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Monetary policy in a model with commodity and financial markets^{*}

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Abstract

This paper builds a small open economy model for a net commodity exporter to consider financial frictions and monetary policies in order to investigate the main determinants of business cycles. Since we make a distinction to the access of financial markets between the commodity and non-commodity sectors, we notice that as usual, a commodity price shock benefits the competitiveness of the economy and its borrowing terms. We outline a novel effect in this paper which we dub the ‘financial market effect’ following a positive commodity price shock that decreases the credit premium and hence exacerbate the commodity price boom. However the negative sectoral downturn affects entrepreneur credit together with disinflationary pressures of a real exchange rate appreciation. This opens the role for stabilization policies which we analyze comparing three types of monetary regimes. Estimating the model on South Africa, a major commodity exporting economy with inflation targeting regime, we find as conventional wisdom suggests that a hypothetical Taylor rule targeting the price-level allows for adjustment in inflation expectations that can dampen disinflationary pressures. Furthermore, due to smoother change in nominal rate of interest, there is lesser variability in financial markets.

Keywords : Business cycles, Small open economy, Commodity prices, Financial frictions, Emerging markets, Monetary policy, Price-level targeting, South Africa economy.

JEL Classification : E32, E44, E58, F41, F44, O16

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1 Introduction

This paper presents a small open economy DSGE model for a net commodity exporter such as South Africa. There are few characteristics of the South African economy that we would like to capture in our model and thus enable us to understand the economic behaviours better.

Firstly, compared to many African and developing economies, South Africa has a relatively well-developed manufacturing sector together with a well established financial market, but it is still heavily dependent on commodities, similar to major commodity exporters such as Argentina, Australia, Canada, Chile, Columbia and Mexico among many others. Mining is the most recognised commodity sector in South Africa and on top of its significance in total output, it also represents a significant industry in terms of employment. Commodity sector makes up around 60% of the country's exports. South Africa supplied around 25% of the world's platinum in 2017 and about 23% of the world's supply of diamonds in 2014. Gold accounts for about 5% of global mining production. It is also the sixth largest exporter of coal and produces nearly half of the world's chromium. It is a major exporter of iron ore and other metals and minerals. Bayoumi and Swiston (2008) found that commodity prices and global financial conditions are the main transmission channels in South Africa. An IMF report (April 2016) showed that a 10 percentage point decline in export commodity prices would reduce real GDP growth by nearly 0.2 percentage points (annualised) after two quarters. In the same report, the evidence from Caceres et al (2016) shows that since almost half of South Africa's portfolio liabilities are held by US investors, an unexpected tightening of monetary conditions that pushes up US interest rate up by 100 basis points would increase South African long-term rates by 73 basis points after one year, but the short-term rates are not significantly affected. South Africa does not just export its commodity output, it consumes and imports some too. It consumes a fair proportion of its agricultural output. It uses some of the metallic ores like aluminum and chromium in its automobile industry. It uses a significant percentage of its own coal production for fuel. Moreover, due to lack of petroleum reserves, it imports this commodity. It imports copper and other industrial metals to support the manufacturing industry. Lower commodity prices and weaker capital inflows have led to substantial currency depreciation (De Gregorio (2016)). Consumer prices have also doubled in South Africa over the last few years, fuelled by currency depreciation. This shows that the trade and economic openness is an important feature of the economy.

