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# Fiscal policy and commodity price shocks in South Africa

Tumisang Loate<sup>1</sup> and Vincent Dadam<sup>2</sup>

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**Abstract:** This paper investigates the effect of commodity price shocks in a commodity-exporting small open economy, and the role of fiscal policy in transmitting these shocks to the rest of the economy. Using South African data, we first estimate an empirical model using a Bayesian vector autoregression model. We then develop a New Keynesian small open economy with labour market hysteresis and commodity price shocks. We find that a commodity price shock typically has an expansionary effect as real GDP and employment increase, which translates into higher tax revenue. The results from our dynamic stochastic general equilibrium model match the data. In addition, despite not modelling the tradable and non-tradable sectors explicitly, we find that there is an opportunity cost associated with taxing the commodity sector more than home production. This results in a higher trade deficit and government spending. Consequently, we also explore the role of countercyclical fiscal policy during a commodity boom.

**Key words:** fiscal policy, hysteresis, commodity price shock

**JEL classification:** E24, E32, E62, O47

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# 1 Introduction

Global shocks have implications for fiscal policy in commodity-dependent small open economies (SOEs). The negative effect of adverse global shocks on commodity exporters' tax revenue affects the financial resources available to governments in these countries to use for stimulating growth, redistribution, and development (Richaud et al. 2019). This further affects the country's borrowing requirements and costs. Thus, maintaining fiscal space through fiscal discipline is important in determining how fiscal policy can insulate a country from external shocks.

The economic performance of the South African economy is intertwined with the commodity cycle.<sup>1</sup> Commodity exports account for 18% and 64% of the country's gross domestic product (GDP) and total exports for the 2019–21 period, respectively (UNCTAD 2023: 224). Figure 1 shows the year-on-year percentage growth of commodity prices and GDP for the 2000Q1 to 2019Q4 period, while Table 1 shows the correlations of selected macroeconomic and fiscal policy variables with commodity prices and GDP for the same period. It is evident from Figure 1 that there is a positive co-movement between the two variables, especially during the commodity boom of 2001–08 and the 2008–09 global financial crisis. The observation from Figure 1 is supported by the correlations in Table 1, which indicate a positive (negative) correlation between commodity prices and real GDP growth (unemployment). Furthermore, we see in Table 1 that periods of high commodity prices are associated with higher tax revenue driven by higher corporate income tax revenue, a feature of the South African economy that was also present during the commodity boom in the 2021 and 2022 period, as documented by Allison et al. (2023) and van Rensburg and Visser (2022). There is a negative co-movement between government spending and commodity prices during the full sample. However, when we only look at the correlation during the commodity boom, we see that there is a positive, though weak, relationship. Periods of positive economic growth are also associated with an increase in government spending, indicating some mild pro-cyclicality of spending.

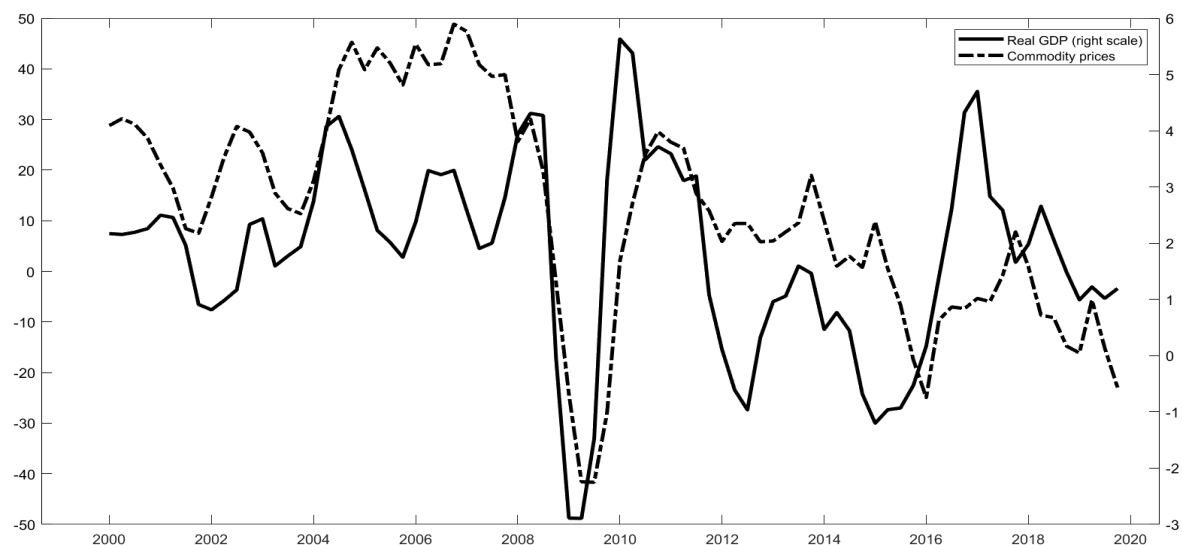
In this paper, we investigate the effect of commodity price shocks on the key South African macroeconomic variables and how fiscal policy affects the response of these variables. We employ both empirical and theoretical approaches to answer the question. For the empirical analysis, we study the effect of external shocks, proxied by a commodity shock, on our macroeconomic variables of interest using a Bayesian structural vector autoregression model (B-SVAR). We then proceed with a theoretical model to understand the transmission mechanisms of the commodity shocks to the economy. We develop an SOE new-Keynesian (NK) dynamic stochastic general equilibrium (DSGE) model that closely matches the empirical re-

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<sup>1</sup> See Makgetla (2021) for the historical background on the significance of the mining sector to the South African economy.

sults of our macroeconomic variables, especially unemployment, tax revenue, and government spending.

**Figure 1: Commodity prices and GDP growth**



Source: authors' calculations based on data from the International Monetary Fund (IMF) and South African Reserve Bank (SARB).

**Table 1: Correlations with commodities and GDP**

	Full sample		2000–07
	Commodity prices	Real GDP	Commodity prices
Commodity prices	1	0.50	1
Real GDP	0.50	1	0.52
Employment (private)	0.28	0.66	0.44
Unemployment rate	−0.12	−0.50	−0.46
Government spending	−0.09	0.14	0.13
Tax revenue	0.41	0.59	0.33
Personal income tax	0.07	0.20	0.38
Value-added tax (VAT)	0.11	0.45	0.00
Corporate income tax	0.37	0.44	0.38

Note: variables are expressed as year-on-year percentage changes.

Source: authors' calculations based on data from the IMF and SARB.

The empirical and theoretical approach in this paper closely follows Naraidoo and Paez-Farrell (2023). However, our study differs from this paper in the following ways. First, we incorporate fiscal policy in our models. As discussed above, fluctuations in commodity prices have a severe impact on government revenue. Since fiscal policy can be affected by commodity shocks and also respond to domestic economic conditions, it can act as a transmission mechanism of global shocks by either insulating or amplifying the effect of these shocks on the local business cycle, as documented by Pieschacón (2012). Second, we do not use a search

matching DSGE model, but follow closely the real business cycle framework of Galí and Monacelli (2005), which accounts for nominal rigidities. We model the labour market using hysteresis. This approach follows empirical evidence by Viegi and Dadam (2023) of hysteresis in the South African labour market. The paper uses a mathematical framework to uncover the hysteresis phenomenon as an explanation for the structural nature of unemployment in South Africa and finds that unemployment presents the typical features of strong hysteresis; namely remanence (large shocks take a while to be absorbed) and selective memory (not all shocks have a persistent response). The authors find evidence of hysteresis in unemployment associated with the 2008 global financial crisis. They also note a sharp increase in hysteresis in 2014, which they attribute to the winding down of countercyclical fiscal policy amid the increase in government debt and a stagnating economy.

The empirical results indicate that a commodity price boom has an expansionary effect on the economy in the short term. Real GDP increases, resulting in an increase in tax revenue. Our measure of unemployment—hysteresis—decreases, though the results are insignificant. However, we find that the shock has a significant effect on employment in the private sector. The results of the DSGE model corroborate the empirical findings of the BVAR model and are in line with similar studies on this topic. We find that an increase in commodity prices has an expansionary effect on the economy: output, hours worked, and wages increase; the real effective exchange rate appreciates; and unemployment decreases. It is important to note regarding unemployment, however, that the persistence in the response is proportional to the magnitude of the hysteresis prevailing in the labour market. We also find that high persistence in unemployment is often associated with a correspondingly higher degree of hysteresis. On the fiscal side, the commodity price shock creates further fiscal space as the revenue collected from the commodity sector increases, which in turn translates into a reduction in overall government debt. Furthermore, we find that when we reduced the tax on the commodity sector lower than the tax on home production, this results in a more productive and competitive commodity sector supported by a lesser appreciation of the currency overall. This comes at the expense of home production, which highlights the opportunity cost associated with varying levels of taxation between home and commodity production. Finally, we explore the role of fiscal policy during a commodity boom. We show that when we restrict the response of government spending during a boom, the effect of commodity prices on the local economy is less inflationary. The unexpected tax windfall can be spent on reducing government debt, and thus creating fiscal space to cushion the economy when the boom winds down or to support industries that are negatively affected by the boom. This finding asserts the macroeconomic benefits of countercyclical fiscal policy.

