential growth falls dramatically, and pulls r-star down with it. However, this post-crisis period is also characterised by falling global savings, increasing policy uncertainty, and a rising domestic risk premium. These factors raise the estimate of r-star above what would be suggested by the fall in potential growth. As a result, the South African r-star is estimated at around 1.5 per cent by early 2017.

Table 1: Data

	Variable	Transformation	Source
Domestic	Real GDP	Log level (seasonally adjusted and annualised)	StatsSA
	Core consumer inflation	Log first difference (seasonally adjusted)	StatsSA
	2-year ahead Inflation expectations	Log first difference (seasonally adjusted)	BER
	Real exchange rate gap	Per cent deviation from equilibrium	de Jager (2012)
	Real interest rate	Repo rate less one-year ahead inflation forecast from core model	SARB
	Country risk premium	SA 5-year CDS spread (HP-filter), year-on year change	Bloomberg
Foreign	Output gap	Real GDP as a per cent of potential GDP	Global Projection Model
	Underlying potential growth (g)	Per cent	Laubach and Williams (2003)
	Neutral real interest rate	Per cent	Laubach and Williams (2003)
	Core PCE inflation	Log first difference (seasonally adjusted)	FRED
	Brent crude oil	Log first difference	Bloomberg
	Real commodity price gap	Export weighted, Per cent deviation from HP-filter trend, deflated using US core PCE	Bloomberg and own calculations
	Effective federal funds rate	Per cent	FRED
	Global savings	Emerging market current account (per cent of GDP), first difference	IMF
	Equity premium	Per cent, first difference	Damodaran (2016)
	Global economic policy uncertainty	First difference	Baker, Bloom and Davis (2016)

Table 2: Prior an posterior estimates

Parameters		Priors		Posteriors	
	Distribution	Mean	Standard deviation	Median	Standard deviation
α_y	gamma	0.5	0.1	0.561	0.086
α_r	beta	0.05	0.02	0.032	0.010
α_{yf}	beta	0.25	0.1	0.218	0.043
α_q	beta	0.02	0.01	0.010	0.003
α_c	beta	0.05	0.02	0.025	0.005
β_π	gamma	0.7	0.1	0.653	0.082
β_y	beta	0.25	0.05	0.235	0.024
β_q	beta	0.1	0.05	0.044	0.011
β_o	beta	0.02	0.05	0.002	0.000
γ_p	gamma	1.0	0.4	0.730	0.181
γ_s	beta	0.33	0.05	0.316	0.029
γ_e	beta	0.07	0.05	0.033	0.016
γ_u	beta	0.02	0.02	0.014	0.020
ρ_q	beta	0.89	0.05	0.785	0.015
ρ_g	beta	0.90	0.05	0.892	0.012
ρ_r	beta	0.78	0.05	0.917	0.019
ρ_c	beta	0.5	0.1	0.782	0.014
ρ_p	beta	0.5	0.1	0.131	0.076
ρ_s	beta	0.5	0.1	0.153	0.098
ρ_e	beta	0.5	0.1	0.122	0.064
ρ_u	beta	0.5	0.1	0.112	0.105
ρ_o	beta	0.5	0.1	0.409	0.051
$\rho_{E\pi}$	beta	0.5	0.1	0.811	0.039
$\varepsilon_{\tilde{y}}$	inv.gamma	0.94	0.2	0.252	0.027
$\varepsilon_{\tilde{\pi}}$	inv.gamma	1.39	0.2	0.726	0.017
$\varepsilon_{\tilde{z}}$	inv.gamma	0.17	0.02	0.163	0.008
$\varepsilon_{\tilde{g}}$	inv.gamma	0.09	0.05	0.246	0.010
ε_r	inv.gamma	0.95	0.2	0.576	0.027
ε_q	inv.gamma	5.16	1	2.246	0.181
$\varepsilon_{\bar{y}}$	inv.gamma	0.09	0.05	0.152	0.007
ε_o	inv.gamma	1.0	0.2	18.58	1.621

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