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Enhancing the Quarterly Projection Model

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June 2023

Abstract

Over the last decade, fiscal dynamics have moved to the forefront of monetary policy deliberations. Elevated country risk premia associated with rising government debt have weighed on the exchange rate, at times fuelling imported inflationary pressures. In addition, fiscal policy actions have impacted economic activity, particularly the stimulus required during COVID-19 recession. This paper documents extensions to the South African Reserve Bank's Quarterly Projection Model that parsimoniously capture these key channels from fiscal metrics to growth and inflation and their feedback to fiscal outcomes. The paper discusses refinements to the model's equilibrium uncovered interest parity condition, which determines the domestic neutral real interest rate, as well as enhancements to the risk channel, labour block and drivers of inflation. It also proposes an updated specification for the Taylor rule.

JEL classification: E50, C53, H68, E62

Keywords: forecasting, fiscal policy, monetary policy, South Africa, macroeconomic models

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1. Introduction

The Quarterly Projection Model (QPM) is the workhorse forecasting model that has been used to inform monetary policy since mid-2017.[1] In its current form, the QPM does not have a mechanism to account for fiscal policy in a systematic manner, limiting its ability to help explain how fiscal dynamics affect inflation, growth and monetary policy. This limitation has become more pronounced in the past 10 years as fiscal metrics have changed greatly, implying that forecasting could improve with more formal treatment of these metrics in the model.

South Africa's ratio of public debt to gross domestic product (GDP) almost tripled from 23% in 2008 to nearly 70% in early 2022 amid persistently large fiscal deficits. Investor concern about debt sustainability has consequently increased, doubling the country risk premium – as measured by the JP Morgan Emerging Markets Bond Index Plus (EMBI+) spread – over this period. Higher country risk has, in turn, raised public sector borrowing costs and put the exchange rate under pressure. At the same time, significant fiscal stimulus since the onset of the COVID-19 pandemic has affected economic activity.

Such changes in the country's fiscal position should be accounted for in the model. A fiscal block in the QPM can allow for interactions between fiscal and monetary policies, which are critical for both policy analysis and forecasting.[2] For example, monetary policy affects economic activity and inflation in the short run, in turn affecting budget balances. Sovereign default risk and the setting of interest rates also influence the yield curve, affecting debt-service costs. Fiscal policy, in turn, strongly influences the conduct of monetary policy, as fiscal sustainability typically reduces the risk premium and inflation, and increases the credibility of inflation targets.[3]

This paper provides an overview of extensions to the QPM that account for key channels through which the setting of fiscal policy affects the macroeconomic landscape. Further enhancements to the model are also discussed. These include:

1. modelling country risk and term premia to account for changes in international investor sentiment;
2. a new specification for unit labour cost pressures and distinct processes for the evolution of wages in the private and government sectors;
3. an update to the model's inflation expectations process;
4. explicit mechanisms to account for indirect spillovers from fuel and electricity price changes to core and food inflation;
5. determination of the neutral real interest rate reflecting international interest rate parity conditions;

[1] See Botha et al. (2017) for details on the current QPM.
[2] See Sims (2013) and Bassetto and Sargent (2020).
[3] For example, see Swanepoel (2004).

6. a measure of bank lending conditions to bolster the credit cost channel's effect on aggregate demand; and
7. adjustments to the model's monetary policy rule, or Taylor rule.

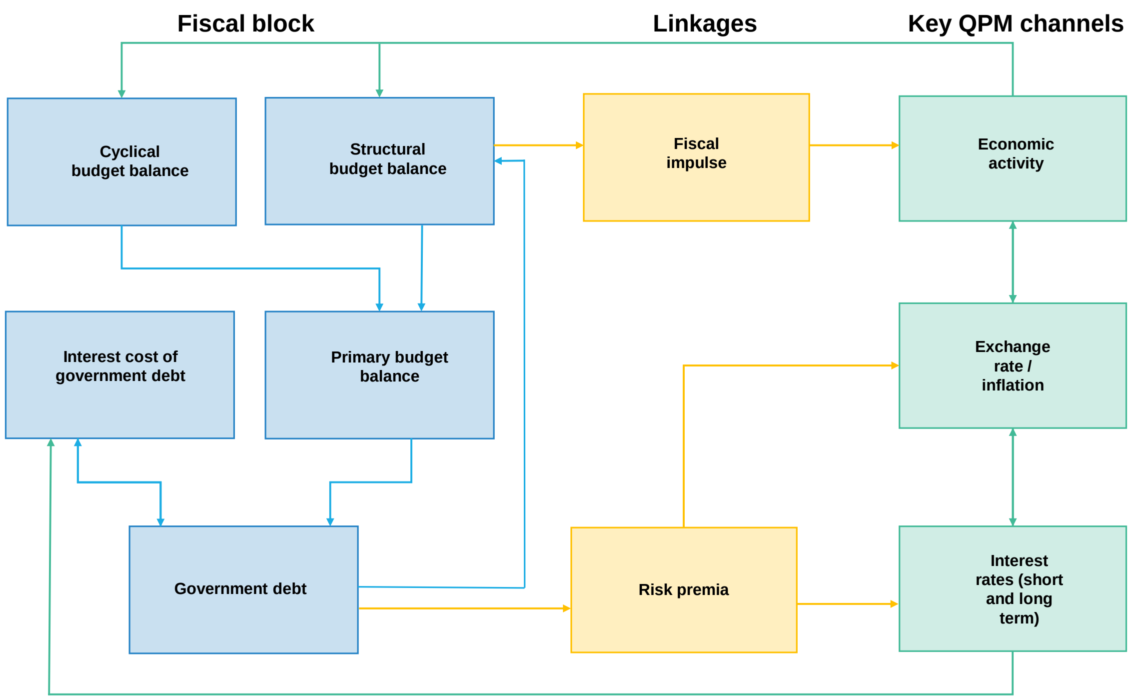
Taken together, these changes to the QPM yield a model that offers a greater array of features to aid monetary policy deliberations. Importantly, the updated model also delivers forecasts of key variables that are superior to those of the current version.

2. Structural changes to the QPM

2.1 The fiscal block

The fiscal block consists of five components: government debt, which evolves according to government's overall fiscal balance – or borrowing requirement – as determined by the primary fiscal balance and interest payments on outstanding debt (Figure 1).[4] The primary fiscal balance, in turn, is split into a structural and a cyclical component. The structural primary balance captures deliberate policy actions to implement countercyclical fiscal policy while being constrained by the need to stabilise public debt; the cyclical balance captures the role of automatic fiscal stabilisers over the economic cycle.

Figure 1: Overview of the fiscal block



The main channels of the original QPM (economic activity, inflation, the exchange rate and interest rates) affect the fiscal block in two ways: changes in economic activity affect the cyclical

[4] All fiscal variables are expressed as ratios to nominal GDP.

and structural primary budget balances, while movements in the repo rates (in response to inflation developments and/or economic fluctuations) along with changes in risk premia affect interest rates over the yield curve. For simplicity, the model's yield curve is proxied by a short and a long rate. Short-term government borrowing rates, such as those on Treasury bills, are proxied by the repo rate, while the longer-term yield reflects expectations of the nominal short rate (i.e. the expected real interest rate and inflation expectations) and risk premia. These ultimately affect payments on government debt across the maturity spectrum.

The fiscal block then feeds back into the QPM via discretionary changes in fiscal policy (changes in the structural budget balance) that affect economic activity. In addition, changes in public debt levels move country risk and term premia, currency levels and inflation. The fiscal block's main components are discussed next.

2.1.1 Evolution of government debt

Accumulation of gross debt as a ratio to GDP, $debt_t$, is determined by dynamics of its components: the current primary budget balance as a ratio to GDP, bal_t^{prim}, the effective interest rate on the existing stock of sovereign debt, i_t^g, the stock of outstanding government debt, $debt_{t-1}$, and the growth rate of nominal GDP that deflates the existing stock of debt, Δy_t^n:[5]

$$debt_t = -bal_t^{prim} + \left(\frac{1}{1+\Delta y_t^n}\right) debt_{t-1} + \left(\frac{i_t^g}{1+\Delta y_t^n}\right) debt_{t-1} + \varepsilon_t^{debt}. \tag{1}$$

2.1.2 Effective interest rate on government debt

Interest payments on government debt are complicated to model, as the interest rate applicable to each of the many outstanding debt instruments varies according to both the instrument's maturity as well as the period in which it was issued. For the sake of simplicity, only two interest rates are used in the model. Interest rates on the short-term debt are proxied by the repo rate, i_t^{repo}, while rates on long-term debt are proxied by the 10-year yield, i_t^{10Y}. The latter is modelled according to the expectations hypothesis: the expected repo rate (i.e. expectations for real interest rates and inflation) over the next 10 years plus a term premium which is linked to the level of government debt.[6]

The equation for the effective interest rate on government debt is as follows:

$$i_t^g = \rho^{gov} i_{t-1}^g + \alpha^{repo} i_t^{repo} + \alpha^{10Y} i_t^{10Y}, \tag{2}$$

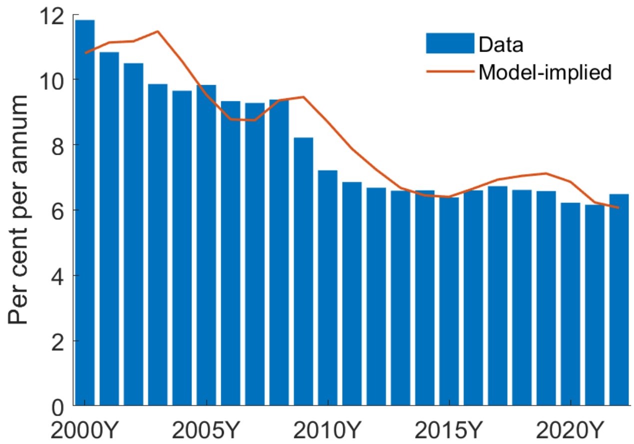
$$\rho^{gov} = 0.90,\ \alpha^{repo} = 0.08,\ \alpha^{10Y} = 0.02,$$

[5] For simplicity, the identity that governs the evolution of government's debt-to-GDP ratio does not explicitly account for other possible contributors to changes in gross debt, such as the revaluation of inflation-linked and foreign currency debt, as well as changing cash balances. These are captured by the residual term ε_t^{debt}.

[6] Empirical evidence suggests that the expectations hypothesis holds in case of South Africa: see Soobyah and Steenkamp (2020) and Muzindutsi and Mposelwa (2016).

where the lagged interest rate term ρ^{gov} accounts for outstanding fixed-rate debt that is yet to mature, while α^{repo} and α^{10Y} capture the weight of variations of the short-term and 10-year rate, respectively, in driving the effective interest rate on government debt. The parameters of equation 2 are calibrated such that the model-implied dynamics of the effective interest rate on debt track its data counterpart closely.[7,8]

Figure 2: Effective government interest rate



Sources: SARB, authors' calculations.

In practice, repo changes map directly to the short-term debt component of government's interest cost. However, the impact of repo changes on government's interest cost related to longer-term debt instruments is state dependent, as it is a function of the current set of shocks driving economic outcomes and what those shocks imply for risk premia and expectations for interest rates and inflation going forward.

2.1.3 Budget balance components

The headline budget balance bal_t consists of the primary budget balance and government interest payments on debt (all as ratios to GDP):[9]

$$bal_t = bal_t^{prim} - int_t, \tag{3}$$

where the primary balance is defined as a difference between total budget revenues and government spending (excluding interest payments): $bal_t^{prim} = T_t - G_t^*$, and interest payments int_t

[7] The search for equation 2's parameter values is performed over a fine grid of values in the [0,1] interval to minimise the squared distance between the data and the model-implied path for the effective rate on debt. The effective interest rate in the data is calculated as the seasonally adjusted ratio of interest payments by government to total gross government debt.

[8] An alternative calibration of equation 2 based on the average maturity of government debt as well as the shares of public debt comprising fixed-rate and inflation-linked securities has also been tested. This alternative specification delivers an implied government interest rate that deviates substantially from the data. Resorting to the optimisation technique outlined above yields a markedly better fit.

[9] Both the overall budget balance and primary balance are positive when in surplus and negative when in deficit. Interest payments in equation 3 are not expressed as a balance, and therefore have a negative sign.

reflect the interest burden on outstanding debt from equation 1. Further, the primary balance is broken down into its cyclical and structural (cyclically-adjusted) components:

$$bal_t^{prim} = bal_t^{cycl} + bal_t^{struct}. \tag{4}$$

The former co-moves with the business cycle and captures the procyclical response of automatic stabilisers to economic fluctuations:[10]

$$bal_t^{cycl} = p_1 y_t^{gap}, \tag{5}$$

$$p_1 = 0.24$$

where y_t^{gap} is the output gap.

The structural component of the primary budget balance captures discretionary fiscal policy actions. The effect of fiscal stimulus (or consolidation) on aggregate demand in the model is captured by the structural balance entering directly into the IS curve (see equation 7 below).

The evolution of the structural budget balance is determined by a fiscal rule with two competing policy objectives: countercyclical stimulus in response to fluctuations in aggregate demand and sovereign debt stabilisation around a targeted level of indebtedness, $debt_t^{tar}$:[11]

$$\begin{aligned} bal_t^{stuct} &= \rho^{fp} bal_{t-1}^{stuct} \\ &+ (1-\rho^{fp})\left[bal_t^{struct,tar} + p_4 y_{t-1}^{gap} + p_2 E_t(debt_{t+1} - debt_{t+1}^{tar})\right] + \varepsilon_t^{bal^{struct}}, \end{aligned} \tag{6}$$

$$p_4 = 0.49,\ p_2 = 1.75,\ \rho^{fp} = 0.84.$$

The parameter values of the fiscal policy rule are in line with the two aforementioned goals. The positive coefficient on the output gap ensures that the countercyclical objective is met. A negative output gap (i.e. insufficient aggregate demand) calls for a more negative structural fiscal balance – a fiscal deficit – to stimulate activity. In turn, a positive output gap requires tighter fiscal policy by means of a structural surplus. The positive coefficient on the deviation of debt from its targeted level forces fiscal consolidation in the event of debt exceeding its target level.[12,13] Ultimately, the debt target serves as a policy anchor to help stabilise government

[10] The elasticity of the cyclical primary balance to the output gap is estimated based on the Organisation for Economic Co-operation and Development (OECD) methodology (Van den Noord, 2000) and accounting for a 'non-commodity output gap' (Amra, Hanusch and Jooste, 2019) to clean the output measure from the effect of international commodity cycles that are shown to generate procyclical fiscal policy responses (see Appendix).