Secondly, the external shocks also affect the local financial environment. In particular, large commodity boom lead to spur in credit growth and the advances in loans to risky business, the so-called risk-taking channel of currency appreciation (Hofmann et al (2016)). Dollar-denominated lending can rise sharply. A large fall in commodity prices may lead to large deposit withdrawal and currency depreciation leading to hike in repayment of dollar-denominated loans and hence default and risk premium increases. The South African Rand has depreciated enormously over the past few years and this phenomena is not new to emerging market economies currencies. Basel II standards have been fully implemented in South Africa. The South African response to the BIS (2011) survey suggest that the South African banking system has been largely insulated from the downturn in commodity prices because of the limited share of loans to the mining sector. Mining operations are mostly run by multinational corporations and funded via equity and bond issuance, both domestically and abroad. Another factor for the insulation of the banking system is the lack of mismatches between banks' foreign exchange assets and liabilities which has reduced banks' vulnerability to the major depreciation of the rand since 2011. Within the commodity sector, many mining companies have their assets held by the global leading miners such as Rio Tinto, Xtrata, Anglo American and BHP Biliton. Their businesses range from platinum to gold, coal, industrial metals and minerals. These firms are all listed and they have no problem in raising equity and/or debt finance. Reported by the FT (September 28, 2015), these companies used to have very similar gearing ratios (net debt to market capitalisation) ranging between 15% and 27% at the beginning of the 21st century. Then shareholders began to own a greater proportion of the overall enterprise value of the company, with average gearing falling to 8% in fiscal year 2005/06. However, with the adoption of debt-based growth strategies and a low cost debt after the financial crisis, these companies took on additional gearing to finance the race to grow production. The aggregate gearing ratio of the mining companies has reached 41%. On the other hand, Anand, Perrelli and Zhang (2016) reported that majority of manufactured products exporters are small and medium sized enterprises. And according to the World Bank report on SMEs finance (September 1, 2015), these smaller firms are less likely to be able to secure bank loans than large firms. They find that 50% of formal SMEs in emerging

economies don't have access to formal finance. The sectoral features are that the large companies dominate the commodity sectors, while SMEs populate the non-commodity sector.¹

Lastly, Céspedes and Velasco (2014), Frankel et al. (2013), and Vegh and Vuletin (2014) have reiterated that developing economies have improved the conduct of fiscal and monetary policies together with macro-prudential policies. Despite that, there are some concerns regarding how to best manage commodity boom-bust cycles in these countries. The case of South Africa is interesting because it changed its monetary arrangements at the beginning of 2000s with the purpose of achieving better macroeconomic stability. South Africa implemented inflation targeting as a preferred framework for monetary policy in 2000. It also has a regime with a fully flexible exchange rate together with a sound banking system.

Our model is a two-sector New Keynesian small open economy model with financial frictions. We assume commodity producers face no financial frictions, while the non-commodity producers are financial constrained. Both sector engage in exporting their produces. The rest of the paper is organized as follows. Section 2 reviews related literature and provides the motivation and contribution of the paper. Section 3 describes the empirical facts of the South African business cycles. Section 4 describes the model. Section 5 discusses the solution and parametrization of the model. Section 6 presents and discusses the estimated impulse-response function of shocks to commodity price and other main shocks under the adopted inflation-targeting regime, together with providing an evaluation and comparison of the adopted inflation-targeting Taylor rule to two hypothetical rules, viz., price-level targeting and nominal GDP targeting. This section also outlines the three effects of a commodity price shock. Section 7 concludes.

2 Literature Review and Motivation

Pioneering works on small open economy model by Mendoza (1991, 1995), Aguiar and Gopinath (2007) and García-Cicco et al. (2010), have shown that both stationary and non-stationary TFP and terms of trade shocks are key drivers of emerging economy business cycles. Another strand of the literature, see for example Uribe and Yue (2006) and Neumeyer and Perri (2005) and García-Cicco et al. (2010), have outlined that countercyclical interest rate movements in general have been found to be a key driver of emerging markets business cycles. Furthermore, empirical evidence by Fernández et al. (2015) and Bastourre et al. (2012) have highlighted the strong negative effect of commodity price increases on country risk premia in sovereign bond spreads. In the same vein, Shousha (2016) and Drechsel and Tenreyro (2018) have embedded this negative relation between the interest rate premium and commodity prices into a two-sector commodity and non-commodity exporting economy to show how such inclusion can provide both a 'competitiveness' and a 'borrowing cost term' effects in explaining key business cycle facts of procyclicality in main macro variables together with a countercyclical trade balance effect. Shousha (2016) also show that the presence of balance sheet mismatches and leverage constraints in the banking sector do not seem to contribute a lot quantitatively either to the amplification of the shocks or the heterogeneity of responses among emerging and advanced countries.