This paper is related to the literature on the transmission of foreign shocks to SOE commodity exporters, such as Houssa et al. (2023), Naraidoo and Paez-Farrell (2023), Pieschacón (2012), Richaud et al. (2019), Bodenstein et al. (2018), and Fernández et al. (2017), among

others. In this literature, commodities are either the source of the shock or an important transmission channel of other foreign shocks. Richaud et al. (2019) find a higher positive relationship between commodity price volatility and output growth, consumption, investment, and government revenue in commodity-exporting emerging markets and developing countries (EMDEs) relative to developed countries. Houssa et al. (2023) investigate the spillover of foreign shocks to SOEs, using South Africa and Canada as proxies for SOEs. Using a BVAR model, with sign restrictions to identify a global demand shock, the authors find a contractionary effect of this shock on consumption, output, investment, employment, and commodity supply. They argue that commodity prices and demand play a significant role in explaining this spillover, together with the financial channel. Naraidoo and Paez-Farrell (2023) study a panel of commodity exporters, including South Africa. They find that an increase in export commodity prices increases output and reduces unemployment.

Another strand of the literature on commodity prices looks at the implications of the cyclicity of fiscal policy in commodity exporters relative to non-commodity exporters. Marioli and Vegh (2023) show that pro-cyclical fiscal policy, spending windfalls from the commodity booms—and vice versa—amplifies the effect of commodity shocks once the boom comes to an end. The results echo work by Cuddington (1989) and Pieschacón (2012), which shows that fiscal discipline during commodity booms helps to mitigate the need to borrow and cut spending or raise taxes when the windfall wanes, thus amplifying the initial negative commodity shocks on the business cycle.

The remainder of this paper is structured as follows. Section 2 looks at the empirical evidence of commodity shocks on the South African economy. The DSGE model is presented in Section 3; we further analyse the effect of fiscal policy in propagating commodity price shocks to the rest of the economy in this section. Section 4 concludes the paper.

## **2 Empirical evidence**

We employ a Bayesian structural vector autoregression model (B-SVAR) by Giannone et al. (2015) for our empirical analysis. We use secondary quarterly data available from the South African Reserve Bank (SARB) and St Louis Federal Reserve Economic Data (FRED), and commodity prices from the International Monetary Fund (IMF). As a starting point, we use the same variables as Naraidoo and Paez-Farrell (2023). These include unemployment, real GDP, the real exchange rate, the commodity price index for South Africa, the trade balance (as a percentage of GDP), the consumer price index, and the policy rate. This allows for ease of comparison with their results as they look at South Africa. Variables such as output, the trade balance, and the exchange rate are commonly included in the literature on the effects of global shocks on SOEs, such as in Houssa et al. (2023), Schmitt-Grohé and Uribe (2018), and Fer-

nández et al. (2017). Given the importance of fiscal variables for our analysis, we also include non-interest government expenditure and tax revenue, as in Pieschacón (2012), and yields on long-term bonds. We also look at the primary balance as an alternative measure of fiscal policy stance, instead of its sub-components. Since we model our labour market in our DSGE model according to Vieggi and Dadam (2023), we also use the hysteresis data by Vieggi and Dadam (2023) as an alternative measure for unemployment in South Africa. Since this variable is not significant, we use employment in the private sector in our benchmark results. The description of the data is provided in Table A1. The sample period under study is 2000Q1 to 2019Q4.

We estimate the following BVAR model:

$$Y_t = c + A(L)Y_{t-1} + D(L)d_{t-1} + \mu_t \quad (1)$$

$$d_t = \frac{1 + i_t}{(1 + \pi_t)(1 + \Delta y_t)} d_{t-1} + pd_t \quad (2)$$

$$pd_t = t - g \quad (3)$$

where  $Y_t$  is a vector of our endogenous variables,  $c$  is a vector of constant parameters, and  $\mu_t$  is the residual, which is normally distributed.  $A(L)$  and  $D(L)$  are the coefficient matrices of the lag polynomials. Favero and Giavazzi (2007) and Caruso et al. (2019) argue for the inclusion of the evolution of government debt in the fiscal VARs to ensure consistency of the empirical VAR model with the DSGE models that impose the government budget constraint. Thus, the government debt-to-GDP ratio ( $d_t$ ) is included in the BVAR model as an exogenous variables, where  $i_t$ ,  $\pi_t$ , and  $\Delta y_t$  are the long-term interest rate, proxied by the yields on government bonds with over ten-year maturity, year-on-year inflation, and year-on-year real GDP growth.  $pd_t$  is the government deficit (as a ratio of GDP) where the deficit is defined as tax revenue ( $t$ ) less non-interest government expenditure ( $g$ ).

Identification of the external shocks is straightforward for an SOE. Since South Africa is a price-taker in the commodities market, commodity prices can be treated as exogenous in the model. To achieve this identification, we order commodity prices first in  $Y_t$  and set to zero the elements in the first rows of the  $A(L)$  matrix which do not correspond to own lag for commodity prices. This identification makes commodity prices an exogenous autoregressive process of order  $p$ , as in Pieschacón (2012) and Naraidoo and Paez-Farrell (2023) or Schmitt-Grohé and Uribe (2018) for the terms of trade shock. Similar to these papers, all elements in the first rows of the  $D(L)$  matrix are set to zero. Since we are only interested in identifying the commodity price shock, the ordering of the remaining variables is not required (Pieschacón 2012).

A summary of the BVAR model is discussed in Appendix A2. For a detailed discussion of the model, see Giannone et al. (2015). The model is estimated with variables in their annual growth



rates, with the exception of variables already expressed as percentages. Government debt and the deficit are reconstructed using their respective components, as defined in Equations 2 and 3, respectively.

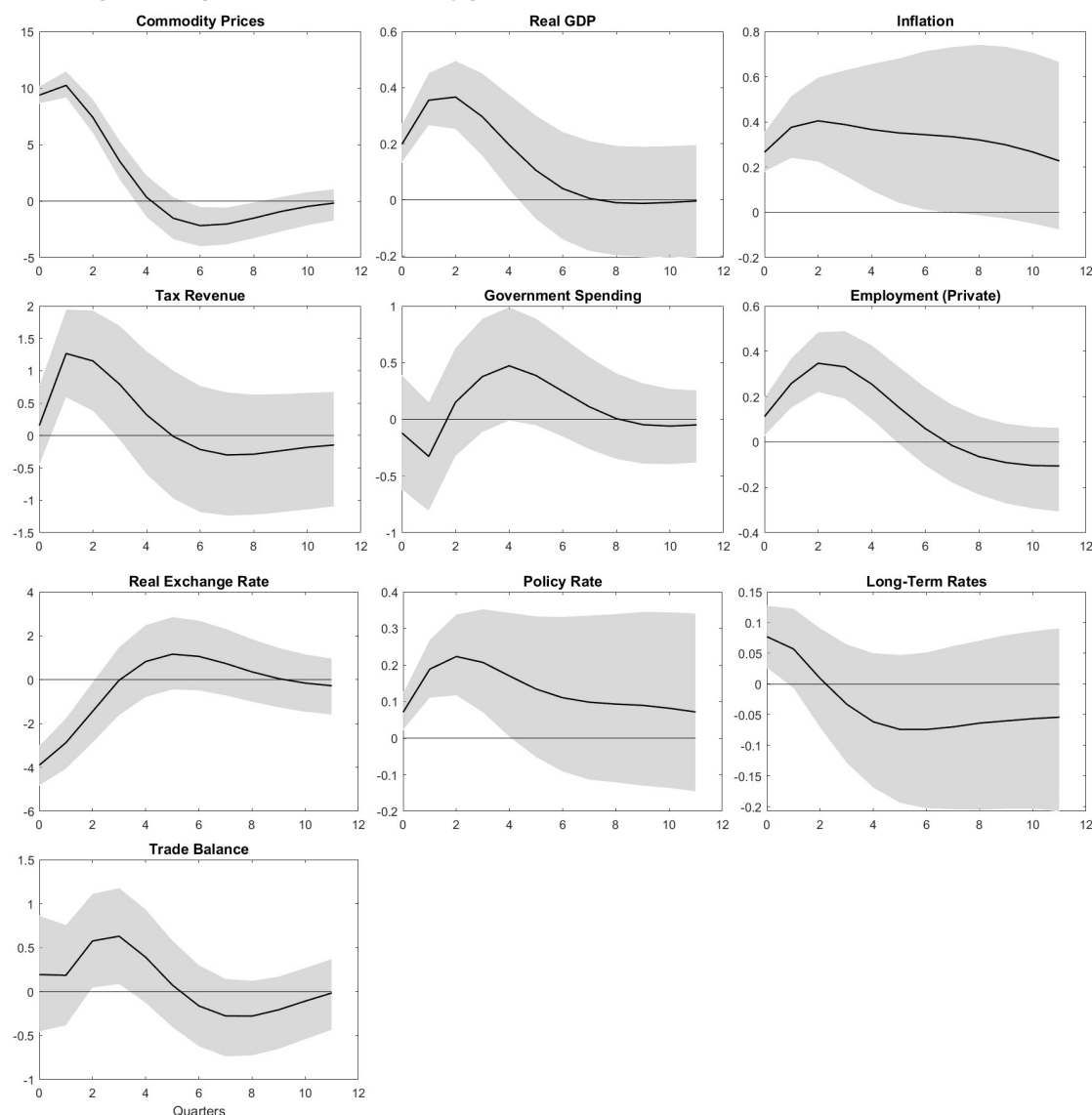
## **2.1 Bayesian vector autoregression results**

## **2.2 Benchmark results**

The results for the commodity price shock are presented in Figure 2. The results show that a one standard deviation increase in commodity prices increases commodity prices by almost 10%. The shock has an expansionary effect on the economy in the short term. Real GDP increases result in an increase in tax revenue. The local currency appreciates. Despite the appreciation of the local currency, net exports increase. Inflation increases, and the central bank responds by increasing interest rates. Employment increases on impact and this effect remains positive and significant for the first five quarters. Overall, the results are consistent with those of Naraidoo and Paez-Farrell (2023), who also find that output, inflation, and interest rates increase after a positive commodity shock. Even in Naraidoo and Paez-Farrell (2023) and Houssa et al. (2023), the results are short-lived.