[11] The fiscal rule used in the model does not aim to replicate the historical setting of discretionary fiscal policy in South Africa, which has generally followed flexible rules consisting mainly of expenditure ceilings (see Calitz, Siebrits and Stuart, 2016). Instead, equation 6 yields a structural balance that delivers countercyclical fiscal policy while aiming to stabilise government debt over a reasonable time frame.

[12] The current year projection of government gross debt as a ratio to GDP by National Treasury is used as the debt target in the model.

[13] The target for the structural primary balance in equation 6 is the period-by-period level of the structural balance that is required for government debt to return to its targeted level.

debt.

2.1.4 Fiscal stimulus

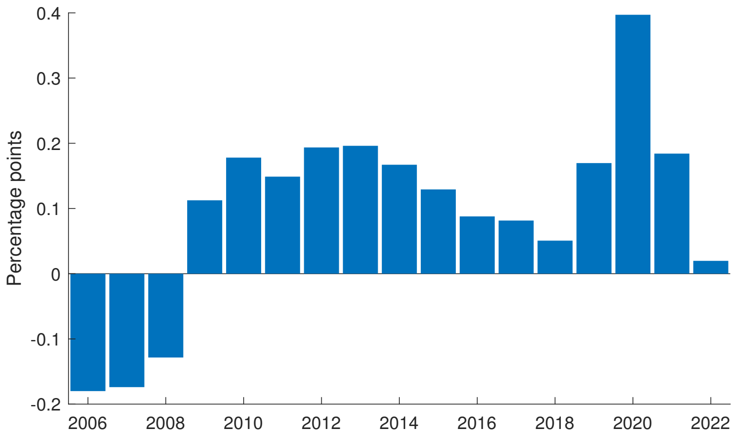
Fiscal stimulus in the model is defined as an increase in the structural deficit, or equivalently, as a reduction in the structural budget balance. The fiscal stance enters the model's IS curve directly, with an immediate effect on aggregate demand:

$$\begin{aligned} y_t^{gap} &= a_1 E_t y_{t+1}^{gap} + a_2 y_{t-1}^{gap} - a_3 rr_t^{eff,gap} + a_4 rer_t^{gap} + a_5 y_t^{world,gap} + a_6 tot_t^{gap} \\ &- a_7 (bal_t^{struct} - bal^{struct,ss}) + \varepsilon_t^{y^{gap}}, \end{aligned} \tag{7}$$

$$a_1 = 0.03,\ a_2 = 0.50,\ a_3 = 0.14,\ a_4 = 0.08,\ a_5 = 0.17,\ a_6 = 0.02,\ a_7 = 0.04,$$

where $rr_t^{eff,gap}$, rer_t^{gap}, $y_t^{world,gap}$, and tot_t^{gap}, are the respective gaps of the risk-adjusted real interest rate, real exchange rate, world output, and terms of trade. $\varepsilon_t^{y^{gap}}$ is the IS curve's stochastic component capturing movements in the output gap not accounted for by the equation's other variables.

Figure 3: Estimated contribution of the fiscal stance to economic activity



Sources: Authors' calculations.

The estimated fiscal multiplier a_7 yields short-term responses of output to fiscal stimulus similar to those of recent empirical studies (see Kemp (2020)).[14] Importantly, the fiscal extension to the model does not distinguish whether fiscal stimulus is driven by changes in government spending or changes in tax policy. Empirical studies point to significant differences in the size and persistence of effects delivered by tax relative to spending-driven fiscal stimuli.[15] However, due to model-specific constraints in incorporating the highly persistent effects induced by tax-related fiscal impulses on aggregate demand, as found in Kemp (2020), the model only allows

[14] Empirical estimates of government spending and tax multipliers in Kemp (2020) are in line with evidence found for other developing economies. See, for example, Grdović Gnip (2014), IMF (2018) and Alichi, Shibata and Tanyeri (2019).

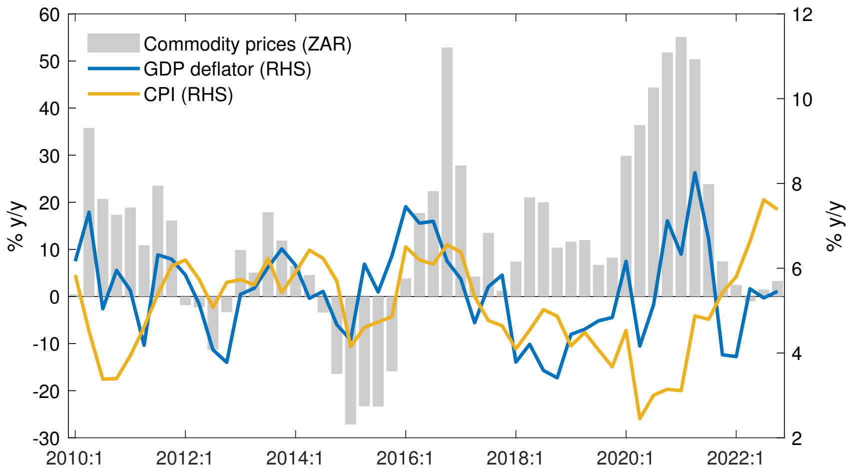
[15] See, among others, Blanchard and Perotti (2002), Mountford and Uhlig (2009) and Ramey (2016) for evidence for developed economies, and Jooste, Liu and Naraidoo (2013), Janse van Rensburg, De Jager and Makrelov (2021), Kemp (2020) and references therein for the fiscal multiplier estimates for South Africa.

for general fiscal stimulus representing an average of tax and spending policy changes. As indicated in Figure 3, the implied measure of fiscal accommodation appears to reasonably capture the stance of fiscal policy with periods of fiscal restraint just before the global financial crisis (GFC) and an accommodative stance post-GFC consistent with Loewald, Faulkner and Makrelov (2020). The outsized fiscal response to the COVID-19 pandemic in 2020–2021 is also evident.

2.1.5 Nominal GDP

Expressing fiscal variables as ratios to nominal GDP necessitates inclusion of the GDP deflator in the QPM, as the original model contains real GDP alone and aggregate prices are solely represented at the consumer level by the headline consumer price index (CPI).

Figure 4: GDP deflator, CPI inflation, and world commodity prices



Sources: Stats SA, SARB, authors' calculations.

The GDP deflator is, however, assumed to move broadly in tandem with consumer prices and rand-denominated international commodity prices. The latter accounts for the role of commodity prices in the mining sector's nominal value added, which is not captured in consumer prices and often causes GDP deflator growth to deviate markedly from CPI inflation (Figure 4). Equation 8 shows the evolution of the GDP deflator:

$$\pi 4_t^{gdp} = g_1 \pi 4_{t-1}^{gdp} + g_2 \pi 4_t + g_3 \pi 4_t^{commZAR} + \varepsilon_t^{\pi 4^{gdp}}, \quad (8)$$

where $\pi 4_t^{gdp}$, $\pi 4_t^{commZAR}$ and $\pi 4_t$ are year-on-year growth rates of the GDP deflator, world commodity prices denominated in rands and headline CPI, respectively.

2.2 Risk channels

Fiscal conditions also feed into the main QPM block via the risk and term premia channels, acknowledging the central role of government debt as a domestic determinant of the sovereign risk premium.[16] Accordingly, the risk premium is driven by the deviation of the debt-to-GDP ratio from its target level, changes in the debt ratio and international investor sentiment:

$$\begin{aligned} prem_t &= \rho^{prem} prem_{t-1} + (1-\rho^{prem}) prem_t^{eq} + p_{13}(debt_t - debt_t^{tar}) + p_{16}(debt_t - debt_{t-1}) \\ &+ p_{10}(VIX_t - VIX_{ss}) + \varepsilon_t^{prem}, \end{aligned} \tag{9}$$

$$\rho^{prem} = 0.60,\ p_{13} = 0.05,\ p_{16} = 0.14,\ p_{10} = 0.05,$$

where VIX_t captures the state of global uncertainty and risk aversion – in particular, episodes of risk-on/risk-off sentiment – to reflect the extent to which global investors require additional compensation for risk (Kalemli-Özcan and Varela, 2021). The debt target is represented by National Treasury's official projections for the debt-to-GDP ratio released biannually during the national budget and mid-term budget. The debt-deviation-from-target mechanism ensures that debt outcomes that turn out to be worse than Treasury projections put upward pressure on the risk premium, and vice versa.

The risk premium's long-term trend (i.e. equilibrium risk), $prem_t^{eq}$, is determined by the extent to which the debt target has deviated from the steady-state debt ratio. In the case of the QPM, the rising trend of the debt-to-GDP ratio since 2010, and thus Treasury's projections thereof, contributes to the rising equilibrium risk premium over time:

$$prem_t^{eq} = \rho^{prem^{eq}} prem_{t-1}^{eq} + (1-\rho^{prem^{eq}}) prem_{ss} + p_{12}(debt_t^{tar} - debt_{ss}) + \varepsilon_t^{prem^{eq}}, \tag{10}$$

$$\rho^{prem^{eq}} = 0.79,\ p_{12} = 0.02,$$

where $prem^{ss}$ is the steady-state risk premium and $debt^{ss}$ is the steady-state level of government debt assumed to equal 50% of GDP.[17]

On the assumption that determinants of the term premium are the same as those driving the risk premium, the term premium is informed by deviations of the risk premium from its steady state:

$$term_t = \rho^{tp} term_{t-1} + (1-\rho^{tp}) term_{ss} + p_{14}(prem_t - prem_{ss}) + \varepsilon_t^{term}, \tag{11}$$

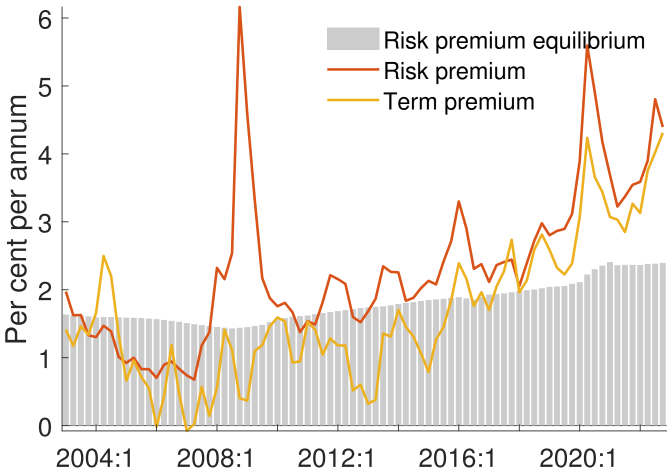
$$\rho^{tp} = 0.7,\ p_{14} = 0.36.$$

The observed risk premium – proxied by South Africa's EMBI+ spread – and the model-determined series of the risk premium equilibrium and term premium are plotted in Figure 5.

[16] See, among others, Schmitt-Grohe and Uribe (2001), Schmitt-Grohe and Uribe (2003), Adolfson et al. (2008), Janse van Rensburg, De Jager and Makrelov (2021), and Loate, Pirozhkova and Viegi (2021).

[17] The debt target deviation's effect on the risk premium equilibrium is estimated outside of the model using the ordinary least squares method. The steady-state debt ratio of 50% reflects the average of the decade ending in 2021Q4. Prior to Statistics South Africa's (Stats SA's) revision of nominal GDP in September 2021, the average ratio was roughly 55% over this period.

Figure 5: South Africa's risk premium, its equilibrium and the term premium



Sources: JP Morgan, authors' calculations.
Note: The risk premium series (South Africa's EMBI+ spread) is observed; the equilibrium risk premium and term premium series are filtered outcomes of the updated QPM.

2.3 Labour block revisions

The labour block is a critical component of the model's price-setting process. Nominal wages are broadly determined by past and expected wage increases and labour productivity, while also responding to inflation developments through indexation. In turn, if wage increases exceed those justified by productivity gains (i.e. a pickup in unit labour costs), they place upward pressure on prices.

2.3.1 Wage Phillips curves

In the original version of the QPM, economy-wide nominal wages are captured by a single wage Phillips curve. Quarterly economy-wide wage growth π_t^w is explained by its own lagged and expected values and is indexed to lagged quarterly CPI inflation and equilibrium real wage growth Δrw_t^{eq}. Lastly, the real unit labour cost gap $rulc_t^{gap}$ – the extent to which the real wage per worker, per unit of output, exceeds or falls short of its level suggested by productivity fundamentals – acts as a correcting mechanism in the wage formation process. Accordingly, workers cannot continually be paid more than their productive worth, and vice versa. This is shown in equation 12:

$$\pi_t^w = (1 - w_1 - w_2)E_t\pi_{t+1}^w + w_1\pi_{t-1}^w + w_2(\pi_{t-1} + \Delta rw_t^{eq}) - w_3 rulc_t^{gap} + \varepsilon_t^{\Delta w}. \qquad (12)$$

A drawback of the current model's single wage formation process is that it ignores the vastly different dynamics of government and private sector wages. In the updated QPM, the single wage Phillips curve is split to distinguish between government and private sector wages:

$$\begin{aligned}\pi_t^{w,priv} &= (1-w_1^p-w_2^p)E_t\pi_{t+1}^{w,priv}+w_1^p\pi_{t-1}^w+w_2^p(\pi 4_{t-1}+\Delta rw_t^{eq}) \\ &- w_3^p rulc_{t-1}^{gap}+\varepsilon_t^{w,priv}, \end{aligned} \quad (13)$$

$$\begin{aligned}\pi_t^{w,gov} &= (1-w_1^g-w_2^g)E_t\pi_{t+1}^{w,gov}+w_1^g\pi_{t-1}^w+w_2^g(\pi 4_{t-1}+\Delta rw_t^{eq}) \\ &- w_3^g rulc_{t-1}^{gap}+\varepsilon_t^{w,gov}, \end{aligned} \quad (14)$$

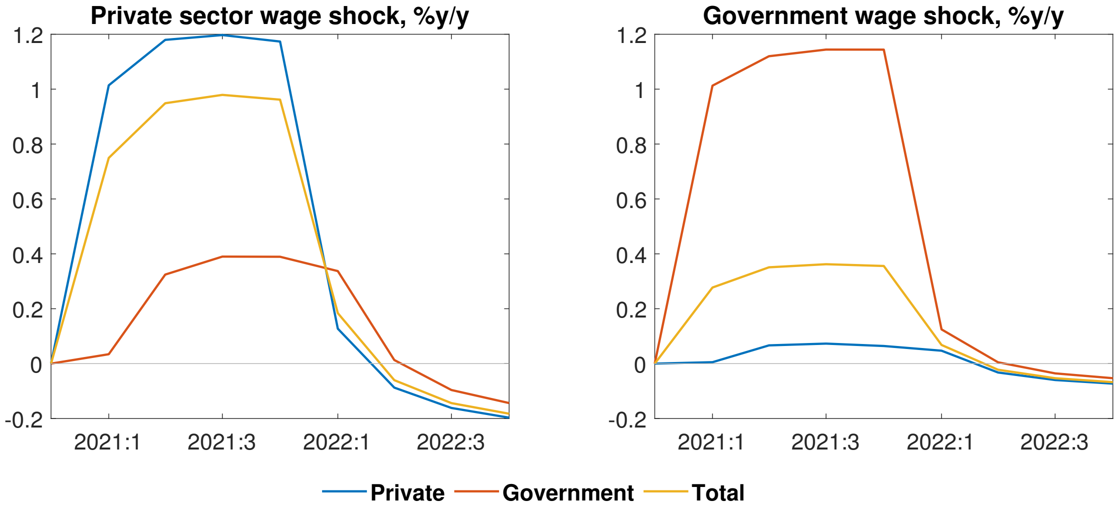
$$w_1^p=0.3,\ w_2^p=0.64,\ w_3^p=0.27,\ w_1^g=0.38,\ w_2^g=0.49,\ w_3^g=0.18.$$

Nominal wage growth in either sector is determined by expected wage growth for the sector, the lag of economy-wide wage growth and a spillover mechanism for wage shocks to transmit from one sector to another (see Figure 6). This is supplemented with lagged year-on-year CPI inflation, $\pi 4_t$, and the economy-wide real unit labour cost gap, with the latter reflecting deviations of the productivity-adjusted real wage from its equilibrium level.[18] Relative to the current wage Phillips curve, the real unit labour cost gap feeds in with a one-quarter lag, motivated by empirical evidence.