Many of these economies tend to have procyclical macroeconomic policies, that exacerbate the sensitivity of the business cycles to commodity price fluctuations. Hence Kumhof and Laxton (2010), García et al. (2011), Pieschacón (2012), Ojeda et al. (2016) and Medina and Soto (2016) among others have illustrated the potential benefits of a countercyclical fiscal rule in an emerging economy that exports commodities. There is also a strand of the literature that is related to how commodity price booms generate Dutch-disease problem which generally refers to a contraction in the industrial or manufacturing tradable sector originated from an increase in the income generated by the export of some commodity and how policies such as exchange interventions, capital control and macro-prudential regulations can deal with them. To this end, Van Wijnbergen (1984), Krugman (1987), Caballero and Lorenzoni (2014), Lama and Medina (2012), Vargas

¹We did some comparison of the share of long-term loans in total equity and liabilities for mining and manufacturing companies. These data are scarcely available for long time series, hence we gather data from annual financial corporate statistics from StatSA (http://www.statssa.gov.za/?page_id=1854&PPN=P0021&SCH=7131) for revised financial year 2016 and preliminary financial year 2017. The numbers report that the percentage of long-term loans in total equity and liabilities for both mining and manufacturing sectors are roughly around 20%. However these numbers should be taken with caution as firstly, mining companies usually contract long term loans from international banks and the fraction of equity quoted on world stock markets is significant and secondly, the data is misrepresentative of the manufacturing sector which have 50% of formal SMEs having recourse to micro finance and hence not captured in the data. All these facts if taken into consideration would make the manufacturing sector even more susceptible to local financial market developments.

et al. (2015) and Garcia-Cicco and Kawamura (2015) evaluate alternative policy responses and instruments in the context of Dutch-disease episodes. Dib (2003) and Rees et al. (2016) among others developed rich sectoral production structure, including a non-tradeable sector, a resources sector and a non-resources tradeable sector NKDSGE model for Canada and Australia respectively and emphasize the importance of the interlinkages between different sectors as implied by a deeper understanding of how changes in interest rates, exchange rates and other macroeconomic variables affect the broader economy and the welfare gains when adopting a flexible exchange rate regime. Fornero et al. (2018) among others, highlight the importance of flexible inflation targeting, floating exchange rates and structural fiscal rules to efficiently manage commodity price volatility.

Modelling developments in terms of small open economy DSGE models have proliferated in the context of the South African economy. Frankel et al. (2008) investigate fiscal and monetary policy in a commodity-based South Africa. Steinbach et al. (2009) use Bayesian methods to estimate a small open economy DSGE model on South African data, while Ortiz and Sturzenegger (2007) used a version of the Gali and Monacelli (2003) model and Bayesian techniques to estimate the policy reaction function of the South African Reserve Bank (SARB). Alpanda et al. (2010) explored the role of the exchange rate in South African monetary policy, before evaluating the forecasting properties of the model in Alpanda et al. (2011). Gupta et al. (2016) investigate the impact of oil shocks on the South African economy.

On another strand, inflation targeting and price-level targeting have excited economists for decades and two surveys of this new research, Ambler (2009) and Hatcher and Minford (2014) confirmed both Eggertsson and Woodford (2003) and Nakov (2008) results that welfare losses conditional are much larger under inflation targeting than price targeting in New Keynesian models, especially when reaching the lower bound. Price-level targeting thus can provide a cushion against deflationary pressures to boost an economy performance since it leads to adjustment in inflation expectations.