Lastly, we look at the fiscal variables. Non-interest government spending decreases on impact before temporarily increasing. However, this expansionary effect is short-lived, lasting only for the first five quarters, and is not significant. Tax revenues increase in the first few quarters due to higher revenue from the commodity sector. The yield on long-term bonds increases on impact, which can be due to reduced demand for bonds following the increase in short-term rates. While the yield on long-term bonds does decline after two quarters, this response is not significant. We re-estimate the model using the primary balance instead of its sub-components. Furthermore, we use hysteresis as our measure of unemployment and productivity in the private sector, proxied by productivity in the manufacturing sector. The results are presented in Figure 3. Since the response of other variables remains the same as in the benchmark results, we only show the response of the three variable changes. From the results, we can see that the primary balance improves after a positive commodity price shock, indicating that the increase in tax revenue outpaces the increase in government spending. Similar results are obtained when using the budget balance, though this variable is not significant across all quarters. The effect of the commodity price shock on unemployment is insignificant. However, qualitatively, the results indicate that a positive commodity shock reduces unemployment. Lastly, productivity increases after a positive commodity price shock.

**Figure 2: Impulse responses to a commodity price shock**



Note: the figure shows the response to a one standard deviation shock. The solid line is the median response; the dashed lines are the 68% credible intervals.

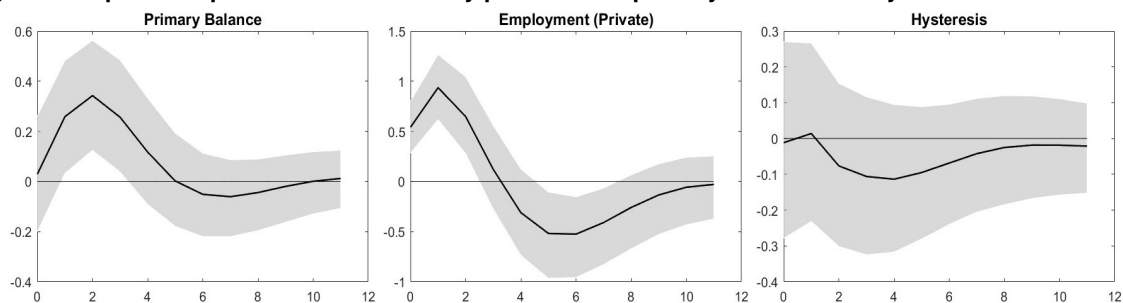
Source: authors' compilation.

Though not significant, the results for unemployment are qualitatively similar to Viegi and Dadam (2023) and Naraidoo and Paez-Farrell (2023) for South Africa, with both papers finding significant results. While not directly looking at commodity shocks, Viegi and Dadam (2023) find that a demand shock reduces unemployment, as measured by hysteresis. Similarly, Naraidoo and Paez-Farrell (2023) find that the unemployment rate decreases after a positive commodity price shock. In their analysis of global shocks to SOEs, Houssa et al. (2023) find that employment for South Africa decreases after a negative global demand shock.

The increase in government spending, while not significant, is consistent with the results by Céspedes and Velasco (2014), and indicates fiscal policy pro-cyclicality for South Africa after a commodity price boom. However, our results for the budget and primary balance are in con-

trast to the results of Céspedes and Velasco (2014), who find that the fiscal balance for South Africa either remains unchanged or deteriorates following a shock to the commodity price index and the cyclical component of the commodity price, respectively. This difference in results could be due to sample size as the study by the authors only covers the period up to the 2008 global financial crisis.

**Figure 3: Impulse responses to a commodity price shock: primary balance and hysteresis**



Note: the figure shows the response to a one standard deviation shock. The solid line is the median response; the dashed lines are the 68% credible intervals.

Source: authors' compilation.

## 2.3 Robustness checks

We run several robustness checks. First, we run the model controlling for the global financial conditions given the importance of these shocks in explaining business cycle fluctuations in emerging markets, as documented by Akıncı (2013) and Houssa et al. (2023). Both papers include South Africa in their analysis. For global financial shocks, we follow Akıncı (2013) and use the Baa spread, measured as Moody's seasoned Baa corporate bond yield minus the federal funds rate, and available from the St Louis FRED. The Baa spread is included as an exogenous variable in the model, in addition to government debt. As a second robustness check, we run the model with the variables in log-levels, except for those already in percentages. All variables are then quadratically detrended. The results are presented in Figure A1 in the Appendix and include the benchmark results for ease of comparison. Overall, the results are qualitatively similar to the benchmark results. The response for commodity prices when we control for the Baa spread is quantitatively the same as in the benchmark model, whereas it is slightly smaller and more persistent for the quadratically detrended model. The noticeable effect of controlling for the Baa spread is less response for inflation and therefore the policy rate. For the quadratically detrended model, the trade balance increases on impact and thereafter decreases, deviating from the response of the other two models.

### 3 A model with hysteresis and commodity price shocks

In order to understand the mechanisms of transmission of commodity price shocks to the economy, we develop an SOE NK model that closely matches the empirical results for macroeconomic variables, especially unemployment, tax revenue, and government spending. The model is calibrated using South African data and simulated. Our DSGE model is based on previous studies by Naraidoo and Paez-Farrell (2023), who develop an SOE NK model. However, we do not use a search and matching DSGE model, but follow closely the framework of Galí and Monacelli (2005), which accounts for nominal rigidities. We further enhance it by the following. First, we include a fiscal sector similar to Pieschacón (2012). As already established above, the commodity sector is not only important for the business cycle in South Africa, but also for tax revenue. Second, we model the labour market by accounting for hysteresis as evident from Viegi and Dadam (2023), who use a mathematical framework to uncover the phenomenon of hysteresis as an explanation for the structural nature of unemployment in South Africa. This motivates us to use the DSGE model with hysteresis in this investigation, first introduced by Galí (2022).

With this model, we explore the important channels through which commodity shocks affect unemployment, fiscal, and additional macroeconomic variables.

#### 3.1 Households

We assume that the SOE is populated by a large number of identical households, each consisting of a continuum of family members. The representative household seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, h_t) \quad (4)$$

in which  $c_t$  is consumption bundle and  $h_t$  denotes total employment or hours worked. The composite index of consumption is defined as

$$c_t = \left[ (1 - \gamma)^{\frac{1}{\eta}} c_{H,t}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} c_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \quad (5)$$

where  $c_{H,t}$  and  $c_{F,t}$  denote consumption of domestic and foreign final goods, respectively. The representative household faces an intratemporal optimization problem in the form of the allocation of consumption expenditure between domestic and foreign final goods. This problem is set up according to

$$\max \left[ (1 - \gamma)^{\frac{1}{\eta}} c_{H,t}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} c_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

$$\text{s.t. } P_{H,t}C_{H,t} + P_{F,t}C_{F,t} = Z_t$$

in which  $P_{H,t}$  denotes the price of the domestic good in local currency,  $P_{F,t}$  is the price of the foreign good expressed in local currency, and  $Z_t$  represents the consumption expenditure. The price of the foreign good coincidentally is the foreign CPI. This is because we are dealing with an SOE with domestic changes that cannot significantly affect the rest of the world. Therefore, we may write:

$$P_{F,t} = e_t p_t^* \quad (6)$$

with  $p_t^*$  the foreign CPI and  $e_t$  the nominal exchange rate. The optimization problem yields the following first-order conditions:

$$c_{F,t} = \gamma \left( \frac{P_{F,t}}{p_t} \right)^{-\eta} c_t$$

$$c_{H,t} = (1 - \gamma) \left( \frac{P_{H,t}}{p_t} \right)^{-\eta} c_t$$

in which  $p_t = \left[ (1 - \gamma)^{\frac{1}{\eta}} P_{H,t}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} P_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$  denotes domestic CPI. We may also write  $p_{H,t} = \frac{P_{H,t}}{p_t}$ . This allows us to interpret  $p_t$  as the real exchange rate  $s_t$ :

$$s_t = \frac{P_{F,t}}{p_t}$$

which can also be written as

$$s_t = e_t \frac{p_t^*}{p_t} \quad (7)$$

Assume that  $\pi_t^* = \frac{p_t^*}{p_{t-1}^*}$  and  $\pi_t = \frac{p_t}{p_{t-1}}$  denote, respectively, foreign and home inflation.  $\Delta e_t = \frac{e_t}{e_{t-1}}$  is the nominal depreciation rate of the domestic currency. We assume that the foreign CPI is constant over time and therefore  $\pi_t^* = 1$ . We introduce the terms of trade variable to the model as follows:

$$tot_t = \frac{s_t}{p_{H,t}}$$

We now move on to the intertemporal utility maximization problem. Throughout its lifetime, the representative household optimizes its allocation between consumption and labour while facing a budget constraint and the law of motion of capital. The problem to be solved is set up as follows:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{1 - \sigma} \left( c_t - \kappa_L \frac{h_t^{1+\varphi}}{1 + \varphi} \right)^{1 - \sigma}$$

$$\begin{aligned} \text{s.t. } & p_t c_t + p_t i_t + b_t + e_t b_t^F = \\ & r_t^k p_t k_{t-1} + r_{t-1} b_{t-1} + e_t r_{t-1}^* b_{t-1}^F + p_t w_t h_t - p_t t_t + p_t \Gamma_t - \frac{\kappa_D}{2} e_t p_t^* \left( \frac{b_t^F}{p_t^*} - \bar{b} \right) \end{aligned}$$

$$\text{and } k_t = (1 - \delta)k_{t-1} + \left[1 - \frac{\kappa_I}{2} \left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t$$

where  $\kappa_L$  is the labour preference parameter,  $b_t$  is the domestic bond paid at the interest rate  $r_t$ ,  $r_k$  is the rent of capital,  $w_t$  denotes the wage,  $t_t$  represents total tax paid,  $\Gamma_t$  is the dividend,  $k_t$  is the stock of capital,  $\kappa_I$  denotes the adjustment cost of investment,<sup>2</sup>  $\kappa_D$  denotes the costs of adjustment when acquiring foreign bonds, and  $b_t^F$  is a one-period foreign bond denominated in foreign currency and paid at rate  $r_t^*$ , which follows an exogenous process:

$$r_t^* = (1 - \rho_p) \frac{1}{\beta} + \rho_p r_{t-1}^* + \nu_t^p \quad (8)$$

with  $\nu_t^p \sim N(0, \sigma_p^2)$  representing the foreign interest rate shock.