The total, economy-wide nominal wage is a weighted average of private and government wages according to their respective shares w_t^{gov} and $(1-w_t^{gov})$ in total compensation:

$$\pi_t^w = w_t^{gov}\pi_t^{w,gov}+(1-w_t^{gov})\pi_t^{w,priv}. \quad (15)$$

Figure 6: Spillovers from government and private sector wage increases



Source: Authors' calculations.

In practice, government wage agreements tend to be pre-announced. The distinction between

[18] Wörgötter and Nomdebevana (2020) provide empirical evidence of the interaction between public and private sector remuneration in South Africa, with particularly strong spillovers from the private to the public sector, and to a lesser degree in reverse.

government and private sector wages allows these announcements to be incorporated in the forecast as an assumption. As such, economy-wide wage growth over the forecast will be consistent with the government's intended medium-term wage increases, and private sector wages will be partly affected by spillovers from government wage agreements according to equations 13 and 14.[19]

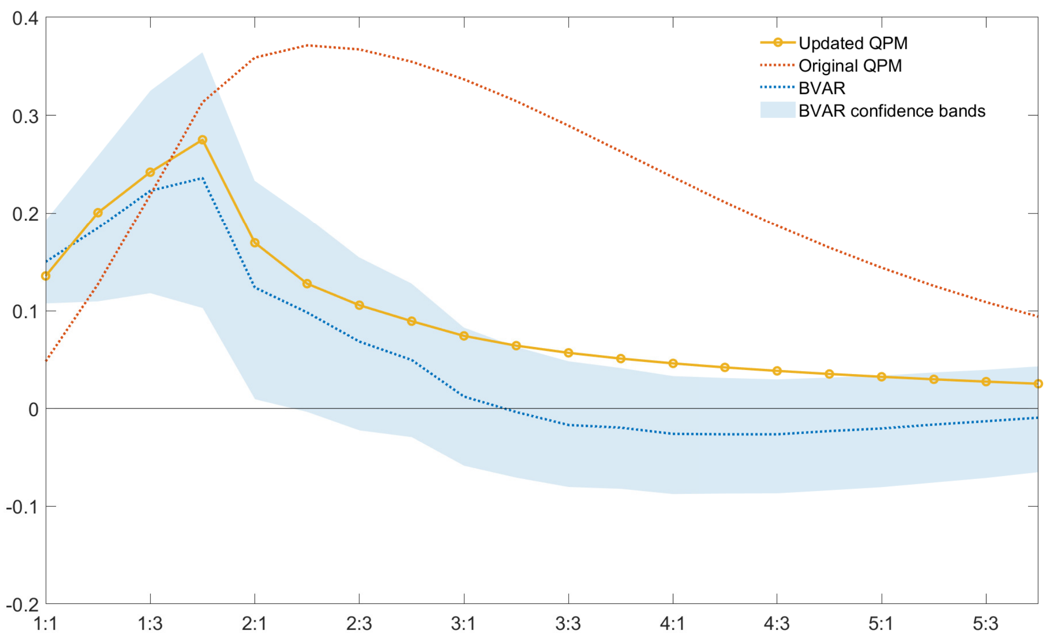
2.3.2 Unit labour costs measure

Next, the way of accounting for unit labour costs as a driver of CPI inflation dynamics is revised. In the original QPM, inflationary pressures emanating from the labour market are reflected solely by the real unit labour cost gap. For example, the current services inflation Phillips curve is specified as:

$$\begin{aligned}\pi_t^{serv} &= (1-b_{11})\left[(1-b_{16})E_t\pi_{t+1} + b_{16}\pi 4_t^{BER}\right] + b_{11}\pi_{t-1}^{serv} + b_{13}y_t^{gap} \\ &+ b_{14}rulc_t^{gap} + b_{15}rer_t^{gap} + \varepsilon_t^{\pi^{serv}}, \qquad (16)\end{aligned}$$

where π_t^{serv} reflects quarter-on-quarter (annualised) CPI services inflation, $E_t\pi_{t+1}^{serv}$ is the model-consistent expectation of the coming quarter's quarter-on-quarter inflation rate, $\pi 4_t^{BER}$ represents the Bureau for Economic Research's (BER's) two-year-ahead inflation expectation, and $\varepsilon_t^{\pi^{serv}}$ captures other shocks to services inflation not emanating from the components discussed above.

Figure 7: Services CPI inflation, year-on-year response to a nominal unit labour cost shock



Source: Authors' calculations.

[19] Sector-specific Phillips curve parameters are estimated with OLS, which informs the priors in the overall model estimation. See section 3 below.

In the new model, the Phillips curves for the various CPI components are augmented to include nominal unit labour cost growth (Δulc_t) together with the real unit labour cost gap. Empirical evidence from a Bayesian vector autoregression (BVAR) supports this new specification with the effect of nominal unit labour cost growth on CPI components being positive and significant (see Figure 7).[20] Moreover, the new specification improves forecast accuracy when both variables are used (see Appendix).

2.4 Spillovers from fuel and electricity prices to core and food price inflation

The original QPM does not explicitly account for spillovers from fuel and electricity price changes to core inflation that may occur beyond their impact on wages and inflation expectations. The only explicit spillover channel in that version was from fuel to food prices, while a sharp pickup in fuel prices would not affect core inflation through the production and distribution of core goods and services. Conflitti and Luciani (2019) find that international oil price shocks have statistically significant pass-through to United States core inflation, albeit of small magnitude. Likewise, in the Global Projection Model, the Phillips curves for core inflation are augmented to account for spillovers from international oil prices.[21] The updated QPM now explicitly accounts for empirically proven spillovers from fuel and electricity prices in the Phillips curves for services and core goods inflation (i.e. core inflation), as well as in that of food inflation.[22]

Figure 8 indicates how separate 10% increases in the electricity and fuel CPI impact core and food inflation in the updated model. A temporary 10% rise in the fuel price driven by higher international oil prices lifts food inflation by almost 0.4 percentage points after four quarters, while lifting core inflation by around 0.2 to 0.3 percentage points. Electricity prices, in turn, have a more marked impact on food inflation and core inflation than fuel price increases of similar magnitude – likely reflecting relatively price-inelastic demand amid the intensive usage of electricity in food production and its associated cold chain, as well as in the production of goods and services.[23] In the absence of an explicit spillover channel, any potential for spillovers from oil and electricity price shocks to core and food inflation are offset to a large extent by the inflation expectations channel, which almost immediately reacts to the anticipated decline – in year-on-year terms – four quarters after the initial relative price increase. In net

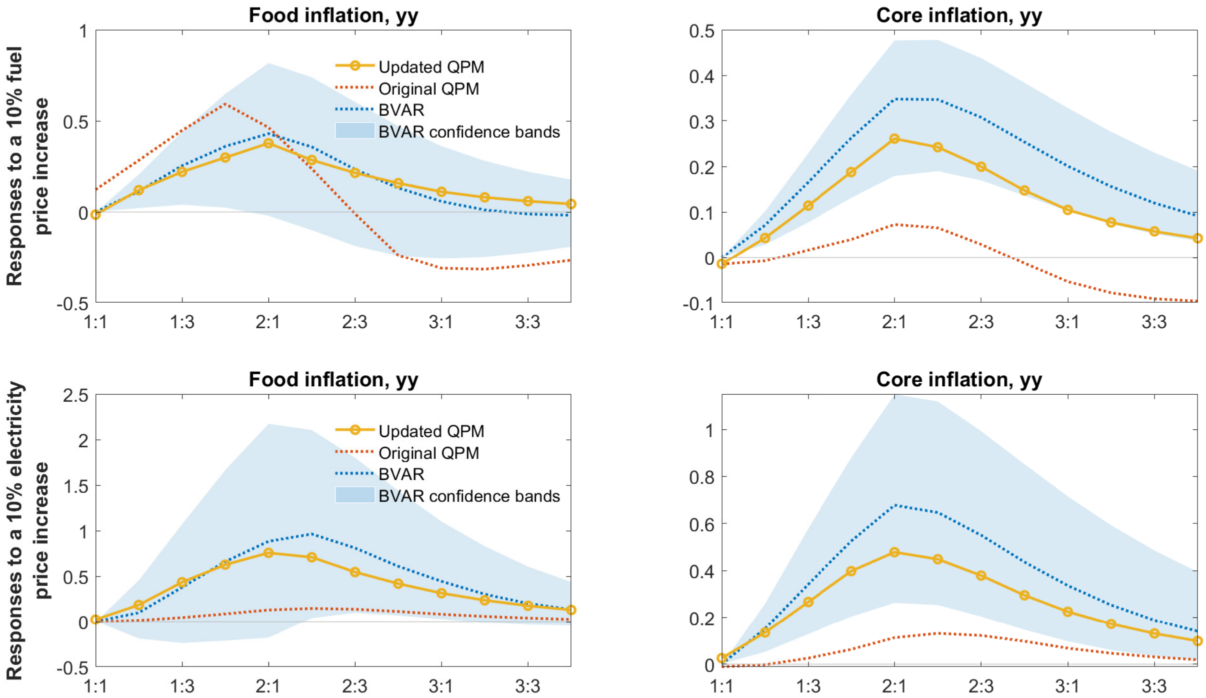
[20] The BVAR model is estimated on quarterly data over 2000Q2–2019Q4 and includes the output gap, nominal unit labour cost growth, services CPI inflation, the short-term interest rate, the risk premium and the real exchange rate variables, in this order. Time series data is taken from the original QPM model database. The unit labour cost shock has a magnitude of 1% in year-on-year terms and is identified with Cholesky ordering based on these variables' order. Independent Normal Wishart priors are used. The shaded area shows the 90% posterior coverage bands. The quarter-on-quarter BVAR response is transformed to a year-on-year growth rate using a four-quarter moving average.

[21] See the Global Projection Model Network (GPMN) (2020). The GPMN is a non-profit research institute based in Prague, the Czech Republic, that provides regular global macroeconomic forecasts and risk scenarios. The institute makes use of the IMF's Global Projection Model as the main tool in its forecasting kit, with additional inputs from other structural models.

[22] Empirical estimates in the South African context suggest that fuel and electricity price increases have notable spillovers to core inflation (see Pirozhkova et al., forthcoming).

[23] See Blignaut, Inglesi-Lotz and Weideman (2015) for estimates of sectoral electricity price elasticities.

Figure 8: Core and food inflation responses to fuel and electricity price changes



Source: Authors' calculations.

terms, spillovers to core inflation from relative fuel and food price movements are roughly three times stronger than in the original model, and are also symmetric. While spillovers from fuel prices to food inflation are slightly weaker in the updated model, they are markedly more pronounced in relation to electricity price changes. The various inflation equations from the updated model are as follows:

Services inflation

$$\begin{aligned}\pi_t^{serv} &= (1-b_{11}-b_{14}^l)\left[(1-b_{16})E_t\pi 4_{t+4}+b_{16}\pi 4_t^{BER}\right]+b_{11}\pi 4_{t-1}^{serv} \\ &+ b_{14}^l \Delta ulc_t + rmc_t^{serv} + spillovers_t^{serv} + \varepsilon_t^{\pi^{serv}}\end{aligned} \tag{17}$$

$$\begin{aligned}rmc_t^{serv} &= b_{13}y_t^{gap}+b_{14}rulc_t^{gap}+b_{15}rer_t^{gap} \\ spillovers_t^{serv} &= b_{17}(relative\ fuel\ price_{t-1,t-2,t-3}^{gap})+b_{19}(relative\ electricity\ price_{t-1,t-2,t-3}^{gap})\end{aligned}$$

$$b_{11}=0.09,\ b_{13}=0.04,\ b_{14}=0.15,\ b_{14}^l=0.15,\ b_{15}=0.06,\ b_{16}=0.20,$$
$$b_{17}=0.03,\ b_{19}=0.04$$

Core goods inflation (excl. food, electricity and fuel)

$$\begin{aligned}
\pi_t^{goods} &= (1-b_{21}-b_{22}-b_{24}^l)\left[(1-b_{26})E_t\pi4_{t+4}+b_{26}\pi4_t^{BER}\right]+b_{21}\pi4_{t-1}^{goods} \\
&+ b_{22}\pi_{t-1}^m+b_{24}^l\Delta ulc_t+rmc_t^{goods}+spillovers_t^{goods}+\varepsilon_t^{\pi^{goods}} \qquad (18)
\end{aligned}$$

$$\begin{aligned}
rmc_t^{goods} &= b_{23}y_t^{gap}+b_{24}rulc_t^{gap}+b_{25}rer_t^{gap} \\
spillovers_t^{goods} &= b_{27}(relative\ fuel\ price_{t-1,t-2,t-3}^{gap})+b_{29}(relative\ electricity\ price_{t-1,t-2,t-3}^{gap})
\end{aligned}$$

$$b_{21}=0.09,\ b_{22}=0.10,\ b_{23}=0.15,\ b_{24}=0.08,\ b_{24}^l=0.13,$$
$$b_{25}=0.06,\ b_{26}=0.20,\ b_{27}=0.05,\ b_{29}=0.08$$