This paper's small open economy extends a two-sector economy such as in Drechsel and Tenreyro (2018) with a distinction for a commodity sector to a model structure that follows the lines of Adolfson et al. (2007) into the open economy setting. The model also contains some nominal and real rigidities similar to Smets and Wouters (2007) among others. It also contains a financial sector a la Bernanke et al. (1999) (BGG henceforth) such as in García-Cicco and Kawamura (2015). Our model adds two main elements absent in

previous analysis. First it distinguishes between the type of financial markets that the two sectors face in the sense that it not only embeds a negative relation between the country's risk premia and commodity prices, consistent with the empirical evidence presented below but it also allows the non-commodity good sector to borrow on the local financial market and hence endogenizes the credit spread of this sector to imply how the goods sector faces a sectoral re-allocation following a Dutch-disease scenario and hence might face falling credit despite a booming commodity price that factually decreases the credit premium. The second contribution, whereas fluctuation in commodity prices around its long-run value represents an important source of cyclical fluctuation in government revenues for a number of economies such as Chile, Columbia, Mexico and Norway for instance and have called for certain economies to adopt a structural balance fiscal rule, making government spending a function of commodity price, these are of lesser importance in South Africa whereby most of the mining companies are privately owned. We nevertheless do not demphasize the importance of commodity price fluctuations to government revenues. We instead demarcate our work by analyzing different monetary policy regimes in the aforementioned model. In particular, we analyze how Taylor rule targeting inflation compares to price-level and nominal GDP targeting rules for interest rates to stabilise the economy when faced by commodity price shock among a number of other important shocks. We discuss the implications of these in details in later sections.

3 Empirical facts of commodity exporting economies

In this section, we present the main empirical business cycle features of the South African economy from 1999 to 2017. We also note that many of these empirical regularities have been noted in other emerging market economies such as Argentina and Chile among others. We focus the empirical evidence in this section on South Africa though there are strong similarities across emerging market economies and moreover averaging cross country effects might be confounding.

For the commodity price index, we need to select an appropriate commodity price index and hence we follow similar index computed by Grilli and Yang (1988) and Pfaffenzeller et al. (2007) for instance. Since commodities exported in South Africa consist of various ones, we use trade weights available from the UN Comtrade database in our computation to weigh platinum, gold and coal. First, we note some key facts between South Africa real GDP and commodity prices in Fig. 1. This strong correlation between these two variables growth rates have been outlined as a key characteristic of commodity exporting economies in a large strand of the literature and as a key factor by the South African Reserve Bank (SARB) and the Treasury to probe further the relationship between the mining sector and the overall economy.

[Insert Fig. 1 here]

On top of the real output growth data, in Fig. 1, we show the cross correlation among commodity prices and other main macro variables such as real investment, trade balance and the nominal central bank interest rate in Table 1. The table shows that there is a positive correlation of output, consumption, and investment. The total trade balance relation is negative. There is also a negative correlation between commodity price and the country’s specific nominal rate of interest. We document this fact in details in this section together with providing factual evidence of a negative correlation between commodity price and domestic credit loan premia, evidence which is pervasive in other commodity exporting economies. These key macro correlations are in line with facts noted for emerging commodity exporters.² Here we add to the literature by also providing real loan rate correlation.

[Insert Table 1 here]

Since the importance of the paper is around the channel between commodity price and financial markets, we first elaborate on the relationship behind the influence of commodity prices on emerging market business cycles. The key observation that has been highlighted in previous research on commodity exporting economies is the negative comovement of interest rate spreads and commodity prices. Garcia-Cicco et al. (2010), Fernández et al. (2015), Bastourre et al. (2012), Shousha (2016) and more recently, Drechsel and Tenreyro (2018) highlight the strong negative effect of commodity price increases on country risk premia in sovereign bond spreads. Earlier prominent works such as for instance, Uribe and Yue (2006) and Neumeyer and Perri (2005) have elaborated on this link. Since in this paper, we add an extra element to previous analysis by first positing that commodity firms are able to borrow on world market and hence face an interest rate spread which is very close to the world market rate of interest. Secondly, we analyze the loan premia relationship that the non-commodity sector faces and its relation with commodity price. It is worthwhile noting that pervasive evidence internationally shows that this relationship is equally negative. In this section, we analyze these effects empirically.