The solution to the optimization problem is given by the following first-order conditions (FOC):

$$\lambda_t = \left( c_t - \kappa_L \frac{h_t^{1+\varphi}}{1+\varphi} \right)^{-\sigma} \quad (9)$$

where  $\lambda_t$  is the Lagrange multiplier derived from the FOC with respect to consumption;

$$\lambda_t = \beta E_t \left( \lambda_{t+1} \frac{r_t}{\pi_{t+1}} \right) \quad (10)$$

which is the FOC with respect to domestic bond;

$$\lambda_t [1 + \kappa_D (b_t^F - \bar{b})] = \beta E_t (\lambda_{t+1} r_t^* \frac{s_{t+1}}{s_t}) \quad (11)$$

denoting the FOC with respect to foreign bond;

$$1 = \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{[r_{t+1}^k + (1 - \delta)q_{t+1}]}{q_t} \right\} \quad (12)$$

representing the FOC with respect to capital, with  $q_t$  defined as Tobin's  $q$ ,

$$\kappa_L h_L^\varphi = w_t \quad (13)$$

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<sup>2</sup> The cost of adjustment of investment is introduced to the model to make further investment endeavours more expensive, which allows for smooth transitions in the stock of capital rather than sharp ones

which is the FOC with respect to hours worked; and

$$1 = q_t \left[ 1 - \frac{\kappa_I}{2} \left( \frac{i_t}{i_{t-1}} - 1 \right)^2 - \kappa_I \left( \frac{i_t}{i_{t-1}} \right) \left( \frac{i_t}{i_{t-1}} - 1 \right) \right] + \kappa_I \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} q_{t+1} \left[ \left( \frac{i_{t+1}}{i_t} \right)^2 \left( \frac{i_{t+1}}{i_t} - 1 \right) \right] \right\} \quad (14)$$

finally denoting the FOC with respect to investment.

### 3.2 Final good firms

Final good firms operate in a perfectly competitive environment and combine a continuum of intermediate goods by using the following technology to produce the final good  $y_{H,t}$ :

$$y_{H,t} = \left[ \int_0^1 y_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

in which  $y_{H,t}(i)$  is the input produced by an intermediate firm  $i$  and sold at a price  $P_{H,t}(i)$ , and  $\varepsilon$  denotes the elasticity of demand for each intermediate good. Making the assumption of a perfectly competitive market, profit maximization, and free entry to the market suggests that the demand for the intermediate good is derived as

$$y_{H,t}(i) = y_{H,t} \left( \frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\varepsilon} \quad (15)$$

with the expression for the price  $P_{H,t}$  in terms of the intermediate good prices given as

$$P_{H,t} = \left[ \int_0^1 P_{H,t}(i)^{(1-\varepsilon)} di \right]^{\frac{1}{1-\varepsilon}} \quad (16)$$

where  $\frac{\varepsilon}{1-\varepsilon}$  can be interpreted as the price markup.

### 3.3 Intermediate good firms

We assume a continuum of firms indexed by  $i$  that produced differentiated domestic input using the Cobb–Douglas function:

$$y_{H,t}(i) = a_t k_{t-1}(i)^\alpha h_t(i)^{1-\alpha} \quad (17)$$

with  $a_t$  the total factor productivity that follows an autoregressive process such that

$$\log a_t = (1 - \rho_a) \log \bar{a} + \rho_a \log a_{t-1} + \nu_t^a \quad (18)$$

$\nu_t^a \sim N(0, \sigma_a^2)$  denotes the technology shock.

Since intermediate firms produce differentiated goods, and to account for price rigidity, they operate in a monopolistic environment. This allows those firms to set the price of the goods that will be bundled by final good firms. Furthermore, and following Rotemberg (1982), these firms face quadratic nominal adjustment costs when they choose to adjust prices with respect to a given benchmark  $\bar{\pi}$ :

$$AC_t(i) = \frac{\kappa_L}{2} \left( \frac{P_{H,t}(i)}{P_{H,t-1}(i)} - \bar{\pi} \right)^2 P_{H,t} y_{H,t} \quad (19)$$

Intermediate firms maximize profit following the set up given as

$$\begin{aligned} \max E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[ \frac{P_{H,t}(i)}{p_t} y_{H,t}(i) - w_t h_t(i) - r_{t-1}^k(i) - \frac{AC_t(i)}{p_t} \right] \right\} \\ \text{s.t. } y_{H,t}(i) = y_{H,t} \left( \frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\varepsilon} = a_t k_{t-1}(i)^\alpha h_t(i)^{1-\alpha} \end{aligned}$$

The solution to the optimization problem is given by

$$r_t^k = \alpha m c_t \frac{y_{H,t}}{k_{t-1}} \quad (20)$$

$$w_t = (1 - \alpha) m c_t \frac{y_{H,t}}{h_t} \quad (21)$$

where  $m c_t$  denotes the Lagrange multiplier and is also the equivalent of the firm's marginal cost. This leads to derivation of the Phillips curve after some algebra, given by

$$\pi_{H,t}(\pi_{H,t} - \bar{\pi}) = \beta E_t \left[ \frac{\lambda_{t+1}}{\lambda_t} (\pi_{H,t+1} - \bar{\pi}) \frac{P_{H,t+1} y_{H,t+1}}{P_{H,t} y_{H,t}} \right] + \frac{\varepsilon}{\kappa_P} \left( \frac{m c_t}{P_{H,t}} - \frac{\varepsilon - 1}{\varepsilon} \right) \quad (22)$$

where  $\pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}} \pi_t$  is the domestic inflation rate. The term  $\pi_{H,t} - \bar{\pi}$  on the left-hand side of the Phillips curve indicates that inflation in our framework accounts for inertia and imbalances emanating from macroeconomic variables, among which deviations from potential output are the most prominent.

### 3.4 Commodity sector

We assume for the sake of simplicity that the commodity sector consists of an endowment that evolves endogenously over time, which we denote as  $y_{C,t}$ . This acts as an extra domestic good demanded by the foreign economy.  $y_{C,t}$  is completely exported and taxed by the government, and the demand is completely elastic at a price set as  $P_{C,t}^*$ . We assume that the law of one price holds for this commodity good, and we can therefore write the domestic currency price of



the commodity good as

$$P_{C,t} = s_t P_{C,t}^* \quad (23)$$

where  $P_{C,t}^*$  is assumed to follow an autoregressive process given by

$$\log \frac{P_{C,t}^*}{P_t^*} = \rho_{pc} \log \frac{P_{C,t-1}^*}{P_{t-1}^*} + (1 - \rho_{pc}) \log P_{C,t}^* + \nu_{pc} \quad (24)$$

where  $\nu_{pc} \sim N(0, \sigma_{pc}^2)$  is the commodity price shock.

### 3.5 The labour market

We now introduce hysteresis in the labour market. Models of labour markets accounting for insider–outsider dynamics were pioneered by Blanchard and Summers (1986), Gottfries and Horn (1987), and Lindbeck and Snower (1988), where a segmented labour force composed of insiders and outsiders emphasizes the dominant power of insiders in wage negotiations. We follow a much more recent approach in Galí (2022), which has the advantage of assuming a Calvo (1983) wage-setting formalism and can therefore be easily embedded in a standard NK DSGE model.

Other than the way the wage Phillips curve is derived, the framework introduced by Galí (2022) is otherwise a standard NK DSGE model. Therefore, all the usual assumptions of an NK DSGE model with unemployment hold in this case. Accounting for unemployment in an NK DSGE framework has been exhaustively covered in the literature by studies including Blanchard and Galí (2010), Galí et al. (2012), and Galí (2011, 2015), among others. We focus on the derivation of the wage equation that departs from the standard NK DSGE model.

Wages are set *à la* Calvo (1983). In particular, a fraction  $\theta_w$  of workers represented by a certain union gets to reset their wages, while the remainder of workers  $1 - \theta_w$  keep wages the same as in period  $t - 1$ .  $\theta_w$  is therefore a measure of wage rigidity. When setting the new wage  $w_t^*(j)$  for a given occupation  $j$ , the representative union considers both current and future demand for labour. It follows that the relationship below holds:

$$h_{t+k|k}(j) = -\varepsilon_w (w_t^*(j) - w_{t+k}) + h_{t+k} \quad (25)$$

where  $k = 1, 2, 3, \dots$ ,  $h_{t+k|k}(j)$  is the employment at time  $t + k$  for occupation  $j$ , for which the wage was last reset in period  $t$ ,  $h_{t+k}$  is aggregate employment in period  $t + k$ , and  $\varepsilon_w > 1$  denotes wage elasticity of labour demand.

In aggregate terms, the average nominal wage can be expressed as follows:

$$w_t = \theta_w w_{t-1} + (1 - \theta_w) w_t^* \quad (26)$$

where  $w_t^*$  denotes the average newly set wage across occupations at time  $t$ .