Food inflation

$$\begin{aligned}
\pi_t^{food} &= (1-b_{31}-b_{32}-b_{36}-b_{34}^l)\left[(1-b_{37})E_t\pi4_{t+4}+b_{37}\pi4_t^{BER}\right]+b_{31}\pi4_{t-1}^{food} \\
&+ b_{32}(\pi_{t-1}^{food,world}+\Delta er_{t-1})+b_{34}^l\Delta ulc_t+rmc_t^{food}+spillovers_t^{food} \\
&+ \varepsilon_t^{\pi^{food}} \qquad (19)
\end{aligned}$$

$$\begin{aligned}
rmc_t^{food} &= b_{33}y_t^{gap}+b_{34}rulc_t^{gap}+b_{35}rer_t^{gap} \\
spillovers_t^{food} &= b_{37}(relative\ fuel\ price_{t-1}^{gap})+b_{39}(relative\ electricity\ price_{t-1,t-2}^{gap})
\end{aligned}$$

$$b_{31}=0.09,\ b_{32}=0.03,\ b_{33}=0.09,\ b_{34}=0.07,\ b_{34}^l=0.18,$$
$$b_{35}=0.04,\ b_{36}=0.05,\ b_{37}=0.20,\ b_{39}=0.09,$$

where $\pi4_t$ reflects year-on-year inflation rates, $target$ is the inflation target, π_{t-1}^m is imported inflation, $\pi_{t-1}^{food,world}$ captures foreign-currency denominated world food inflation, Δer_t is changes in the nominal exchange rate, and the spillover variables — $relative\ fuel\ price_t^{gap}$ and $relative\ electricity\ price_t^{gap}$ — are the levels of these CPI components relative to headline CPI (i.e. real prices), expressed as deviations from their underlying trends. The timing of these spillover variables in the equations above varies, based on empirical evidence.[24]

Further changes are also incorporated based on empirical evidence. Indexation to past and expected year-on-year inflation rates – as opposed to quarter-on-quarter rates in the current model – has stronger empirical backing.[25] In addition, pass-through of changes in world food prices to domestic food inflation is immediate in the original QPM. Based on the BVAR evidence, however, world food inflation enters the food Phillips curve in the updated model with a

[24] CPI fuel inflation is split between the basic fuel price component and fuel taxes, with the former being a function of international oil prices and the nominal exchange rate. Fuel taxes and CPI electricity prices follow simple processes and are generally treated as exogenous assumptions over the forecast horizon.

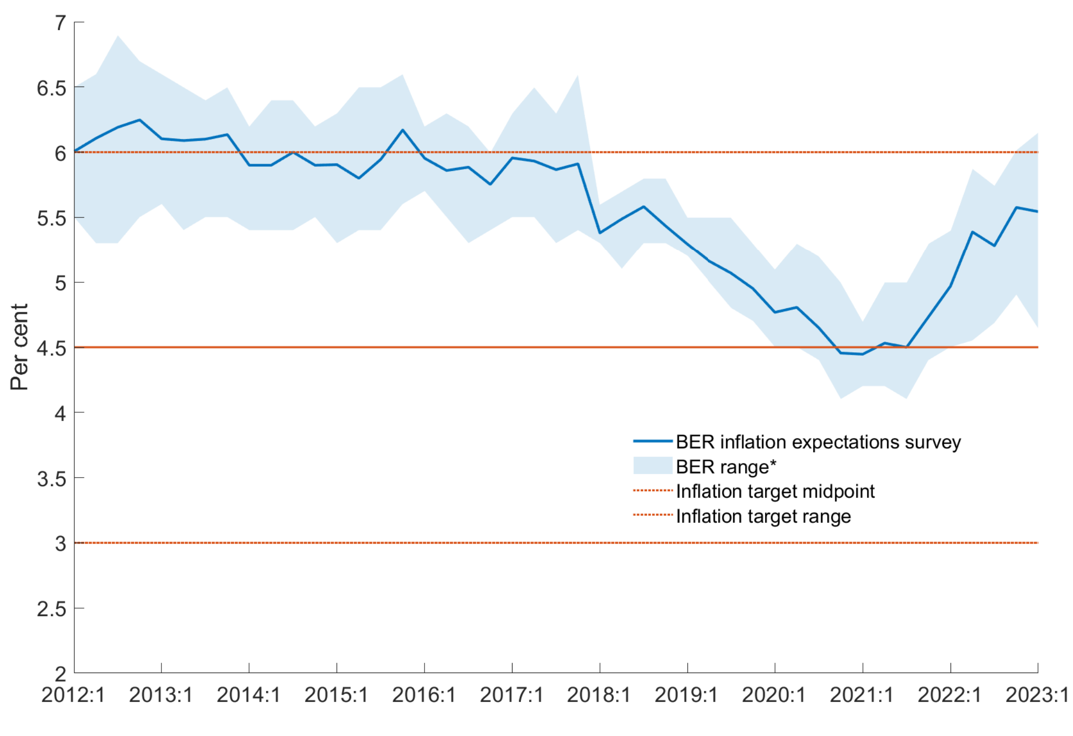
[25] Publication of year-on-year inflation rates by Stats SA, as well as their more widespread reporting in the media, likely helps explain the greater empirical support for indexation to year-on-year inflation rates relative to quarter-on-quarter rates. See Reid et al. (2020).

one-quarter lag, and is slightly stronger than before.

2.5 Updated inflation expectations dynamics

Another aspect of the model that has been updated is the dynamics of the exogenous inflation expectations process – predicated on the BER's two-year ahead expectations – which were last calibrated in 2016–2017. Preliminary evidence suggests price setting in the economy has changed markedly over the last six years. For one, inflation – particularly services inflation, which accounts for about half of the CPI basket – appears to have become less persistent over this period. The Monetary Policy Committee (MPC) has also embarked on anchoring inflation expectations near the 4.5% midpoint of the inflation target range (SARB 2017), whereas the 3–6% range was previously targeted. As a result, inflation expectations have begun to gradually converge toward the midpoint of the target range (Figure 9). Importantly, the downward trend in surveyed inflation expectations, as well as in market-implied expectations derived from breakeven rates, corresponds to the timing of the announcement by the MPC in mid-2017 that it would aim to anchor inflation expectations near the range's 4.5% midpoint.[26]

Figure 9: BER 2-year ahead inflation expectations vs the inflation target



Source: Bureau for Economic Analysis.
Note: The BER range refers to the range of expectations of the survey's three social groups, i.e. trade unions, businesses, and analysts.

[26] Miyajima and Yetman (2019) show that the SARB has become more effective in anchoring inflation expectations, particularly those of analysts.

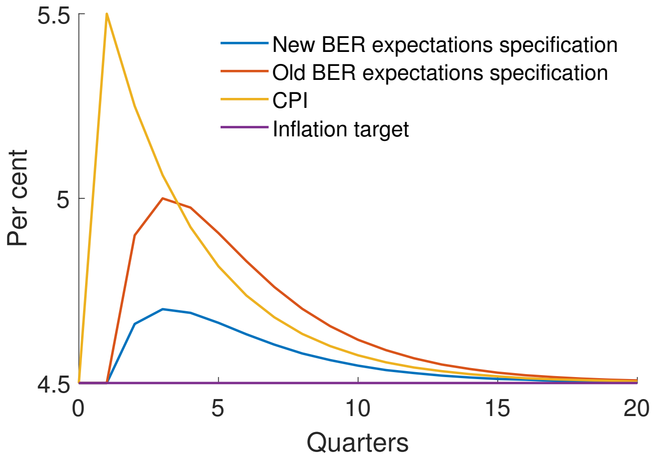
This reinforces the view that expectations are now much better anchored than before and need to be accounted for as such in the new model. The new specification of the exogenous expectations process is less backward-looking toward past inflation outcomes, placing a larger weight on the inflation target's midpoint than before:

$$\pi_t^{BER} = u_1\pi4_{t-1} + u_2 target_t + (1-u_1-u_2)\pi4_{t-1}^{BER} + \varepsilon_t \tag{20}$$

$$u_1 = 0.16,\ u_2 = 0.34.$$

In terms of the model's dynamics, inflation expectations are better anchored in response to shocks than in the original QPM (see Figure 10).

Figure 10: BER inflation expectations response to an inflation shock



Source: Authors' calculations.

2.6 Revised equilibrium uncovered interest parity and real interest rate specification

A modification to the measurement of the equilibrium (neutral) real interest rate (NRIR) in the model is also implemented. The NRIR is the level of the real interest rate that should prevail if economic activity is at potential (i.e. a closed output gap) and inflation is in line with the target. The real interest rate in the model is defined as per the Fisher equation, which adjusts nominal interest rates for one-year-ahead expected inflation:[27]

$$rr_t = i_t^{repo} - E_t\pi4_{t+3} \tag{21}$$

where rr_t denotes the real interest rate.

In practical policymaking, the NRIR helps gauge the appropriate stance of monetary policy, with policy considered contractionary when the real interest rate is above the NRIR, expansionary when it is below and neutral when they are aligned. It is worth noting, however, that

[27] One year ahead in the QPM refers to four quarters after the latest available quarterly inflation print, which is the quarter preceding the MPC meeting.

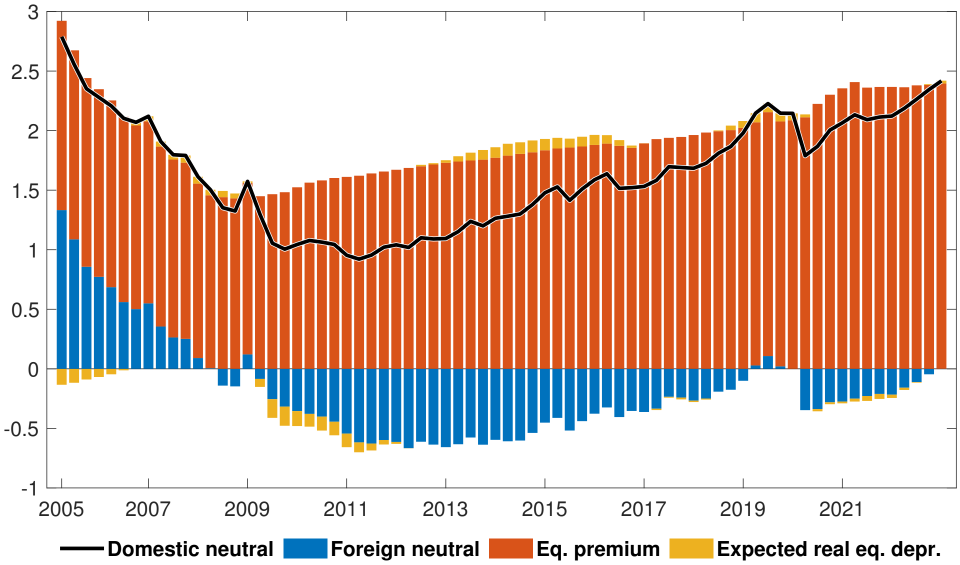
significant statistical uncertainty surrounds NRIR estimates.[28]

The SARB has broadly followed two approaches in estimating South Africa's NRIR. The first, a more closed-economy approach, explicitly considers the economy's potential growth rate along with other factors that could affect the NRIR, but incorporates some open-economy aspects such as country risk.[29] The second is an open-economy approach based on the uncovered interest parity (UIP) condition and thus explicitly considers the role of global neutral interest rates, country risk and expectations around the equilibrium real exchange rate:

$$\begin{aligned} \text{Domestic neutral real rate}_t &= \text{Foreign neutral real rate}_t \\ &+ \text{Equilibrium risk premium}_t \\ &+ E_t\left[\text{Change in equilibrium real exchange rate}_{t+1}\right], \quad (22) \end{aligned}$$

where an increase in the exchange rate represents depreciation.[30]

Figure 11: Decomposition of the NRIR



Source: Authors' calculations.

In the original QPM, a modified version of the UIP condition in equation 22 was used, in which a shock component was added to the condition to allow for some deviation in the resulting NRIR estimate from what the strict UIP condition would yield, enabling the incorporation of other NRIR drivers, such as potential growth. In the updated model, the stricter version of equation 22 is used.

While some deviation from the strict UIP can be expected in the short run, over the longer run it should approximately hold. Furthermore, the UIP condition can capture global factors via the foreign NRIR and domestic factors via the equilibrium risk premium and the equilibrium real

[28] Uncertainty around NRIR estimates has been further heightened in the wake of the COVID-19 pandemic, given extraordinary volatility in underlying determinants.

[29] See Laubach and Williams (2003), Holston, Laubach and Williams (2017) and Kuhn, Ruch and Steinbach (2019).