First, we analyze the beneficial effects of commodity price booms on South Africa’s key rate of interest by running a regression of South Africa real interest rate spread (using the money market rate) on the real commodity price, where

$$r_t - r_t^* = \alpha + \varsigma (\ln p_t^{X^*} - \ln p^{X^*}) + \beta X_t + \epsilon_t \quad (1)$$

r_t is the real interest rate of South Africa, r_t^* is a measure of the world interest rate (taken as the US), with both of these rates reflecting quarterly 3-month treasury bill rate.³ $p_t^{X^*}$ is the commodity price (with $\ln p_t^{X^*} - \ln p^{X^*}$ being the log deviation from mean (we take the mean to be the HP trend), and X_t is a vector of control variables including output growth, the debt-to-GDP ratio and the trade balance. The key parameter of interest is ς , which denotes the sensitivity of the real interest rate spread with respect to changes in world commodity prices. Note that this sensitivity parameter will also feature in our model and we will calibrate it based on the results presented in this section. The baseline results are presented in Table 2.

[Insert Table 2 here]

²See for instance Drechsel and Tenreyro (2018) for instance.

³We also try with an measure of the shadow rate estimated from yield curve data by Krippner (2013), which is the nominal interest rate that would prevail in the absence of its effective lower bound. The results are qualitatively the same.

The regression gives an estimate of -0.015 approximately for the parameter of interest, ς , which is statistically significant at the 10% significance level. This estimate is significantly smaller than the -0.2 estimate of Shousha (2016) for Chile and Drechsel and Tenreyro (2018) for Argentina. However, it is still provides evidence of a negative link between commodity price and interest rate spread.

Second, we analyze the impact of commodity price booms on South Africa’s domestic lending rate by running a regression of the South Africa real loan interest rate spread (computed as the difference between real loan rate and the US 3-month treasury bill rate) on the real commodity price, where

$$r_t^L - r_t^* = \alpha + \varsigma (\ln p_t^{X^*} - \ln p^{X^*}) + \beta X_t + \epsilon_t \quad (2)$$

Note that the loan premia, $r_t^L - r_t^*$, captures the credit premium faced by non-commodity sector in the domestic economy. The results are presented in Table 3.

[Insert Table 3 here]

The regression gives an estimate of -0.017 for the parameter of interest. Though small in magnitude, it provides evidence of a negative link between commodity price and loan premia in the domestic economy which is in line with the evidence in previous studies such as Dreschsel and Tenreyro (2018) have obtained for Chile for instance. As we later show per our model, though the non-commodity sector faces an overall negative credit premium, the sectoral downturn following a Dutch-disease scenario implies a falling credit per se.

4 Model

We consider an economy populated by the final goods producers, the intermediate goods, the importers, the capital producer, the commodity producer, the lender, the entrepreneur, the household and the central bank. Households consume and supply labor to firms. They can also borrow and save in the form of bank deposits and foreign bonds. The domestic economy consists of four sectors: a commodity sector, a non-commodity tradable retail sector, an imports sector and a sector that produces final goods and services. The commodity producer output are homogeneous and the price of these goods (in foreign currency) is determined entirely abroad. Their output is exported and sold to wholesale goods producers. Entrepreneurs (wholesale goods producers) unlike commodity producers face financial frictions and their external financing cost is decreasing in net worth, as in BGG. Hence banks are key in the transmission of shocks to the rest of the economy. Commodity products are used as one of the inputs together with capital and labor in the production of competitive wholesale goods. The domestic intermediate goods producer differentiate the wholesale goods so that individual firms have some market power and these retailers sell their goods locally and abroad. Firms in the import sector are imperfectly competitive and they purchase goods from abroad and sells them in the domestic economy. The final goods sector transforms the domestically sold output of the non-commodity tradable and imports sectors into final goods that are then sold to households for use in consumption or investment or to the public sector. Monetary policy has real effects because there are nominal frictions in the intermediate and imports sectors. Since we are interested in studying monetary policies, we consider a central bank with three policy instruments: the benchmark Taylor rule targeting inflation, price-level targeting and nominal GDP targeting.