In an insider–outsider model, a union resetting wages in a specific occupation will do so keeping in mind a target level of employment  $h_t^*(j)$ . The following condition therefore holds:

$$(1 - \beta\theta_w) \sum_{k=0}^{\infty} (\beta\theta_w)^k E_t h_{t+k|t}(j) = h_t^*(j) \quad (27)$$

By substituting Equation (26) into (27), we obtain the following wage-setting rule:

$$w_t^*(j) = -\frac{1}{\varepsilon_w} h_t^*(j) + (1 - \beta\theta_w) \sum_{k=0}^{\infty} (\beta\theta_w)^k E_t (w_{t+k} + \frac{1}{\varepsilon_w} h_{t+k}) \quad (28)$$

We now turn to the introduction of the hysteresis phenomenon. Galí (2022) does so following Blanchard and Summers (1986). The measure of insiders for any given occupation (which in this case is also the equivalent of the union employment target) is defined as follows:

$$h_t^*(j) = \gamma_{hys} h_{t-1}(j) + (1 - \gamma_{hys}) h^* \quad (29)$$

where  $h^*$  denotes the union's long-run target of employment. Equation (29) introduces in  $\gamma_{hys} \in [0, 1]$  the hysteresis parameter. It determines changes in the measure of insiders, and by association in the level of total employment, which may in turn have a direct impact on the state of the economy. This is explained by the fact that insiders have a high weight in wage bargaining. Added to this, their ability to strike is an important source of union bargaining power. We estimate  $\gamma$  in the next section using South African data.

Combining Equations (28) and (29) and aggregating throughout yields:

$$w_t^* = -\frac{\gamma_{hys}}{h_t - \bar{h}_{t-1}^*} + (1 - \beta\theta_w) \sum_{k=0}^{\infty} (\beta\theta_w)^k E_t (w_{t+k} + \frac{1}{\varepsilon_w} (h_{t+k} - \bar{h})) \quad (30)$$

Equation (30) combined with the evolution of average nominal wage defined in Equation (26) yields the proposed wage Phillips curve:

$$\pi_t^w = \beta E_t (\pi_{t+1}^w) + (1 - \gamma_{hys}) \lambda_w (1 - \beta\theta_w) (h_t - \bar{h}) + \gamma_{hys} \lambda_w \left( \frac{h_{t+1}}{h_t} \right) \quad (31)$$

where  $\lambda_w = \frac{1 - \theta_w}{\theta_w \varepsilon_w}$  is a constant that decreases the more rigid wages are. This equation is a function of the level of employment prevailing in the economy. Consequently, a change in the

size of employment will have direct repercussion for the response of macroeconomic variables, depending on the degree of hysteresis accounted for. Two extremes are worth considering here. First, in the case of full hysteresis ( $\gamma_{hys} = 1$ ), the measure of insiders will remain unchanged from the previous period, with virtually no weight assigned to the set of the unemployed in wage negotiations. In this case, a contraction in employment will negatively impact the level of output in the economy. This can be amplified the more rigid wages are in the economy. Put simply, adverse developments in the labour market can be directly tied to a contraction in GDP through Equation (31). This equation can therefore forecast a negative outcome for GDP growth, depending on the data available. Second, in the other extreme ( $\gamma_{hys} = 0$ ), the wage Phillips curve will simply correspond to that of a standard NK DSGE model, in which most of the features of a competitive labour market hold. Therefore, estimating the hysteresis parameter will provide crucial information on which side of the balance the South African labour market tips further.

### 3.6 Policy

We assume that the government finances public expenditure by collecting taxes on both home production ( $\tau_G$ ) and production emanating from the commodity sector ( $\tau_{Co}$ ):

$$p_{H,t}g_t = \tau_G y_{H,t} + \tau_{Co} y_{C,t} \quad (32)$$

Following Menuet and Villieu (2014), we set the government budget as

$$B_{t+1} = (1 + r_t)B_t + p_{H,t}g_t - \tau_G p_{H,t}y_{H,t} - \tau_{Co} P_{C,t}y_{C,t} \quad (33)$$

where  $B_t$  is the level of public debt and  $\tau$  denotes taxes on home production and commodity sector production.

On the fiscal block, we compare the above set up with two additional scenarios. First of all, we assume that the fiscal authority can finance government expenditure through the following set of fiscal rules:

$$T_{K,t} = \tau_k \alpha y_{H,t} \quad (34)$$

denoting the tax on capital, and where

$$T_{H,t} = \tau_h (1 - \alpha) y_{H,t} \quad (35)$$

represents the tax on labour. Finally, consumption tax evolves around the following:

$$T_{C,t} = \tau_c c_t \quad (36)$$

The second scenario revolves around modelling government expenditure exogenously. Therefore:

$$\log g_t = (1 - \rho_g) \log \bar{g} + \rho_g \log g_{t-1} + \nu_t^g \quad (37)$$

with  $\nu_t^g \sim N(0, \sigma_g^2)$  the public spending shock.

Finally, we close the model with the behaviour of monetary policy, with the Taylor rule evolving according to the following:

$$\frac{r_t}{r} = \left( \frac{r_{t-1}}{r} \right)^{\rho_r} \left[ \left( \frac{\pi_t}{\bar{\pi}} \right)^{\varphi_\pi} \left( \frac{y_{H,t}}{y} \right)^{\varphi_y} \left( \frac{\Delta e_t}{\Delta e} \right)^{\varphi_e} \right]^{1-\rho_r} \exp(\nu_t^m) \quad (38)$$

### 3.7 Calibration

Most of the parameters in the model are set according to their standard values in the literature. As such, the discount factor takes the familiar value of  $\beta = 0.99$ , while the inverse of Frisch elasticity is set as  $\varphi = 3$ , suggesting a labour supply elasticity of  $\frac{1}{3}$ . On the labour market, we assume a hysteresis coefficient of  $\gamma_{hys} = 0.9$ . This is based on evidence from Vieg and Dadam (2023) showing that South Africa's labour market displays signs of strong hysteresis, therefore tilting  $\gamma_{hyst}$  towards the value of 1. We set the production elasticity with respect to capital as  $\alpha = 0.33$ , suggesting a value of 0.67 for the one with respect to labour. The elasticity of substitution between differentiated goods is  $\varepsilon = 6$ , while the depreciation rate is  $\delta = 0.025$  and the relative risk aversion is set at  $\sigma = 2$ . The degree of openness is assumed to be  $\gamma = 0.6$ , and we assume an elasticity of intertemporal substitution of  $\eta = 1.5$ .

We further consider cases where government spending is exogenous versus where it is explicitly modelled. In the latter case, we first assume that the fiscal authority only receives tax revenues through corporate tax ( $\tau_G = 21\%$ ) and through commodity tax ( $\tau_{Co} = 28\%$ ). The two taxes are parametrized based on the average corporate income tax rate (ACITR), calculated as:

$$ACITR_t = \text{tax on corporate profits}_t / \text{corporate profits}_t$$

where corporate taxable income is proxied by gross operating surplus. Company tax is calibrated as the average for the ACITR for the 2000–19 sample period, which is 21%. Commodity tax is calibrated as the maximum ACITR, which is 28% during the 2001–08 commodity boom. Second, we assume that government revenues are collected through taxes on commodities ( $\tau_{co} = 28\%$ ), capital ( $\tau_k = 18\%$ ), labour ( $\tau_h = 20\%$ ), and consumption, which we proxy as the standard VAT ( $\tau_c = 14\%$ ). VAT is calibrated at 14%, the rate that it was for most of our sample period before changing to 15% in 2018. Similar to the ACITR, we use average personal income tax rate (APITR) as a proxy for labour income, calculated as:

$$APITR_t = \text{personal income tax}_t / \text{personal taxable income}_t$$

where the compensation of employees in the private sector is used as a proxy for the tax base, personal taxable income. The average APITR for the sample period is 20%. Table 2 summarizes the parametrization of the model.

**Table 2: Parametrization**

Parameter	Description	Coefficient
$\beta$	Discount factor	0.99
$\varphi$	Inverse Frisch elasticity of labour	1
$\theta$	Price rigidity	0.6
$\theta_w$	Wage rigidity	0.5
$\varepsilon$	Elasticity of substitution between differentiated goods	6
$\delta$	Depreciation rate	0.025
$\sigma$	Relative risk aversion	2
$\eta$	Elasticity of intratemporal substitution	1.5
$\gamma$	Trade openness	0.6
$\gamma_{hys}$	Level of hysteresis	0.9
$\tau_{co}$	Commodity tax	0.28
$\tau_k$	Capital tax	0.18
$\tau_h$	Labour tax	0.19
$\tau_c$	Consumption tax	0.15
$\kappa_I$	Investment adjustment cost	2.48
$\kappa_D$	Foreign bond adjustment cost	0.001
$\varphi_\pi$	Elasticity of monetary policy to inflation	1.5
$\varphi_y$	Elasticity of monetary policy to output	0.125
$\varphi_e$	Elasticity of monetary policy to exchange rate	0
$\rho_a$	Productivity shock persistence	0.9
$\rho_{pco}$	Commodity price shock persistence	0.9
$\rho_g$	Government spending shock persistence	0.9

Source: authors' compilation.

### 3.8 Impulse responses

We conduct several analyses corresponding to the response of macroeconomic variables to an increase in commodity prices, which we expect to have an overall expansionary effect. The objective of the paper, however, remains the same: to assess how fiscal policy can amplify or dampen the effects of a commodity shock. We begin with a scenario that is a comparative analysis of the fiscal authority choosing different levels of corporate and commodity taxes. We follow this with a deeper investigation of different levels of hysteresis prevailing in the economy. We conclude by comparing the responses of various fiscal rules against the backdrop of endogenously and exogenously modelling government spending. This allows us to thoroughly investigate the response of fiscal policy following a commodity boom—it being countercyclical or otherwise.