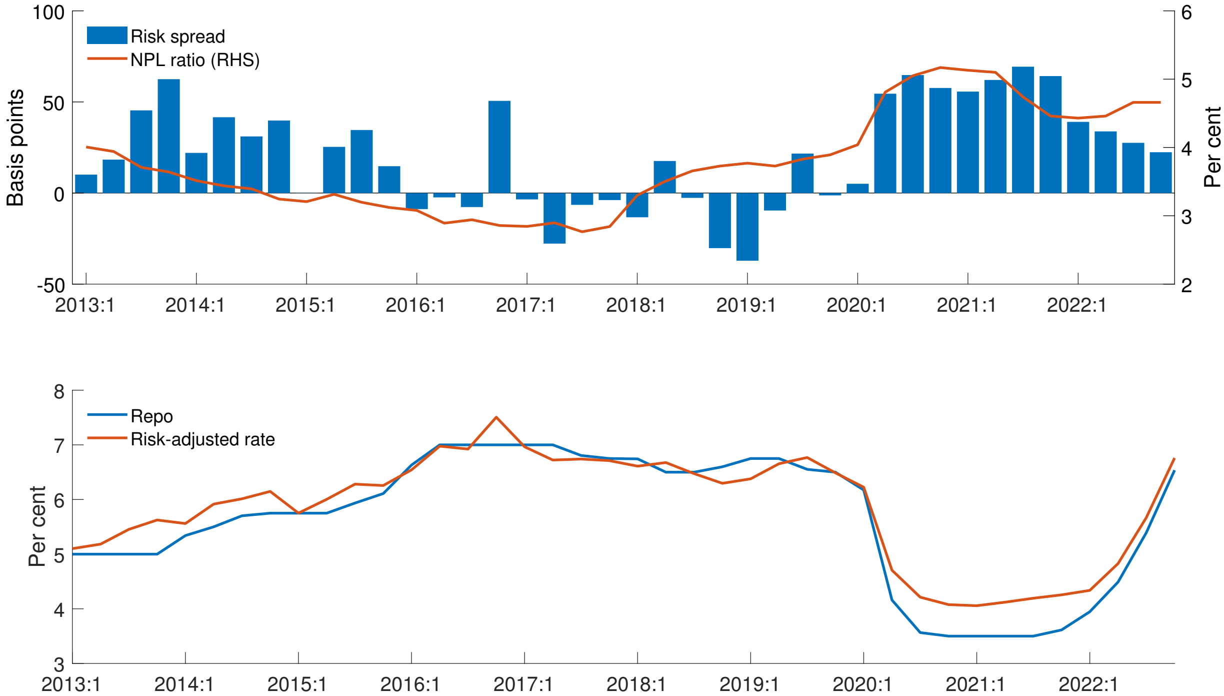
[30] The foreign neutral rate is a weighted average of the neutral rates for the United States, euro area and Japan.

exchange rate. The real exchange rate should reflect productivity differentials and fiscal sector dynamics, among other factors (see Appendix for details). Figure 11 shows a decomposition of the NRIR over the period 2005–2022 according to the updated QPM.

2.7 Bank lending conditions

Credit supply conditions can exhibit frictions in the transmission of monetary policy, seen as a spread between policy and lending rates.[31] A smaller spread indicates more efficiency and vice versa. In the event of a sharp downturn in economic activity, banks may anticipate a rise in non-performing loans. As banks reprice risk to compensate for the deterioration in borrower balance sheets, they increase the cost of credit by raising the lending spread over official interest rates (see Figure 12). As a result, policy interest rate changes may not always be fully passed on to borrowers.[32]

Figure 12: The risk-adjusted lending rate



Sources: Author's calculations, Haver Analytics, SARB.
Note: The pickup in non-performing loans in 2018Q1 is largely technical, reflecting changes to the measurement and disclosure of financial assets by banks due to the implementation of International Financial Reporting Standard 9 in January 2018.

To account for the impact that changing credit conditions may have on borrowing costs, the bank lending spread — or credit premium — is included in the model to yield a risk-adjusted

[31] See Curdia and Woodford (2010), Gilchrist and Zakrajšek (2012), Greenwood-Nimmo, Steenkamp and van Jaarsveld (2022), Steinbach, du Plessis and Smit (2014) and SARB (2015), among others.

[32] In addition to market factors, implementation of several prudential regulations since the GFC has partly contributed to a general rising trend in South African bank lending spreads amid increased bank funding costs. See Rapapali and Steenkamp (2020).

real interest rate:[33].

$$rr_t^{eff} = rr_t + credprem_t. \tag{23}$$

Over the forecast, the credit premium is a moving-average function of the country's sovereign risk premium, given the co-movement observed between these two variables.

2.8 Revisiting the current Taylor rule

The model's Taylor rule sets an interest rate consistent with the inflation and output gaps, expected shocks to them, and a path to return to the target.[34] The revision here updates response coefficients and improves model-generated policy responses in a variety of circumstances. The Taylor rule in its current form is specified as follows:

$$\begin{aligned} repo_t &= 0.79 * repo_{t-1} \\ &+ (1-0.79) * \Big[\\ &+ 0.57 * \left(inflation\ forecast_{t+3,4,5} - \pi^{target}\right) \\ &+ 0.52 * output\ gap_t \\ &+ neutral\ repo_t \Big] \end{aligned} \tag{24}$$

Accordingly, the repo rate reported by the Taylor rule is a function of the prevailing repo rate (i.e. the lagged repo rate), headline inflation's average deviation from its target at three, four and five quarters ahead ($inflation\ forecast_{t+3,4,5} - \pi^{target}$), the output gap, and the 'nominal' neutral rate (i.e. $real\ neutral\ rate_t + inflation\ forecast_{t+3,4,5}$).[35] Each of these components, while commonly used in central bank models, entails costs and benefits for the specification of the Taylor rule. We discuss some of the issues in their use below, along with suggested enhancements.

2.8.1 Policy smoothing

In practice, smoothing terms are embedded in Taylor rules to account for policy inertia (the likelihood that the rate in t+1 will be near the rate in t). While early versions of the rule, such as that documented in Taylor (1993), had no role for policy intertia, rules including a smoothing component soon gained prominence in the literature.[36] 'Smoothing' of policy rate changes has several justifications. Chief among them is the uncertainty surrounding many aspects of

[33] The banking sector lending spread is calculated as the difference between the average interest rate reported by banks (inclusive of both new and existing loans) and the official prime interest rate. The average interest rate is calculated from the aggregated South African banking sector returns for banks' interest income (BA120) and their balance sheets (BA100).

[34] See Taylor (1993, 2007) for background on monetary policy rules.

[35] The inflation target (π^{target}) is defined as the 4.5% midpoint of the inflation target range.

[36] See Lowe and Ellis (1997), Goodhart (1998), Clarida, Gali and Gertler (1998) and Sack and Wieland (2000), among others.

the central bank's information set when setting the policy rate, particularly where short-term data is volatile and have larger effects on near-term forecast horizons than longer-term data. Therefore, without a policy smoothing condition for the rule, large swings in the policy rate can be advised by policy models. The predictability of the direction of policy is also important for the credibility of the monetary policy framework, as well as the functioning of financial markets. While the ideal weight that a central bank should place on smoothing is not necessarily clear, the literature suggests that values of 0.8 or higher are quite common.

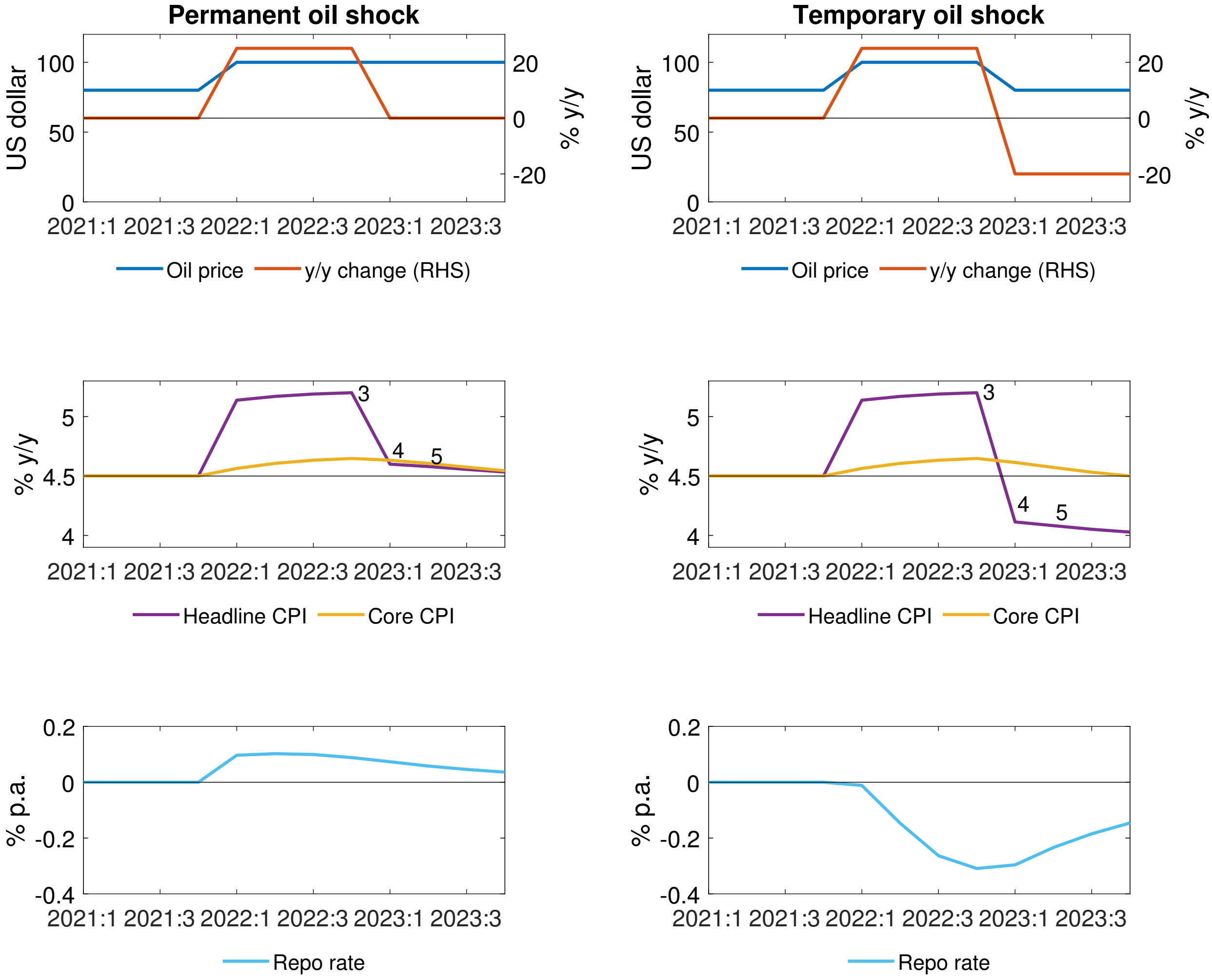
In practice, a smoothing coefficient of 0.8 implies that the Taylor rule's suggested interest rate change at a particular meeting has placed an 80 percent weight on keeping the repo rate at its current level, and a 20 percent weight on inflation and growth developments. Assuming inflation at the policy horizon has risen 1 percentage point above the target and the Taylor rule coefficient on inflation is 1.5, the rule's suggested repo rate increase would be 0.3 percentage points or 30 basis points (i.e. 0.2 x 1.5 x 1) at that meeting. If the inflation shock persists at the next policy meeting, the rule would suggest that the repo rate be lifted further to a level of 54 basis points (i.e. 0.8 x 0.3 + 0.2 x 1.5 x 1). The hiking cycle would continue for as long as the shock persists, with the repo rate eventually being increased by more than the inflation pickup — causing tighter real rates — in roughly five meetings. Conversely, if by the second meeting the inflation pickup had turned out to be temporary after completely dissipating for some external reason, the repo rate would only have increased by 30 basis points, while a Taylor rule without a smoothing coefficient would have suggested a 150 basis point hike for an inflation shock that disappeared.

2.8.2 The inflation forecast horizon

The current rule uses an average of the three-, four-, and five-quarter-ahead forecasts of the deviation of headline inflation from the target. At the time when the QPM was adopted as the main forecasting model in 2017, this longer forecast horizon was thought to be an appropriate policy horizon to guide interest rate decisions, given lags involved in the transmission of monetary policy to economic outcomes (see, for example, Dorich et al. (2013) and Gervais and Gosselin (2014)). However, inclusion of the fourth- and fifth-quarter-ahead forecasts dilute the rule's inflation signal, particularly in specific circumstances where base effects have marked impacts on the inflation forecast. An oil price shock serves as a useful example in this regard.

Figure 13 indicates the impact of both a permanent and temporary shock to international oil prices. In the panel on the left, oil rises from USD80 to USD100 – a 25% increase – in the first quarter of 2022, and then remains at this level. The inflationary impact of this shock will cause the oil price component of the domestic fuel price to increase by 25% on a year-on-year basis for four quarters, before base effects take over in the first quarter of 2023, causing the year-on-year rate to fall back to zero as the oil price is still at the same level it was right after the shock – USD100. Headline CPI will exhibit similar dynamics, reflecting the sudden rise in fuel prices, followed by an abrupt reversal in the fourth quarter after the shock. If the oil shock turns out to be temporary, with its price reverting back to the USD80 level after four quarters

Figure 13: Hypothetical oil price shock scenarios



Source: Authors' calculations.

– a 20% decline – headline inflation dynamics turn negative with the year-on-year rate falling below the target, despite second-round effects and spillovers from the initial fuel price increase keeping core inflation elevated.

With the current rule's focus on the forecast horizon at three, four, and five quarters ahead, below-target inflation rates at horizons four and five will signal a lowering of the repo rate, while headline inflation is expected to pick up for at least four quarters, and core inflation for even longer.[37] Such a counterintuitive interest rate response is bound to worsen the inflationary impacts of the oil shock, not dampen them, and renders the longer inflation forecast horizon in the current Taylor rule problematic. The revised rule focuses only on the t+3 inflation forecast, or 9 to 12 months into the future.[38]

[37] The inflation shock's repo responses in the bottom panel are based on the current Taylor rule. For expositional purposes, however, they are stylised in that there is no feedback from the interest rate response back to inflation.

[38] Orphanides (2003) argues in favour of the three-quarter-ahead horizon, as it essentially represents the one-year-ahead forecast from the latest available inflation data point. To illustrate, an MPC meeting in July – the third quarter – would only have actual outcomes for quarterly inflation for the second quarter of that year at its disposal. A three-quarter-ahead forecast of inflation at the July meeting would be for the second quarter of the

2.9 Output gap dynamics

Taylor rules, such as the current rule in the QPM, generally consider the level of economic activity relative to potential output – the output gap – without reference to GDP growth. Orphanides (2003), however, finds that historical policy decisions are well characterised by a rule which also incorporates a growth gap – how GDP growth deviates from potential growth – along with the output gap. Considering relative growth dynamics in conjunction with the level of activity helps provide additional information about the pace at which the economy is expected to slow or expand over the policy horizon. Incorporating growth in the policy rule also adds a more concrete variable to the decision set.

In Figure 14's left panel, the output gap starts from a hypothetical negative position of -1.5%; however, GDP growth is projected to exceed potential growth over the forecast, causing the output gap to eventually close. In the current Taylor rule, with the output gap being the sole indicator of economic activity, slack in the economy suggests that the repo rate should be eased. The rule that accounts for both the output gap and the projected growth gap – the direction and speed of change of the output gap going forward – calls for less accommodation for an output gap that is bound to close.

In contrast, if the nature of the shock to activity is expected to cause the output gap to widen over the forecast as growth is projected to fall below its potential rate – the onset of the GFC as well as the COVID-19 pandemic are apt examples – the revised rule would call for even greater monetary policy accommodation.