4.1 Households

The economy is inhabited by a continuum of identical households. A typical household selects a sequence of consumption (C_t), labour supply (N_t), domestic (B_t) and foreign bond (B_t^*) holdings to maximise its discounted lifetime utility. The objective of the representative household is

$$E_t \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) \quad (3)$$

subject to the budget constraint in real terms

$$C_t = w_t N_t - T_t + \Pi_t - (B_t - (1 + r_{t-1}) B_{t-1}) - (s_t B_t^* - (1 + r_{F,t-1}) s_t B_{t-1}^*) \quad (4)$$

and labour supply is provided to both goods and commodity producing firms

$$N_t = N_t^G + N_t^X \quad (5)$$

where G, X stands for goods and commodity producing sectors respectively, s_t is the real exchange rate, w_t is the real wage in terms of consumption index ($w_t = \frac{W_t}{P_t}$ where P_t is the consumption price index and W_t is the nominal wage) and Π_t is the profits from all producers. In particular, following small open economy assumption, $r_{F,t}$, the interest rate on the foreign debt is a spread on the world rate of interest r_t^* determined by a premium term composed of two main additive terms:

$$r_{F,t} = r_t^* + \psi^{B^*} \left(e^{B_t^* - \bar{B}^*} - 1 \right) + \varsigma \left(\ln p_t^{X^*} - \ln p^{X^*} \right) \quad (6)$$

where the first term is standard in the literature as in Schmitt-Grohe and Uribe (2003) and reflects that the spread is increasing in the level of foreign debt relative to its steady state level. The second term is the term governing the sensitivity of the spread with respect to commodity price deviations from steady state and is similar to Drechsel and Tenreyro (2018), Shousha (2016) and Fernández et al. (2015), backed by the empirical evidence in the previous section. The parameter ς is negative and displays the decreasing premium following booming commodity price. We assume the following standard utility function⁴:

$$U(C_t, N_t) = \frac{C_t^{1-\sigma} - 1}{1-\sigma} - \frac{(N_t)^{1+\psi}}{1+\psi}, \quad (7)$$

where $\sigma, \psi > 0$

The first order conditions (FOCs) are as follows:

$$(C_t) : C_t^{-\sigma} = \Lambda_t \quad (8)$$

$$(n_t) : N_t^\psi = w_t \Lambda_t \quad (9)$$

$$(B_t) : \Lambda_t = \beta (1 + r_t) E_t \Lambda_{t+1} \quad (10)$$

$$(B_t^*) : s_t \Lambda_t = \beta (1 + r_{F,t}) E_t (s_{t+1} \Lambda_{t+1}) \quad (11)$$

The consumption Euler equation is given as

$$C_t^{-\sigma} = \beta (1 + r_t) E_t C_{t+1}^{-\sigma}, \quad (12)$$

the labor supply⁵ as

$$N_t^\psi = w_t C_t^{-\sigma}, \quad (13)$$

and the uncovered interest parity as

$$E_t \frac{s_{t+1}}{s_t} = \frac{(1 + r_t)}{(1 + r_{F,t})}, \quad (14)$$

and in log linearized term is:

$$r_t = r_t^* + E_t \ln \left(\frac{s_{t+1}}{s_t} \right) + \psi^{B^*} \left(e^{B_t^* - \bar{B}^*} - 1 \right) + \varsigma \left(\ln p_t^{X^*} - \ln p^{X^*} \right). \quad (15)$$

⁴The preferences in Greenwood et al. (1988) is often adopted for small open economy DSGE model following Mendoza (1991) where labor supply does not have an income effect. The utility function in this paper is similar to Medina and Soto (2007, 2016) among others for commodity exporting economies.

⁵It is worthwhile mentioning that the South African labour market, particularly, the commodity sector is heavily unionised. While we have tried a version of the model with unionised commodity and non-commodity sector, we chose not to pursue such model given the lack of data at the sectoral level on real wages and related variables.