### 3.9 Commodity shock under different levels of corporate and commodity taxes

We begin our analysis of the results with the response of macroeconomic variables to a positive commodity price shock. The fiscal authority can decide to set corporate and commodity production taxes at various levels. In the tax system in South Africa, the commodity sector tax is composed of a fixed component and variable one, with the latter consisting of royalties that are paid based on total revenue of firms operating in the sector, depending on the conditions prevailing in the economy. Therefore, at any point in time, the effective tax rate is either higher, the same, or lower in the commodity sector relative to the effective tax rate in the non-commodity sectors.<sup>3</sup> We therefore consider three cases in Figure 4: (1) first we assume the commodity sector is taxed at a higher rate than home production, which allows the government to reap higher revenue following a commodity boom ( $\tau_G < \tau_{Co}$ ); (2) we follow this with the results from both sectors being taxed at the same level ( $\tau_G = \tau_{Co}$ ); and (3) we conclude with the scenario where home production is taxed more when commodity prices increase ( $\tau_G > \tau_{Co}$ ). It is important to highlight that in these three cases, the home production tax remains constant while we change the tax rate on the commodity sector.

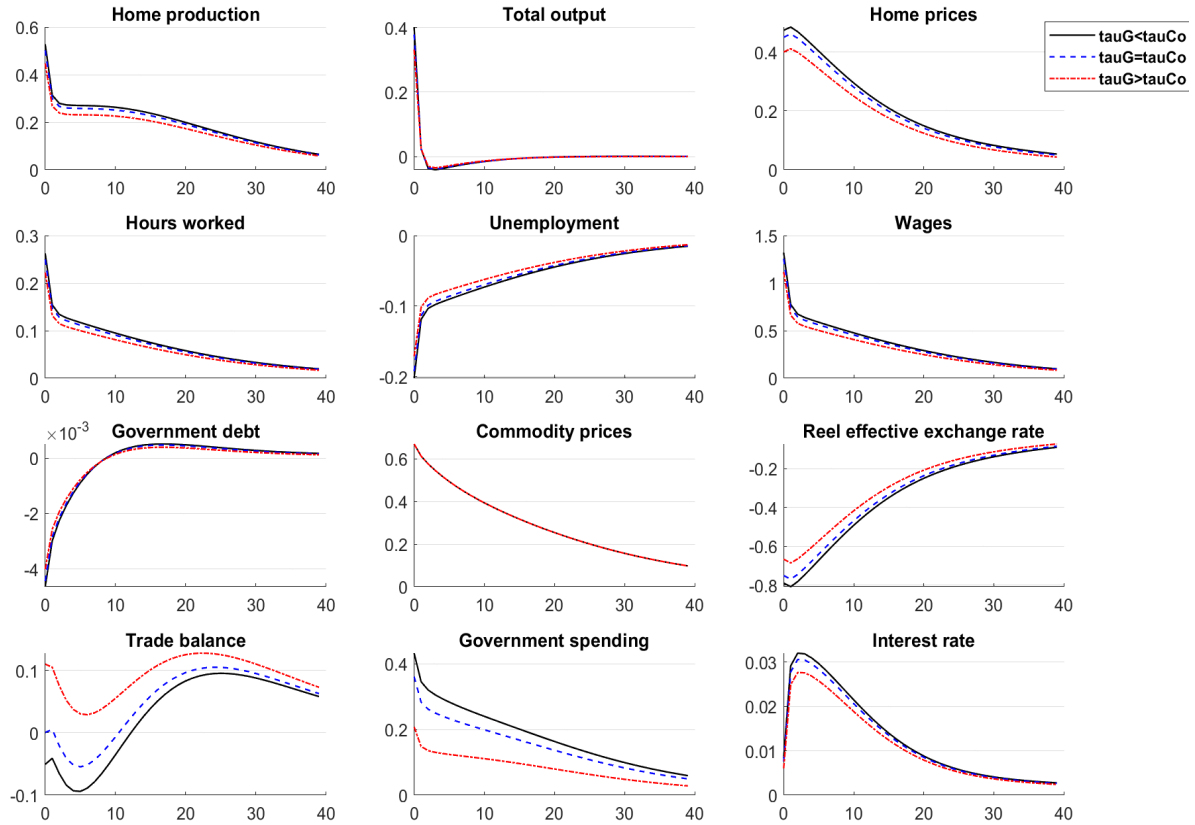
Overall, the simulation of the DSGE model follows the findings in the empirical section of the paper, which suggests our framework fairly mimics observed moments. A positive commodity price shock has an overall expansionary effect. We note a spillover in home production and a similar increase in GDP as unemployment falls. As a result, inflation increases, as do hours worked and wages. Furthermore, we notice an appreciation of the currency, which is in line with the findings of Naraidoo and Paez-Farrell (2023).

Additionally, because of the increase in tax collection from both home production and the revenue increase in the commodity sector, the public debt decreases, providing some fiscal space. Emphasizing the hysteresis effects, we notice that when we change the hysteresis coefficient  $\gamma_{hys}$  from an average value of 0.5 to the calibrated 0.9, unemployment displays strong evidence of persistence. This suggests that a labour market with characteristics of strong hysteresis results in unemployment taking a considerable amount of time to absorb an otherwise transitory shock. The cases with lower levels of hysteresis are reported in the next subsection.

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<sup>3</sup> See Parliamentary Monitoring Group (2013) for further information.

**Figure 4: Response to a commodity price shock**



Note: responses of the variables are deviations from the steady state. Horizontal axes represent quarters.  $\tau_G$  = home production (corporate) tax;  $\tau_{Co}$  = commodity sector tax. Hysteresis:  $\gamma_{hys} = 0.9$ .

Source: authors' compilation.

The magnitude of the response of some of the variables is correlated to different parameterizations of the tax coefficient between home production and the commodity sector. Therefore, the findings suggest that the spillover of a commodity boom on home production is subdued when home production is taxed more than the commodity sector. This results in a lesser increase in home prices and wages, while hours worked are comparatively lower and there is a smaller decrease in unemployment. As a result of the lesser impact on home production prices, the interest rate is increased less when home production is taxed more, signalling a lower inflationary impact.

The difference in response from accounting for the three scenarios is more prominent for the trade balance and government spending. Looking at the trade balance and focusing on the extremes, the results show that following a commodity price increase, the trade balance deficit widens when the commodity sector is taxed higher, whereas we report a trade balance surplus when home production faces higher taxes. When the commodity sector is taxed more, this reduces the profitability of the sector, therefore making it less productive and competitive in the international market. This competitiveness is further dampened because in this scenario the rand appreciates the most, making exports more expensive. This results in a reallocation of

resources as home production and hours worked increase. Conversely, when home production is taxed higher in the aftermath of a commodity boom, the commodity sector thrives more at the expense of the non-tradable sector, where we notice shrinkage. A thriving and productive commodity sector translates into higher exports and ultimately into a trade balance surplus supported by lower appreciation of the currency.

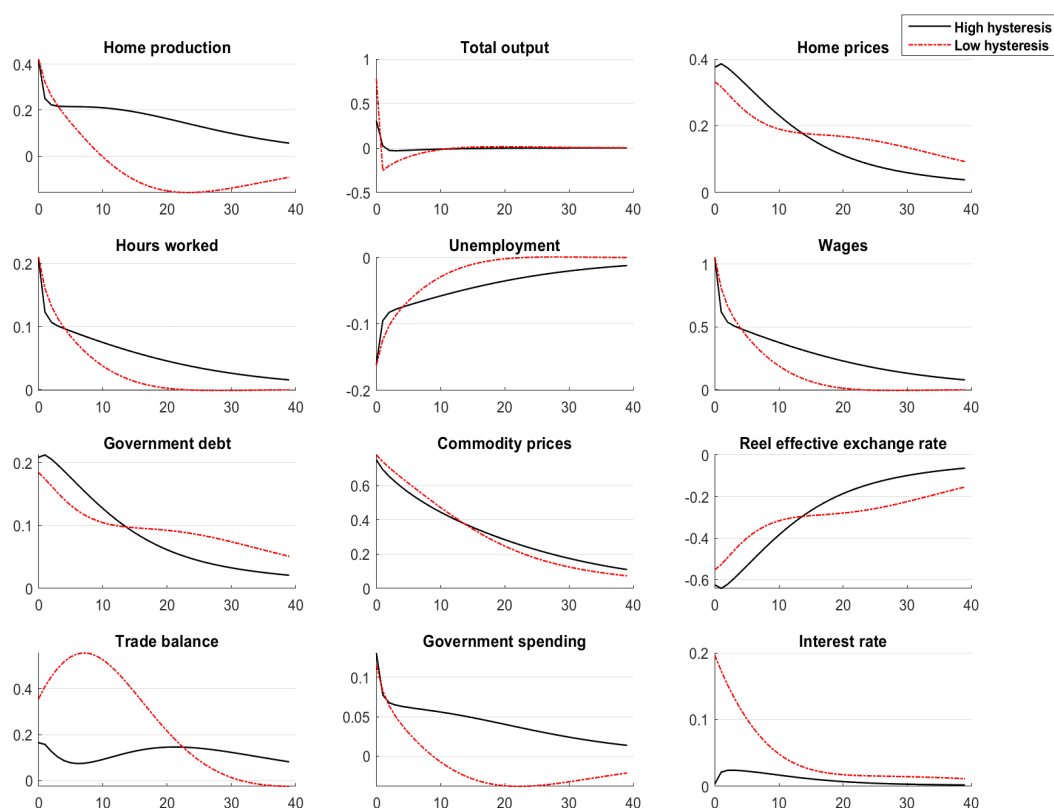
The response of government spending is fairly straightforward. Higher commodity sector tax following a commodity boom increases fiscal space the most out of the three scenarios considered. In our framework, this tax windfall is immediately spent, therefore ruling out a countercyclical fiscal policy. However, in practice, the fiscal authority faces the additional option of saving the tax windfall for economic downturns. In South Africa, the National Treasury's main objective has been to follow a balanced approach that consists of showing restraint in public spending, tax collection, and additional borrowing. This task has been complicated in recent times following the COVID-19 pandemic, which put South Africa on a higher debt-growth path than predicted prior to the crisis as a result of higher borrowing in the international market and increased social transfers.