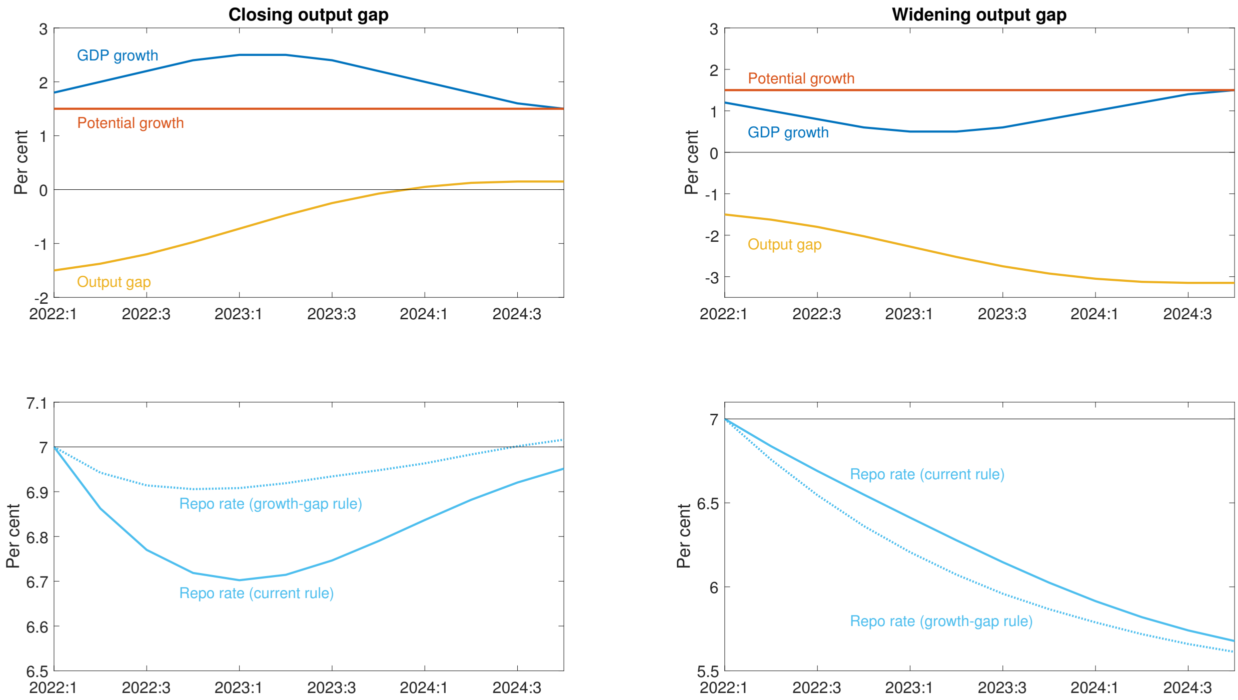
2.9.1 Updated Taylor rule estimates

Uncovering the parameters of an updated rule that incorporates the aspects discussed above (i.e. the weights that the MPC over recent years has put on inflation, output, growth, interest-rate smoothing and the NRIR, respectively) is made possible by our access to the data the MPC had at its disposal at each rate-setting meeting. Without this data, unrepresentative proxies for inflation and growth forecasts – such as private sector consensus – would have had to be used. Estimates of the output gap at each meeting would also have been hard to obtain, as these are not readily published.

Implementing the changes discussed above yields the following updated Taylor rule specifica-

following year – that is, one year ahead from the latest available data point for inflation.

Figure 14: Hypothetical output gap scenarios



Source: Authors' calculations.
Note. For ease of exposition, the scenarios do not account for feedback effects of the different policy stances on economic activity. If such feedback were to be accounted for, the output gap in the 'closing output gap' scenario for the current rule would close sooner and most likely overshoot due to a relatively greater degree of easing. In the 'widening output gap' scenario, however, the output gap would deteriorate further than indicated in the figure given a relatively tighter policy stance suggested by the current rule.

tion and parameter estimates:[39]

$$
\begin{aligned}
repo_t &= 0.78 * repo_{t-1} \\
&+ (1-0.78) * \Big[\\
&+ 0.60 * \left(inflation\ forecast_{t+3} - \pi^{target}\right) \\
&+ 0.60 * output\ gap_{t-1} \\
&+ 0.36 * E_t growth\ gap_{t+3} \\
&+ neutral\ repo_t \Big],
\end{aligned} \tag{25}
$$

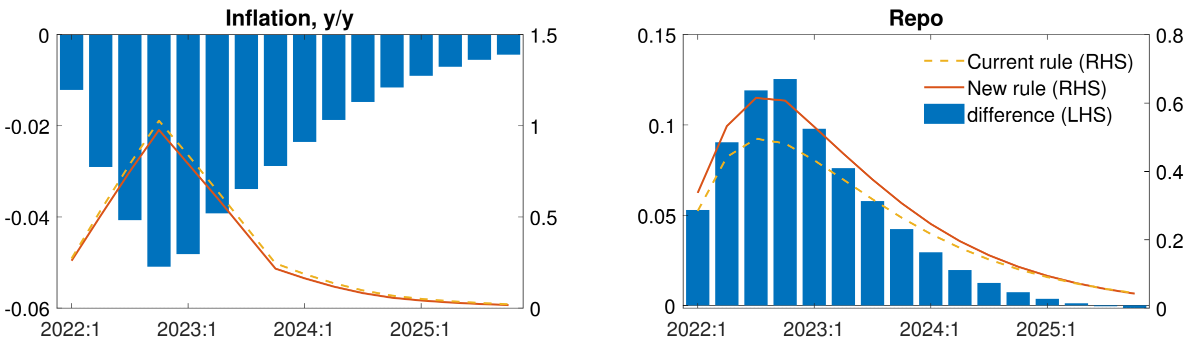
where inflation's deviation one year ahead of the last available quarterly number (i.e. $inflation\ forecast_{t+3} - \pi^{target}$) has replaced the three-, four-, and five-quarter-ahead horizon and the newly introduced growth gap is the difference between the one-year-ahead forecast of GDP growth and potential growth, both in year-on-year terms. The change in the inflation horizon also affects the neutral repo rate (i.e. $real\ neutral\ rate_t + inflation\ forecast_{t+3}$). The output gap enters the updated rule with a one-quarter lag. This one-period shift backward is motivated by the longer lags involved with GDP releases. At best, the previous quarter's GDP would have been released before any particular MPC meeting, while in half of the meetings (e.g. May, July and November), the most recent GDP release reflects activity only up to two quarters prior to

[39] The Taylor rule parameters reflect Bayesian posterior modes, with prior means determined by robust least squares estimates of real-time inflation and activity estimates and forecasts.

that meeting.

The updated parameter values point to a similar degree of interest rate smoothing, with the weight edging lower from 0.79 to 0.78. Inflation has a slightly higher weight at 1.6 – when the inflation component of the neutral repo rate is accounted for – compared to 1.57 in the current rule. The weight on the output gap has picked up from 0.52 to 0.6 in the updated rule, while the newly added growth term has a weight of 0.36.

Figure 15: Repo responses to an inflation shock in the current and updated Taylor rules



Source: Authors' calculations.

The interest rate response to inflation deviations from the target is slightly stronger under the new rule, reflecting the combination of lower persistence, a higher inflation weight, and the new rule's three-quarter-ahead inflation focal point as opposed to the current three to five quarters ahead. The three-quarter rule reduces the inefficiencies in the repo response in the model, as discussed above in the oil price example. Figure 15 compares the updated model's response to a shock to core inflation that lifts headline inflation by about 1 percentage point at its peak – depending on the specific Taylor rule reaction. The greater interest rate response in the updated rule helps quell inflation sooner than under the current rule.

3. Model calibration and re-estimation

To match key empirical regularities of the South African economy, the updated model's parameter values are determined using several sources. Although the majority of parameters are calibrated – a common approach in QPM-type models – their values are mostly determined by off-model empirical analyses. For example, BVARs were used to find appropriate values for many parameters in the model's labour market and CPI inflation channels. Ordinary least squares (OLS) estimates were also employed, specifically to help identify the persistence parameters in the model's various autoregressive processes. Similar to the original QPM, some parameter values were taken straight from empirical evidence presented in other studies on the topic. A subset of parameter values required the authors' calculations, such as the parameterisation of government's effective interest rate on its outstanding debt. Remaining parameter values were, however, estimated in the full-model context, conditional on the calibration discussed above.

4. Structural analysis with updated model

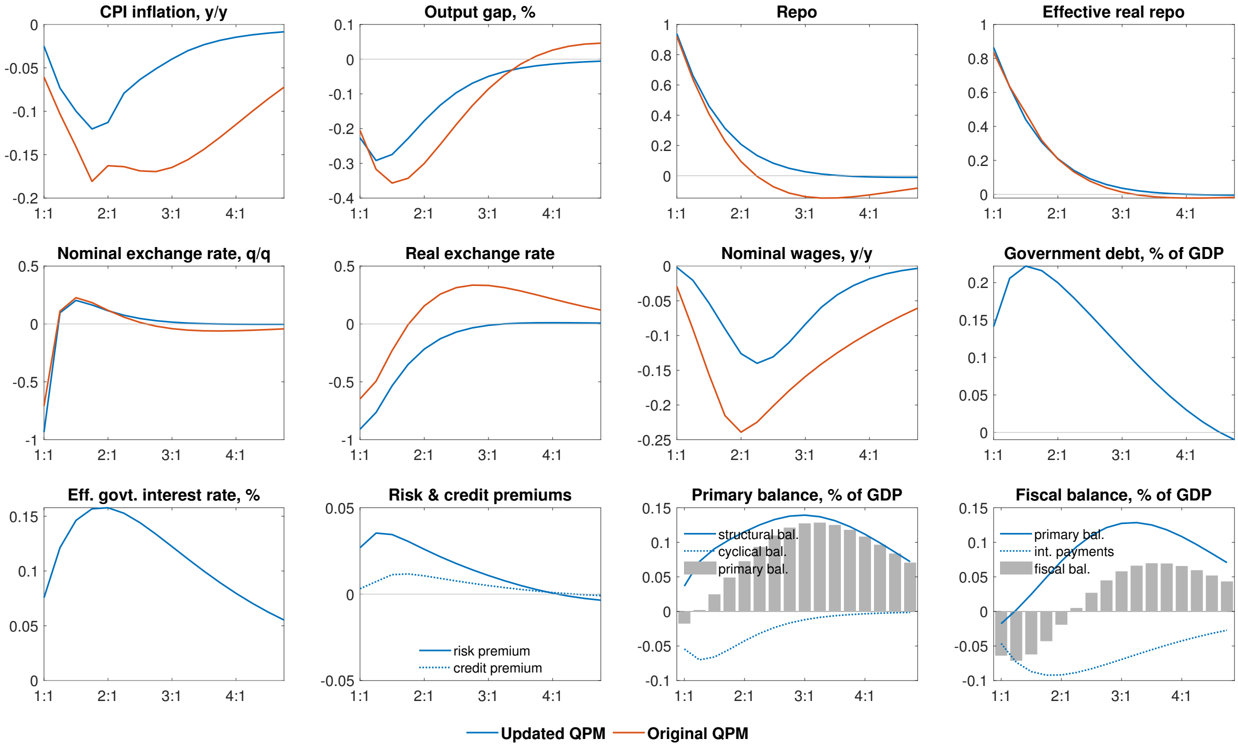
4.1 Responses to shocks

We next consider the model's response to several shocks and compare them to those from the original QPM model.

Tighter monetary policy

An increase in the repo rate of 100 basis points causes inflation in the updated QPM (blue line) to fall by about 0.13 percentage points after four quarters, as higher interest rates lead to exchange rate appreciation and a slowdown in real economic activity (Figure 16).[40] Compared to the original QPM, inflation's decline is smaller and markedly less persistent – partly reflecting revised inflation dynamics in the model that are generally less persistent than before. Updated wage dynamics result in a slightly delayed response of nominal wages to falling inflation – the trough is reached about one to two quarters after that of inflation, and is of a smaller magnitude than the original QPM trough. The more appreciated real exchange rate reaction in the updated model partly reflects the differing inflation dynamics.

Figure 16: Contractionary domestic monetary policy shock



Fiscal metrics are also affected by tighter monetary policy, albeit marginally, and here excluding any other change in fiscal policy or other shock. Softening real activity causes the cyclical

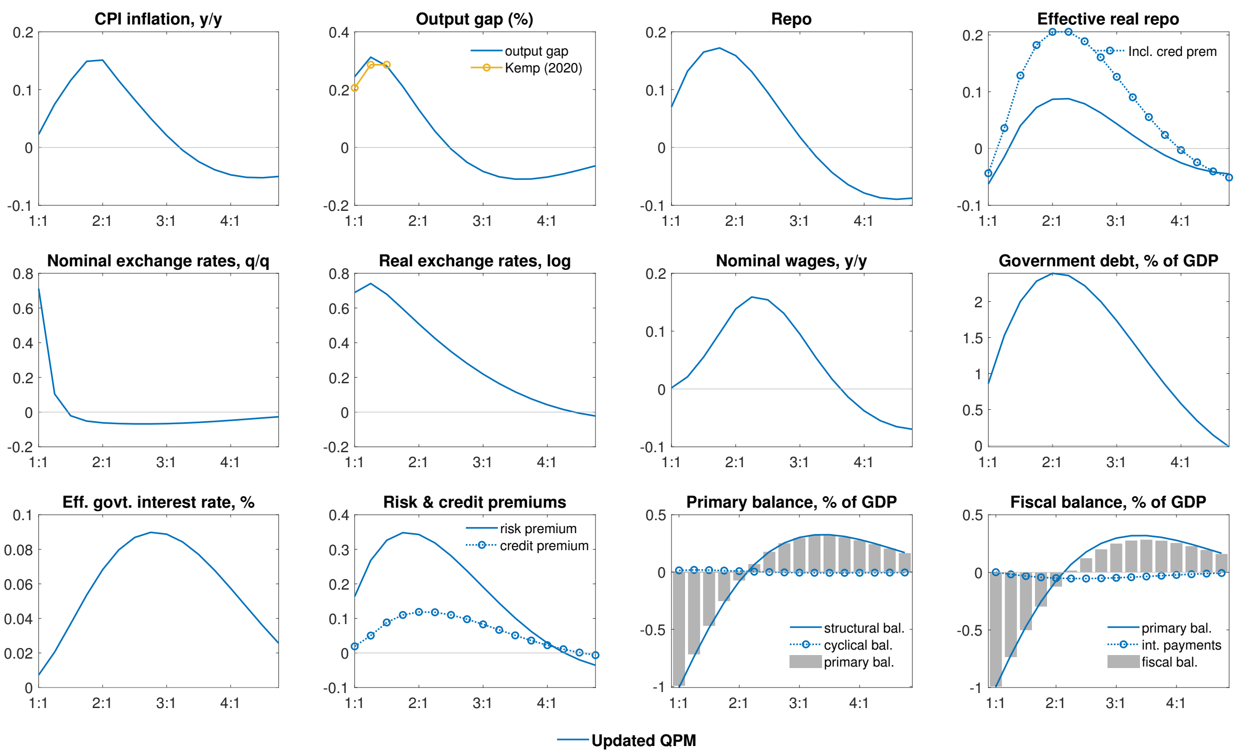
[40] Exchange rates in the QPM are defined as local currency units per unit of foreign currency (e.g. rand per dollar). A decline in the exchange rate therefore reflects an appreciation.

component of the primary balance to fall into deficit as automatic stabilisers reduce government revenue. In addition, falling inflation in conjunction with moderating activity translates into lower nominal GDP, which raises the government debt-to-GDP ratio through a denominator effect. Increased government interest payments – in part due to higher interest rates – contribute further to rising debt in the short run.[41] To stabilise debt, government is required to run a structural (primary) surplus for an extended period. Rising interest payments (reflected as a negative interest payment balance in Figure 16), amid higher interest rates and increased indebtedness, lead to an overall budget deficit during the initial quarters after the shock, before the primary surplus needed to stabilise debt begins to dominate.