4.2 Commodity Sector

The commodity sector is indexed by X . Production captures the importance of natural resources. The production uses capital (K_t^X), labour (N_t^X) and land (L_t). It follows Cobb Douglas technology

$$Y_t^X = a_t^X (K_t^X)^{\alpha_X} (N_t^X)^{\gamma_X} (L_t)^{1-\alpha_X-\gamma_X} \quad (16)$$

where α_X and γ_X are shares of capital and labour in production of commodities. It is assumed that supply of land evolves exogenously process

$$\log L_t = (1 - \rho_l) \log L + \rho_l \log L_{t-1} + \varepsilon_{lt} \quad (17)$$

where L is a steady state value of L_t , ρ_l is AR coefficient, and ε_{lt} is uncorrelated and normally distributed innovation with zero mean and standard deviation σ_l . A positive shock represents an increase in the supply of the natural resource factor due to favourable weather or a new mining discovery. The commodity output is divided into commodity exports (Y_t^{EXX}) and domestic uses (Y_t^{GX}) as direct input into the intermediate goods production, so that $Y_t^X = Y_t^{EXX} + Y_t^{GX}$.

Given a country is a net exporter of commodities, commodity price (P_t^{X*}) is set in the world market, denominated in the foreign currency, and affect the fluctuations in terms of trade and the economy of the considered country exogenously. Multiplying P_t^{X*} by the nominal exchange rate e_t yields the commodity producer's revenue for each commodity output in terms of domestic currency. The commodity producer chooses labour (N_t^X) and land (L_t) it needs for production to maximise the discounted lifetime real profit. It needs to borrow in order to buy capital stock. We assume that it does not face financial frictions. It uses loan ($loan_t$) that it borrows at nominal gross rate (R_t) to buy capital (K_{t+1}^X) in the present period to be used in the production in the next period. At the end of the period after producing commodity output, the producer sells back the undepreciated capital stock back to the capital producer at the price Q_t . The commodity producer purchases capital from the capital producers at price Q_t .⁶ The one-period real profit function is

$$\pi_t^X = \frac{1}{P_t} [e_t P_t^{X*} Y_t^X - Q_t K_{t+1}^X - W_{Xt} N_t^X - P_{Lt} L_t + Q_t (1 - \delta) K_t^X + loan_t - R_{t-1} loan_{t-1}]. \quad (18)$$

The commodity producer maximizes

$$\max_{K_{t+1}^X, N_t^X, L_t, loan_t} E_t \sum_{t=0}^{\infty} \beta^t \frac{1}{P_t} [e_t P_t^{X*} Y_t^X - Q_t K_{t+1}^X - W_t N_t^X - P_{Lt} L_t + Q_t (1 - \delta) K_t^X + loan_t - R_{t-1} loan_{t-1}]$$

subject to the production function (Eq. (16))

$$Y_t^X = (K_t^X)^{\alpha_X} (N_t^X)^{\gamma_X} (L_t)^{1-\alpha_X-\gamma_X}.$$

The FOCs yields

$$(K_{t+1}^X) : q_t = \beta E_t \left[(1 - \delta) q_{t+1} + \alpha_X s_{t+1} p_{t+1}^{X*} \frac{Y_{t+1}^X}{K_{t+1}^X} \right] \quad (19)$$

$$(N_t^X) : w_t = \gamma_X s_t p_t^{X*} \frac{Y_t^X}{N_t^X} \quad (20)$$

$$(L_t) : p_{Lt} = (1 - \alpha_X - \gamma_X) s_t p_t^{X*} \frac{Y_t^X}{L_t} \quad (21)$$

$$(loans) : 1 = \beta R_t E_t \frac{1}{\Pi_{t+1}} \quad (22)$$

⁶It is important to assume that the price of capital faced by both the commodity and non-commodity sector is the same in order for both sectors to face a fall in credit premium following a commodity price boom, which is factual evidence as we noted in the previous sector. In García-Cicco and Kawamura (2015), there are two group of capital producers for the two sectors and hence the price of capital differs.