### **3.10 Hysteresis, fiscal rules, and countercyclical fiscal policy**

We follow our benchmark results with a set of experiments to deepen our understanding of: (1) the effects of hysteresis; (2) different fiscal rules, which allows us to model government revenue collection through taxes on commodity production, capital, consumption, and labour; and (3) countercyclical fiscal policy, which is based on the notion that optimal fiscal policy response to shocks should be countercyclical—that is, saving during booms to smooth the responses of macroeconomic variables in an eventual adverse shock. The paper by Naraidoo and Paez-Farrell (2023) focuses on the role of monetary policy in mitigating the effect of commodity price shocks on SOEs, and thus reducing the Dutch disease. Instead, in our final experiment, we focus on fiscal policy since empirical evidence (Céspedes and Velasco 2014; Kaminsky et al. 2004; Marioli and Vegh 2023) indicates that fiscal policy tend to be pro-cyclical in commodity-exporting countries, especially in developing countries. This pro-cyclicity is induced by the tendency of commodity exporters to spend the unexpected windfall from higher-than-expected tax revenue. This goes against countercyclical fiscal policy practices, which suggest that government must save the windfall and build a buffer to be used when the shock dies out. We consider an alternative fiscal policy scenario where the government chooses not to spend the tax windfall from the commodity price shock, as in the benchmark results. The first two points in (1) and (2) are reported in Figure 5.



**Figure 5: Response to a commodity price shock with hysteresis-sensitivity-test modelled fiscal rules**



Note: responses of the variables are deviations from the steady state. Horizontal axes represent quarters. High hysteresis (solid black line):  $\gamma_{hys} = 0.9$ . Low hysteresis (dotted red line):  $\gamma_{hys} = 0.5$ .

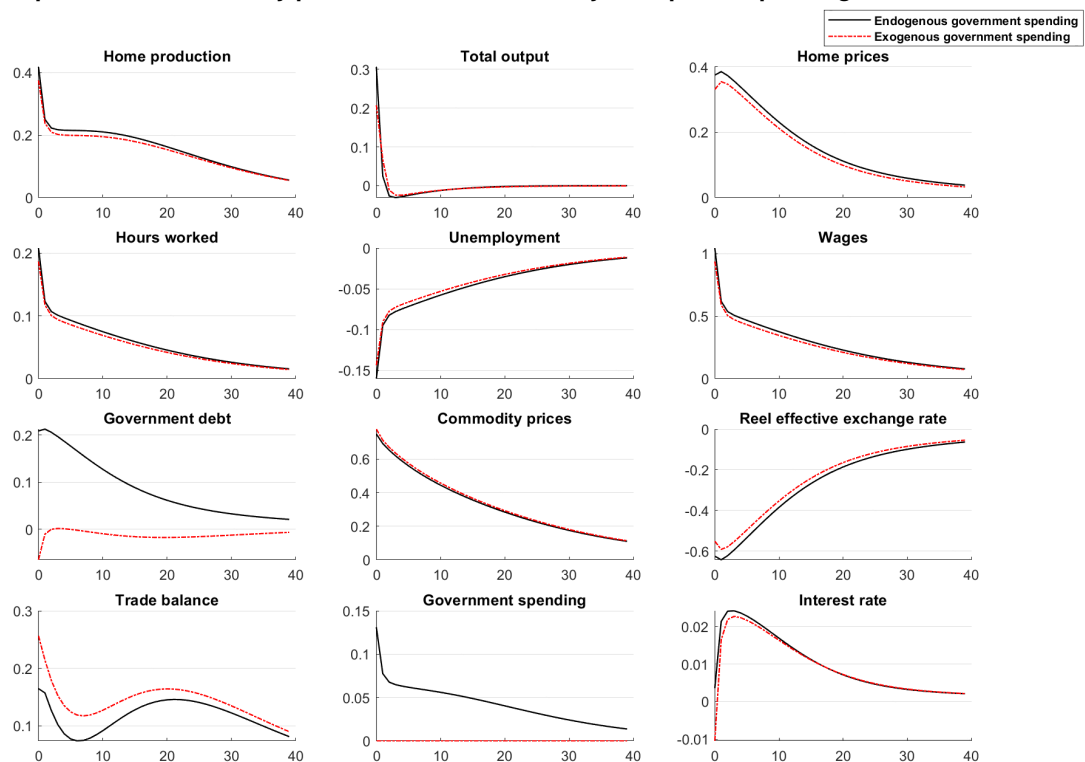
Source: authors' compilation.

Overall, the responses are in line with the benchmark findings—a commodity price shock results in an expansion of the economy. The sensitivity test in terms of hysteresis in the labour market shows that, for most variables, the persistence is more prominent when the hysteresis coefficient is increased. This is particularly noticeable for labour market variables where employment, unemployment, and wages take a significant amount of time to converge to pre-shock values. We must, however, note the peculiar response of home production prices. Although the prices decrease less in a low hysteresis environment, they remain significantly above the steady state value relative to a scenario with high labour market hysteresis. This, in turn, results in a stronger response from monetary policy, represented by a higher interest rate response.

These results include different fiscal rules and a scenario where the tax windfall resulting from a commodity boom is completely spent, resulting in an increase in public debt. In Figure 6 we compare this scenario to a case where the government embarks on a countercyclical fiscal policy. To achieve this, we model public spending as an exogenous process. The findings of this exercise show that modelling government spending exogenously results in an over-

all marginally less persistent and less inflationary response of variables to a commodity price shock. While the differences between some of the variables are marginal, they nevertheless show that because restrained government spending results in a smaller appreciation of the local currency, the trade balance is better than when government spending is pro-cyclical. Lastly, the persistence of the variables is more striking in the case of government debt and spending. Particularly, since the tax windfall does not translate into an increase in government spending, government debt decreases significantly more, suggesting the implementation of a counter-cyclical fiscal policy.

**Figure 6: Response to a commodity price shock with countercyclical public spending**



Note: responses of the variables are deviations from the steady state. Horizontal axes represent quarters.

Hysteresis:  $\gamma_{hys} = 0.9$ .

Source: authors' compilation.

## 4 Conclusion

This paper investigates the effect of commodity price shocks in a commodity-exporting SOE, and the role of fiscal policy in transmitting the shocks to the economy. We employ empirical and theoretical approaches for our analysis. The empirical results indicate that a commodity price boom has an expansionary effect on the economy in the short term. Real GDP increases, resulting in an increase in tax revenue. Our measure of unemployment—hysteresis—decreases, though the results are insignificant. However, we find that the shock has a signifi-

cant effect on employment in the private sector. Despite the appreciation of the local currency, net exports increase.

The results of the model corroborate the empirical findings of the VAR model and are in line with similar studies on this topic. In particular, we find an increase in commodity prices has an overall economic boom effect, with output rising, hours worked and wages both increasing, and the real effective exchange rate appreciating, while unemployment decreases.

On the fiscal side, the commodity price shock creates further fiscal space as the revenue collected from the commodity sector increases, which translates into a reduction in overall government debt. We find that failure to tax profits from the commodity sector after the commodity price shock makes the commodity sector more productive and competitive. However, this comes at the cost of the tradable sector, where productivity falls. Finally, we explore the role of fiscal policy during a commodity boom. We show that when we restrict the response of government spending during a boom, the effect of commodity prices on the local economy is less inflationary. The unexpected tax windfall can be spent on reducing government debt, and thus creating fiscal space to cushion the economy when the boom winds down or to support industries that are negatively affected by the boom. This finding asserts the macroeconomic benefits of countercyclical fiscal policy.

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# Appendix A

## A1 Data

**Table A1: Data for the BVAR model**

Variable	Description	Source
Commodity prices	Average of monthly commodity export price index for South Africa; index; June 2010 = 100	IMF
Real GDP	Gross domestic product at constant 2015 prices; R millions	SARB
Policy rate	Average of monthly central bank rates; percentage	IMF
Long-term rates	Yield on loan stock traded on the stock exchange for government bonds with maturity of ten years and over; percentage	SARB
Unemployment rate	Official unemployment rate	SARB
Employment (private)	Total employment in the private sector; 2015 = 100; index	SARB
Employment (non-agri)	Total employment in the non-agricultural sectors; 2015 = 100; index	SARB
Government debt	Total loan debt of national government: total gross loan debt	SARB
Hysteresis	Hysteresis transformation of the unemployment rate*	Viegi and Dadam (2023)
Consumer price index	Consumer price index (all items): total for South Africa, index; quarterly, not seasonally adjusted; index	St Louis FRED
Real exchange rate	Calculated as the nominal bilateral exchange rate of the rand to the US dollar (EXSFUS) multiplied by the ratio of the two countries consumer price index ; quarterly; not seasonally adjusted	St Louis FRED
Trade balance (% GDP)	Balance of payments: trade balance, seasonally adjusted. own calculation—divided by nominal GDP	SARB
Government spending	Average of national government total expenditure less the average of monthly interest payment on debt; R millions	SARB
Primary balance	Primary balance as percentage of GDP; percentage	SARB
Budget balance	National government deficit or surplus as percentage of GDP; percentage	SARB
Tax revenue	Total tax revenue; R millions	IMF

Note: R millions is millions of South African rand. \* This paper uses traditional stationarity tests and non-linear transformation methods to provide evidence of hysteresis in the unemployment series for South Africa.