A fiscal expansion

A shock to fiscal policy, via a 1-percentage-point fall in the structural primary balance, as a ratio of GDP, induces an expansion of economic activity that corresponds to short-term multiplier impacts observed by Kemp (2020). The negative fiscal balance results in an equivalent increase in the government debt-to-GDP ratio of 1 percentage point on impact. Greater indebtedness, in turn, leads to a higher risk premium and causes the exchange rate to depreciate – a 10-percentage-point rise in debt results in roughly a 1.7-percentage-point rise in the risk premium on impact. The expansionary impulse is short-lived, however, as rising debt necessitates fiscal tightening, which ultimately weighs on activity as fiscal deficits turn into surpluses.

Figure 17: Expansionary fiscal policy shock

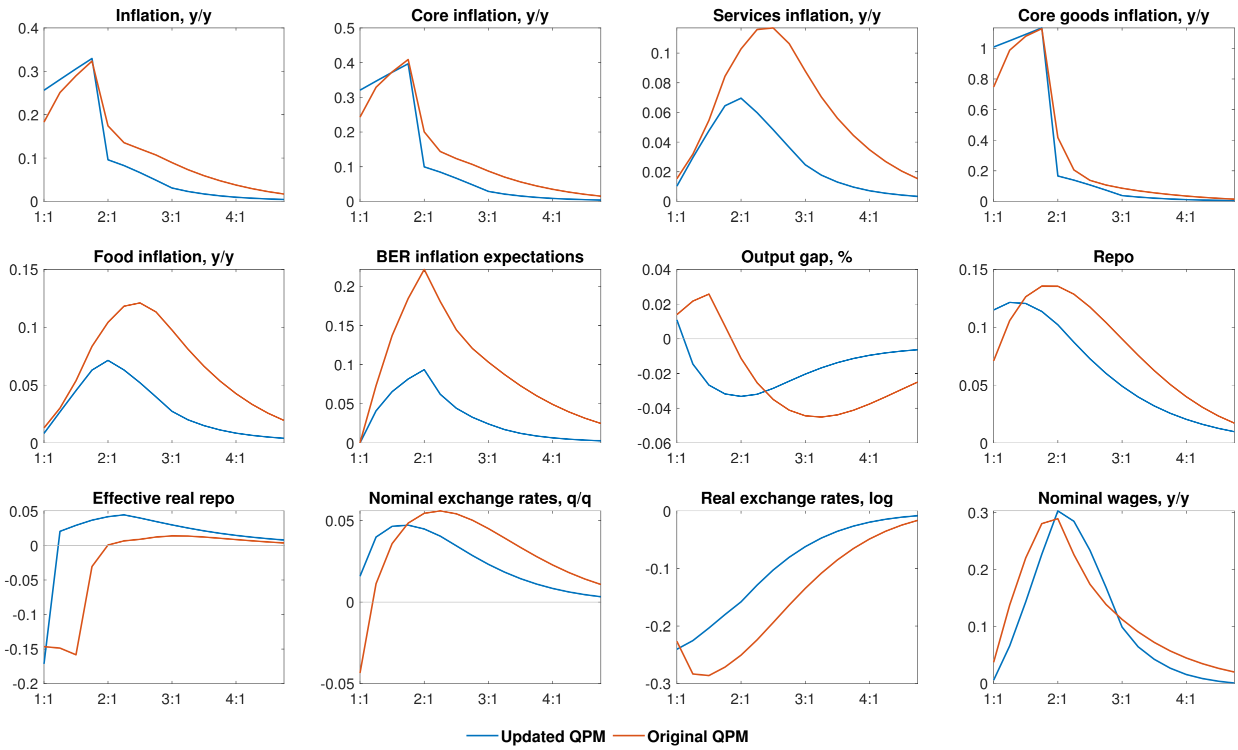


[41] The impulse response functions show a simplified representation of short-term effects and not necessarily the medium-term benefits of lower inflation for the fiscus.

Higher core inflation

A shock to core goods inflation that raises the year-on-year rate by around 1 percentage point on impact results in slightly softer peak responses, as well as less persistence, when compared to the original QPM (Figure 18). This is partly a result of better anchored inflation expectations in the updated model, but also a stronger real interest rate response. Monetary policy responds to rising inflation by raising the nominal interest rate accordingly to tighten real interest rates, in turn weighing on output and the exchange rate in order to help moderate the inflation pickup. Indexation to past inflation in the labour market causes wage inflation to rise almost in tandem with headline inflation.

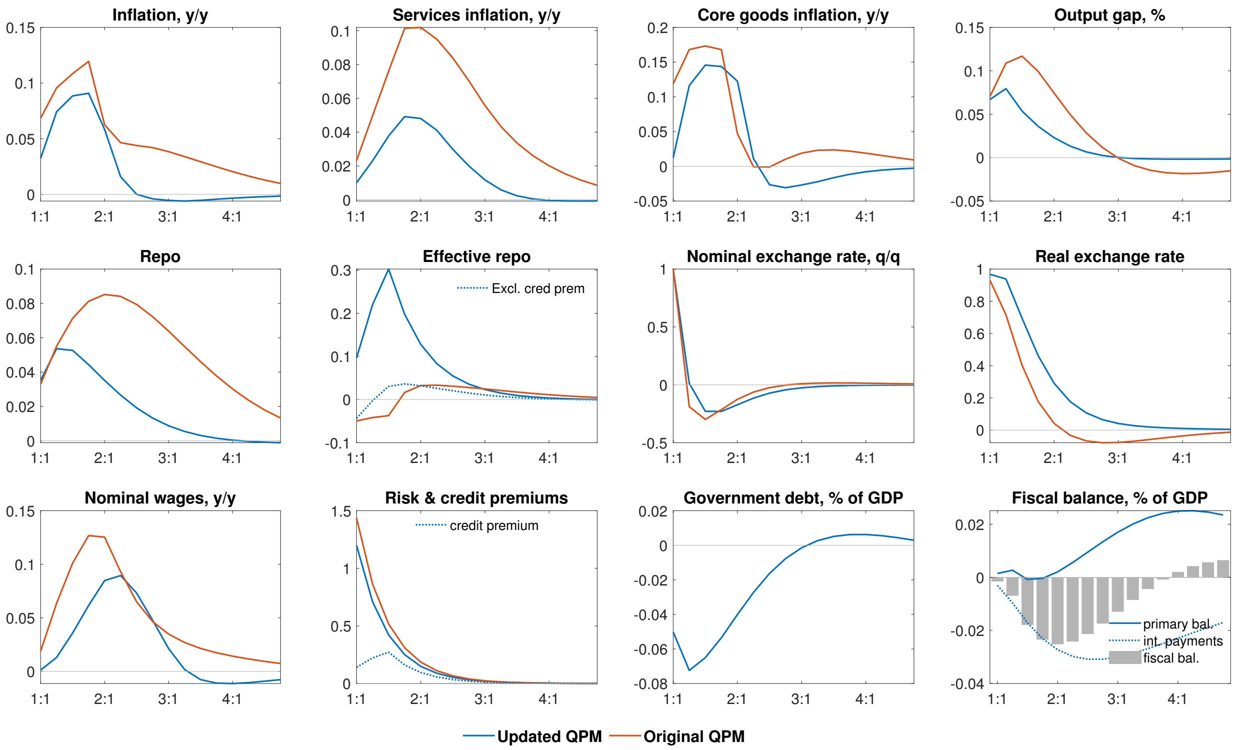
Figure 18: Core goods inflation shock



Exchange rate depreciation due to increased country risk

An exchange rate depreciation of 1 percent, fuelled by an increase in the country risk premium, raises inflation by nearly 0.1 percentage points – less than in the original QPM. A key difference in the updated model is the less-expansionary response of growth and the output gap, which increases initially as net exports benefit from the depreciated exchange rate. However, the output gap then turns negative, as tighter financial conditions eventually outweigh the boost from net exports. This dynamic in the updated model is due to the inclusion of a credit premium in the interest rate channel to account for the detrimental impact of tighter financial conditions on activity. The smaller output response, in turn, also generates less upward pressure on inflation than in the original QPM, leading to a softer interest rate response. On the fiscal front, an initial increase in nominal GDP causes government debt to fall slightly, but this is reversed by higher government interest payments that ultimately lift the debt ratio.

Figure 19: Risk-induced exchange rate shock



4.2 Model forecast evaluation

To determine whether the model's structural enhancements discussed in this paper contribute to its forecasting accuracy, in-sample forecasts for headline, core, and food inflation, along with quarter-on-quarter GDP growth, the nominal exchange rate and the repo rate are compared to those generated by the original QPM. Root mean squared errors (RMSEs) are calculated for one-, four-, eight- and 12-quarter-ahead forecasts over the sample from 2006Q1 to 2022Q4, and are expressed as a percentage share of those from the original QPM. A relative RMSE below 100 suggests that the updated model performs better than the original QPM, with a value of 80 for example implying that the updated model's forecast errors are 20 percent smaller.[42]

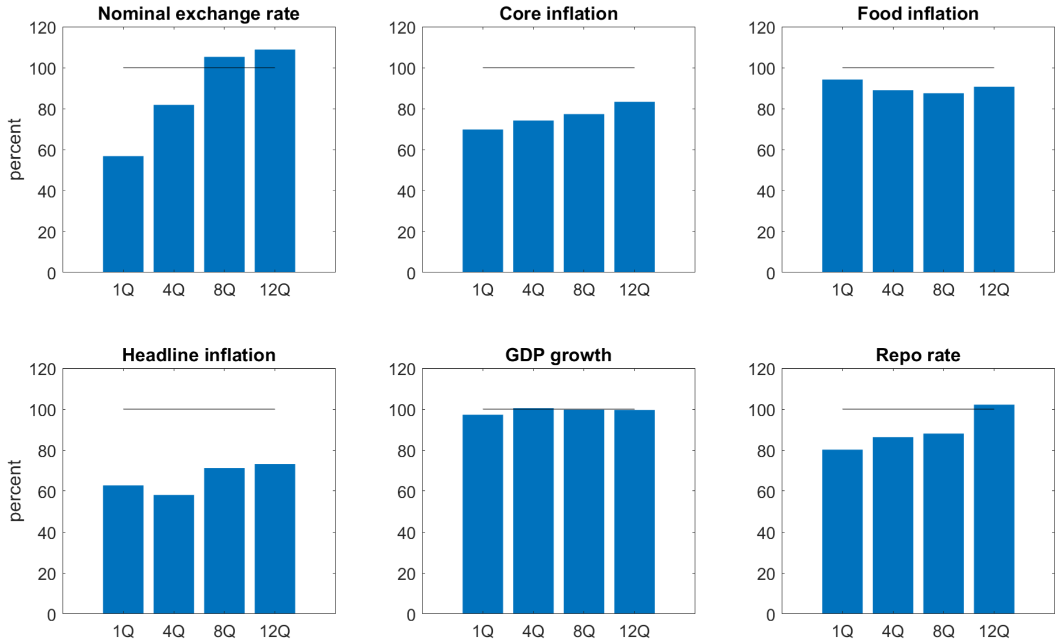
Overall, when comparing forecast errors, the updated model mostly outperforms the original model (see Figure 20). This is particularly true for headline inflation, core goods inflation, food inflation and the repo rate. Headline inflation forecasts are better at all the horizons. At the four-quarter-ahead horizon, headline inflation forecast errors in absolute terms are over one-third smaller than before, measuring 0.9 percentage points on average. Both food and core inflation forecasts are also better throughout.[43] Core inflation errors one year ahead are about four-fifths their previous size, measuring 0.6 percentage points on average. The improved

[42] The charts in Figure 20 show RMSEs produced by the updated model relative to the original QPM at different forecast horizons, i.e. $(RMSE^{updated}/RMSE^{original}) * 100$. A relative RMSE equal to 100 means that the size of forecast errors for a particular variable in two models at a given forecast horizon are the same, while a value below (above) 100 indicates smaller (larger) errors generated by the updated model.

[43] Electricity and fuel price inflation are not discussed, as these two components are generally treated as assumptions during the forecasting process. For fuel prices, the international oil price as well as the tax component are assumptions.

inflation forecasting performance of the updated model can be ascribed to the numerous enhancements to the model's price block.

Figure 20: Relative forecast errors: updated QPM vs original QPM



The nominal exchange rate forecasts produced by the updated QPM are better over the first half of the forecast horizon, possibly due to the more detailed modelling of country risk. Although GDP growth forecasts are not noticeably better over the medium term, they are slightly more accurate over the very near term. This improvement likely reflects the inclusion of the fiscal stance's impact on output in the updated model.

Repo rate forecasts in the updated model are better throughout, barring at the 12th-quarter-ahead horizon where they are broadly similar. This improvement is a result of more accurate inflation forecasts and, importantly, also the revised Taylor rule.

In all, the updated model – extended to account for fiscal policy's macroeconomic impacts along with enhancements to other aspects of the model – appears to encompass the characteristics of the South African economy in a more relevant way.

5. Conclusion

This paper documents enhancements to the SARB's QPM. Chief among these is a fiscal extension enabling the forecast to account for effects of fiscal policy and sovereign debt sustainability in a systematic manner — an aspect which was mostly accounted for by off-model analyses in the original QPM. In the extended model, discretionary changes in the budget balance — guided by countercyclical fiscal policy and debt stabilisation objectives — affect economic activity. In addition, vulnerabilities associated with government's indebtedness are reflected in both country risk and term premia, thereby affecting the exchange rate and sovereign yields.

Further changes include a distinction between the evolution of private and government wages along with a revised manner in which labour market price pressures affect CPI inflation, explicit mechanisms to strengthen indirect spillovers from fuel and electricity price changes onto core and food inflation, updated formation of inflation expectations to reflect improved anchoring at the target midpoint, a risk premium channel that accounts for changes in global investor sentiment, and a refined equilibrium UIP condition which determines the domestic neutral real interest rate.

Additionally, an updated version of the model's current Taylor rule is outlined. Enhancements to the rule include an inflation forecast horizon focusing on three quarters ahead and the inclusion of a growth gap — the deviation of GDP growth from potential growth — which points to the direction in which the output gap is to move over the forecast.

Comparing in-sample forecasts of the revised model to those of the original QPM, suggests that the various model enhancements generally deliver improved forecasts of the repo rate, as well as core and headline inflation. The accuracy of GDP growth forecasts is relatively unchanged.

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Appendix

1 Model steady-state values

Table 1: Model steady-state values

Variable	Value (%)
Debt-to-GDP ratio	50
Trend growth of potential output	2,5
Trend growth of employment	0,4
Inflation	4,50
Neutral real interest rate	2,5
Trend change in real exchange rate	0
Equilibrium risk premium	2
Effective rate on government debt	7,15
Term premium	1,5
Trend growth of foreign potential output	3,2
Foreign inflation	2
Foreign neutral real interest rate	0,5
VIX	19,97

Note. All model steady state values are calibrated.

2 Elasticity of cyclical budget balance to output

2.1 Methodology and data

To determine the elasticity of the cyclical budget balance with respect to output, the OECD methodology as formulated in Van den Noord (2000) is followed. Given the characteristics of South Africa's budget balance, the following budget items are considered to fluctuate with the business cycle: personal income tax, corporate income tax and indirect tax/value-added tax (VAT). Estimating elasticities of these tax categories with respect to output, the cyclical component of the budget balance is calculated as:

$$bal_t^{cycl} = \frac{1}{Y}\sum_i T_i\left[1-\left(\frac{Y^*}{Y}\right)^{\alpha_i-1}\right] - \frac{G}{Y}\left[1-\left(\frac{Y^*}{Y}\right)^{-1}\right] + \frac{X}{Y}\left[1-\left(\frac{Y^*}{Y}\right)^{-1}\right] \tag{26}$$

where T_i is actual tax revenues for the i^{th} category of tax, Y is level of actual GDP, Y^* is level of potential output, G is actual government expenditures excluding capital and interest spending, X is non-tax revenues minus interest on public debt minus net capital outlays and α_i are estimated elasticities of the tax categories considered.

2.2 Commodities and the output gap

Amra, Hanusch and Jooste (2019) emphasise the importance of accounting for international commodity prices when estimating cyclically adjusted budget balances for commodity-exporting economies. In presenting evidence for South Africa, they argue that exclusion of international commodity prices risks generating procyclical fiscal policy stances during periods of commodity super cycles. This occurs when positive transitory shocks associated with temporarily elevated commodity prices are mistakenly viewed by policymakers as shocks to potential GDP

— as opposed to being cyclical — resulting in overestimation of potential output and increased government expenditures.

As a result, we estimate a 'non-commodity' measure of the output gap by controlling for the international commodity price gap, ICP_t^{gap}:

$$OG_t = (\beta_0 + \beta_1 ICP_t^{gap}) + \varepsilon_t \tag{27}$$

or

$$OG_t^{nc} = OG_t - (\beta_0 + \beta_1 ICP_t^{gap}), \tag{28}$$

where OG_t is the standard output gap estimate, and OG_t^{nc} is the 'non-commodity' measure. OLS estimation suggests that international commodity prices have a significant and positive effect on the output gap estimate (see Table 2).

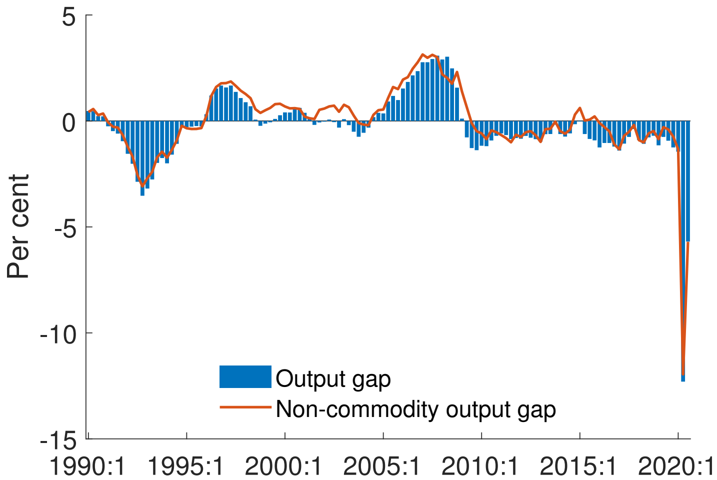
Table 2: Estimated effect of international commodity prices on the output gap.

	Constant	ICP^{gap}	Nobs
OG_t	-0.33**	0.03**	123
	(0.15)	(0.01)	

Note: The sample is 1990Q1-2020Q3. Standard errors in parentheses, *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Figures 21 and 22 indicate the non-trivial effect that accounting for international commodity prices has on the output gap and potential output. In the latter figure, the standard measure of potential output in the post-GFC period consistently exceeds its counterpart that accounts for international commodity price movements.

Figure 21: Standard and 'non-commodity' output gap measures



2.3 The primary budget balance decomposition

Our estimates of tax elasticities are broadly in line with the results in Van den Noord (2000). The corporate income tax elasticity is 1.43 (1.59 when international commodity prices are

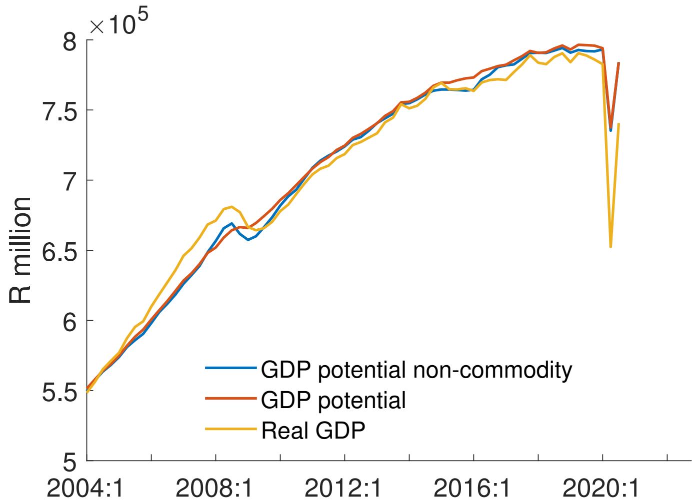


Figure 22: Real GDP and alternative potential level of output estimates

controlled for) with the average value for countries in the Van den Noord (2000) sample around 1.3 (the highest value of 2.1 is found for Japan). The elasticity of personal income tax revenues is 0.52 (0.30 when taking account of when international commodity prices) while the average value in Van den Noord (2000) is 1.0 (the lowest value of 0.4 is estimated for Japan). The elasticity of VAT revenues is estimated at 1.31 (1.27), compared to an average value for other countries of 1.0, with an elasticity of 1.3 for Germany and Belgium.

Table 3: Elasticities of budget balance components

	Tax elasticities	% of revenues
Personal income tax	0.30	30-54
Corporate income tax	1.59	14-33
VAT	1.27	22-32

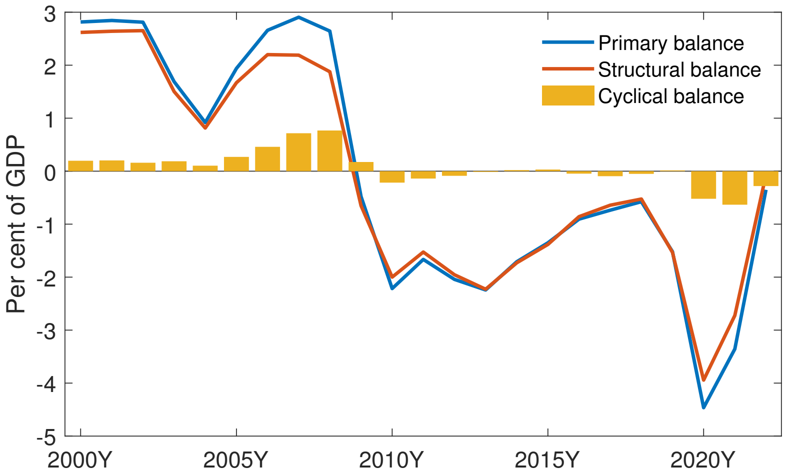
Using results from Table 3, the weighted elasticities series WE_t is calculated, which in its turn is used to evaluate the semi-elasticity measure p_1 that shows a change in budget deficit as a percentage of output for a 1% change in GDP:

$$\text{Semi-elasticity}_t = \frac{Exp_t}{GDP_t} - (1 - WE_t) * \frac{Rev_t}{GDP_t}, \tag{29}$$

that has a mean value over 2010Q1–2020Q3 of 0.24. This latter value is the elasticity of the model's cyclical primary balance to the output gap. The resulting disaggregation of the primary balance into its cyclical and structural components is shown in Figure 23.[44]

[44] Challenges faced in identifying the output gap in real time are likely to affect cyclical budget balance estimates in a similar manner.

Figure 23: Primary budget balance components



3 Real exchange rate equilibrium satellite model

The real exchange rate equilibrium level, rer_t^{eq}, is identified outside the QPM via a satellite model. It is observed (with measurement error $\xi_t^{rer,eq}$) from the updated vector error-correction model (VECM) specification of De Jager (2012), and modeled as a random walk with time-varying drift, $g_t^{rer,eq}$, as follows:

$$rer_t^{eq} = rer_{t-1}^{eq} + g_t^{rer,eq} + \varepsilon_t^{rer,eq} \tag{30}$$

$$rer_t^{eq,VECM} = rer_t^{eq} + \xi_t^{rer,eq}, \tag{31}$$

where $g_t^{rer,eq}$ captures the underlying real exchange rate trend:

$$g_t^{rer,eq} = 0.95 g_{t-1}^{rer,eq} + \varepsilon_t^g. \tag{32}$$

The deviation of the real exchange rate from its equilibrium level (real exchange rate gap), rer_t^{gap}, is further informed by the gap between South Africa's real commodity price index and its equilibrium level:

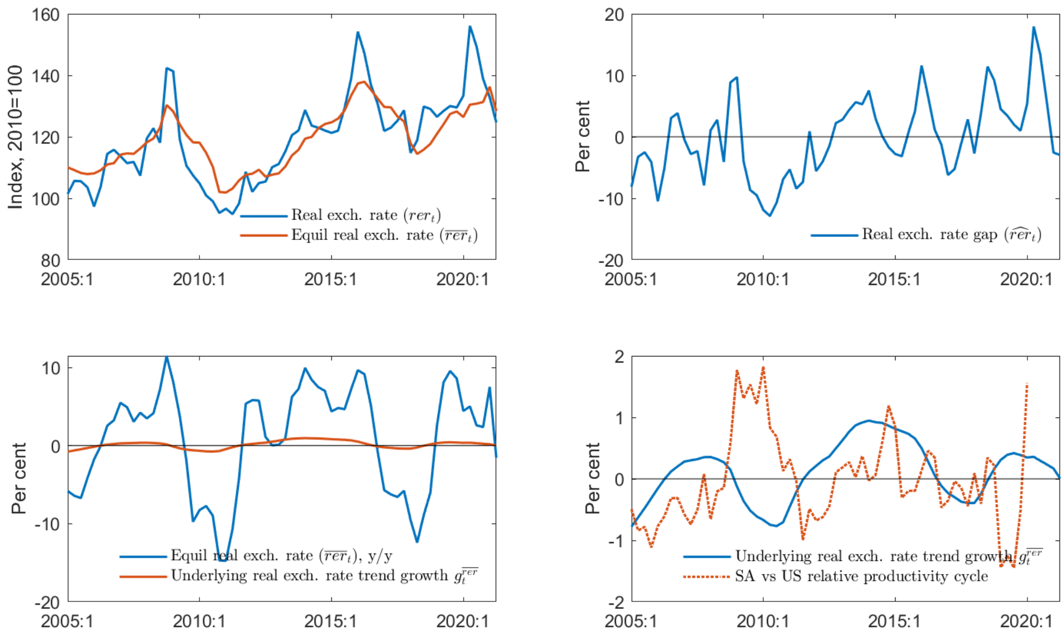
$$rer_t^{gap} = 0.91 rer_{t-1}^{gap} + 0.13 comm_t^{gap} + \varepsilon_t^{rer,gap}. \tag{33}$$

Both the real exchange rate equilibrium, rer_t^{eq}, and the underlying trend growth rate, $g_t^{rer,eq}$, from the satellite model above are observed in the QPM. Incidentally, when fluctuations in relative productivity relative to the United States are considered in Figure 24, the underlying trend growth rate appears to broadly support the Balassa-Samuelson hypothesis, i.e. that periods of relative improvement (deterioration) in productivity drive real exchange rate appreciation (depreciation).[45,46]

[45] Fluctuations in relative productivity reflect deviations from the Hodrick-Prescott trend of South Africa's GDP per worker relative to that of the United States.

[46] The 2013–2016 period is an exception, as falling international commodity prices likely dominated real exchange rate trend growth.

Figure 24: Real exchange rate equilibrium and underlying trend



4 Unit labour costs as a driver of inflation

Following evidence from a BVAR model which suggests that the nominal unit labour cost (ULC) growth is important in explaining inflation outcomes, both nominal ULC growth and the real ULC gap are used in the model as drivers of inflation. The nominal ULC growth is calibrated to explain two thirds of the dynamics from the labour market while the real ULC gap explains one third. The use of both these measures appear to improve forecast accuracy, with forecasts generated from using the combination of nominal ULC growth and real ULC gap being better than those generated using any of the two, individually.

Figure 25: Inflation forecast accuracy