Source: authors' compilation.

## A2 Methodology

This section provides a summary of the BVAR model by Giannone et al. (2015). The BVAR model is estimated using the Minnesota prior and the sum-of-coefficients prior (see Robertson and Tallman (1999) and Blake and Mumtaz (2012) for a detailed discussion of the two priors). The Minnesota prior incorporates the belief that the endogenous variables in the BVAR follow a random walk process for variables that are stationary or an autoregressive process of order 1, AR(1), for variables that need to be differenced to be stationary. The prior is implemented using the normal inverse Wishart prior, which assumes the coefficients of the BVAR,  $A_l$ , are normally distributed while the covariance structure of the error terms,  $\Sigma$ , is inverse Wishart. This prior is incorporated by letting the mean of the BVAR coefficients equal 1 for stationary variables and 0 for the variables that follow the AR(1) process:

$$E_t[(A_l)_{ij}|\Sigma] = \begin{cases} \delta_i & \text{for } i = j \text{ and } l = 1 \\ 0 & \text{otherwise} \end{cases} \quad \text{Var}[(A_l)_{ij}|\Sigma] = \begin{cases} \frac{\lambda}{l} & \text{for } i = j, \forall l \\ \frac{\lambda}{l} \frac{\Sigma_{ij}}{\sigma_j^2} & \text{for } i \neq j, \forall l \end{cases} \quad (39)$$

where  $\delta_i$  takes the value of 0 or 1. The ratio  $\Sigma_{ij}/\sigma_j^2$  is included in the prior standard deviation to account for different measurement units of the variables. The hyper-parameter  $\lambda$  controls the tightness of the prior. For  $\lambda \rightarrow \infty$  the prior is uninformative and for  $\lambda \rightarrow 0$  the prior is implemented tightly. The hyper-parameter  $\sigma_i$  is the standard deviation of the error terms of the AR process for each variable on its own lags and is estimated from the sample via ordinary least squares (OLS). The Minnesota prior is implemented by creating dummy variables  $Y^1_d$  and  $X^1_d$ , using the following equation:

$$Y^1_d = \begin{pmatrix} \text{diag}(\delta_1\sigma_1, \dots, \delta_N\sigma_N)/\lambda \\ 0_{N \times (P-1) \times N} \end{pmatrix} \quad X^1_d = \begin{pmatrix} J_P \otimes \text{diag}(\sigma_1, \dots, \sigma_N)/\lambda & 0_{NP \times 1} \end{pmatrix} \quad (40)$$

where  $\text{diag}(\delta_1\sigma_1, \dots, \delta_N\sigma_N)/\lambda$  and  $J_P \otimes \text{diag}(\sigma_1, \dots, \sigma_N)/\lambda$  governs the prior of the coefficients of the first lag of each variable where  $\delta_i = 1$ , where  $i = 1, \dots, N$  for the random walk process. The dummy variables that govern the prior on other lags  $0_{N \times (P-1) \times N}$  and  $0_{NP \times 1}$  imply a prior mean of 0 (Blake and Mumtaz 2012).

The second prior used in the model is the sum-of-coefficients prior, also known as the no-cointegration prior. This prior is used to reflect the belief that the variables in the model follow a random walk process, sometimes with a drift. It is useful especially when modelling a relationship between variables with different frequencies, such as macrovariables and financial variables, or stock and flow variables (Caruso et al. 2019). The prior is implemented by creating  $N$  dummy observations, one for each variable, centred around 1 for the sum-of-coefficients for own lags for each variable and 0 for other variables (Giannone et al. 2015). The dummy



variables are constructed as follows:

$$Y^2_d = \left( \text{diag}\left(\frac{\bar{y}_{0,1}}{\tau}, \dots, \frac{\bar{y}_{0,N}}{\tau}\right) \right) \quad X^2_d = \left( y_d, \dots, y_d, 0 \right) \quad (41)$$

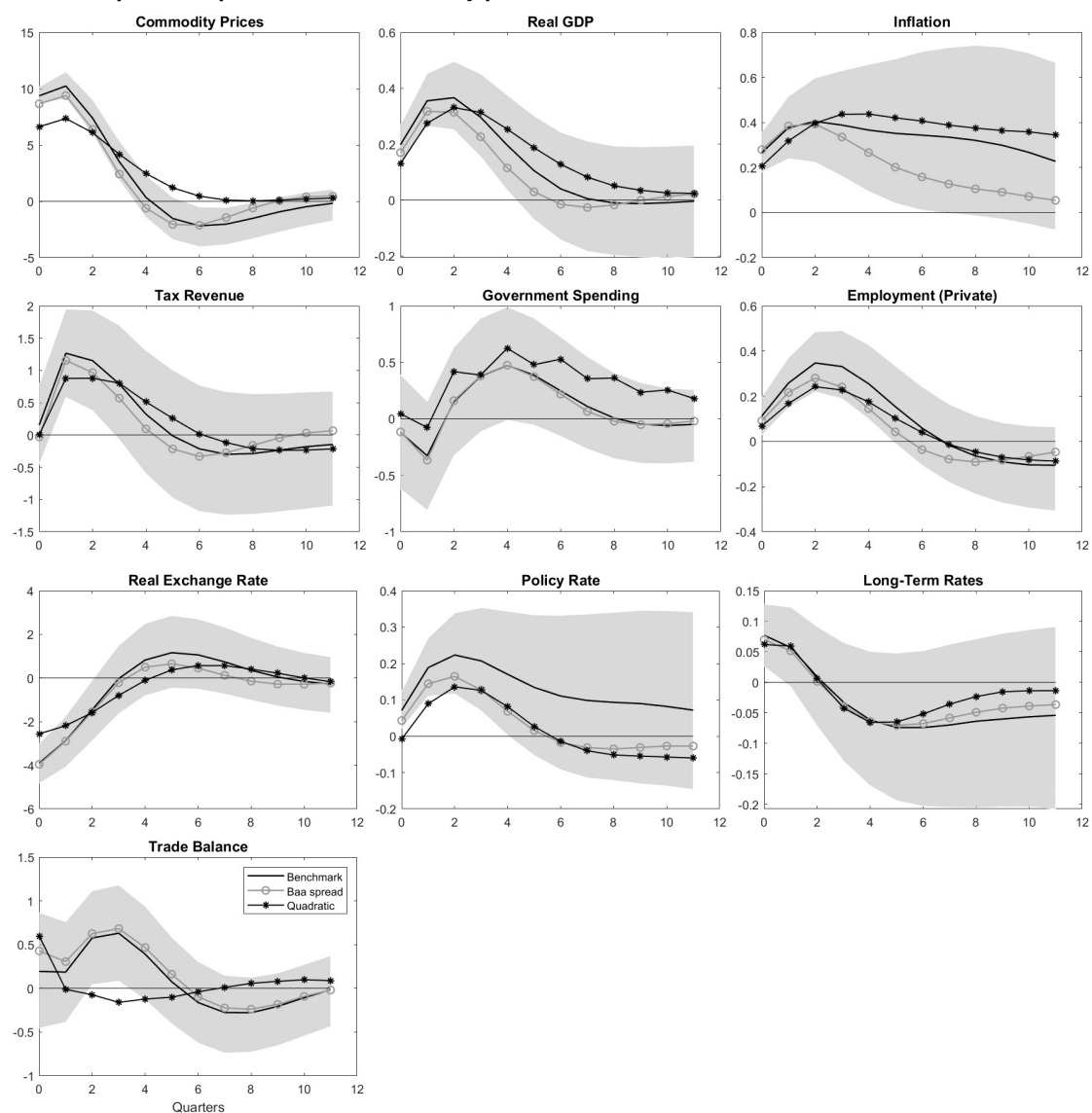
where  $\bar{y}_{0,i}$  where  $i = 1, \dots, N$  is the mean for each variable calculated using the first  $p$  variables. We set  $p = 2$ . The hyper-parameter  $\tau$  controls the variance of the prior with  $\tau \rightarrow \infty$  indicating an uninformative prior and  $\tau \rightarrow 0$  indicating a tight prior of no cointegration. In order to assign high probability to models in which the variance of the series is explained by the stochastic trend more than it is explained by the deterministic trend (i.e.  $c = 0$ ), the sum-of-coefficients prior is supplemented with dummy variables  $Y^3_d$  and  $X^3_d$ :

$$Y^3_d = \left( 0_{1 \times N} \right) \quad X^3_d = \left( 0_{1 \times Np} \quad \varepsilon \right) \quad (42)$$

where the hyper-parameter  $\varepsilon$  is set to a loose prior of  $10^6$  (Caruso et al. 2019). Giannone et al. (2015) use hyper-parameters that are selected using a hierarchical modelling approach. With this approach, the procedure automatically selects the appropriate amount of shrinkage, where tight priors are selected when there are too many unknown parameters and loose priors otherwise (Giannone et al. 2015: 437). This is in contrast to Bańbura et al. (2010), who use the in-sample fit of the smallest BVAR model to implement Bayesian shrinkage.

## A3 Robustness checks

Figure A1: Impulse responses to a commodity price shock: robustness



Note: the figure shows the response to a one standard deviation shock. The solid line is the median response for the benchmark results in Figure 2; the shaded area is the 68% credible interval. The solid lines with the stars and circles are the median response for controlling for the Baa spread and the quadratically detrended model, respectively.

Source: authors' compilation.