where $e_t = \frac{s_t P_t^*}{P_t}$ – the real exchange rate, $p_t^{X^*} = \frac{P_t^{X^*}}{P_t}$ denotes the real commodity price, $q_t = \frac{Q_t}{P_t}$ denotes the real capital price and $p_{lt} = \frac{P_{lt}}{P_t}$ denotes the real land price. These equations dictate the demand for capital, labour, land and loan in this sector. They say that marginal cost of each input must be equal to its marginal productivity. We combine the demand for capital and loan together to get the real return on capital

$$R_t E_t \frac{1}{\pi_{t+1}} = \frac{E_t \left[(1 - \delta) q_{t+1} + \alpha_X s_{t+1} p_{t+1}^{X^*} \frac{Y_{t+1}^X}{K_{t+1}^{X^*}} \right]}{q_t}. \quad (23)$$

We assume that the real commodity price $p_t^{X^*}$ evolves as

$$\log p_t^{X^*} = (1 - \rho_{p_X}) \log p_t^{X^*} + \rho_{p_X} \log p_{t-1}^{X^*} + \varepsilon_{p_X t} \quad (24)$$

The shock is a shock to the terms of trade and it is normally distributed.

4.3 Goods sector

There are a continuum of risk neutral entrepreneurs in this sector. Based on BGG, at time t , an entrepreneur j purchases stock of capital $K_{t+1}^G(j)$ to use in the next period production. It finances this capital expenditure with its own internal resources, the network, and loans. We assume bank loans only come from the domestic market. There is asymmetric information between the bank and the entrepreneur regarding the realised returns of capital and thus the entrepreneur has to pay a risk premium on loans. The good producer purchases capital from the capital producers at price Q_t . Therefore, the expected return on capital must equal the expected cost of external finance, and thus the premium ($prem_t$) is represented as

$$prem_t = E_t \left(\frac{r_{t+1}^k}{\beta r_t} \right) = f \left(\frac{q_t K_t^G}{nw_t} \right) \quad (25)$$

where nw_t denotes the network of the entrepreneur and it is $nw_t = \eta \left(r_t^k q_{t-1} K_t^G - \frac{R_{t-1} prem_{t-1}}{\pi_t} loan_{t-1} \right)$ and the bankrupt entrepreneur's consumption is $CE_t = (1 - \eta) \left(r_t^k q_{t-1} K_t^G - \frac{R_{t-1} prem_{t-1}}{\pi_t} loan_{t-1} \right)$. The entrepreneur j uses capital ($K_t^G(j)$), labour ($N_t^G(j)$) and commodity input ($Y_t^{GX}(j)$) to produce wholesale good $Y_t^G(j)$

$$Y_t^G(j) = a_t (K_t^G(j))^{\alpha_G} (N_t^G(j))^{\gamma_G} (Y_t^{GX}(j))^{1 - \alpha_G - \gamma_G} \quad (26)$$

where a_t is the technology shock and follows $\log a_t = \rho_a \log a_{t-1} + \varepsilon_t^a$. The entrepreneur wants to maximise the discounted profit function

$$\max_{K_{t+1}^G(j), N_t^G(j), loan_t^G(j)} E_t \sum_{t=0}^{\infty} \beta^t \frac{1}{P_t} \left[\frac{P_t^W Y_t^G(j) - Q_t K_{t+1}^G(j) - W_t N_t^G(j) - e_t P_t^{X^*} Y_t^{GX}(j) +}{Q_t (1 - \delta) K_t^G(j) + loan_t^G - prem_{t-1} R_{t-1} loan_{t-1}^G} \right] \quad (27)$$

The FOCs are

$$(K_{t+1}^G(j)) : \beta E_t \left[\alpha_G p_{t+1}^W \frac{Y_{t+1}^G(j)}{K_{t+1}^G(j)} + q_{t+1} (1 - \delta) \right] = q_t \quad (28)$$

$$(N_t^G(j)) : w_t = \alpha_G p_t^W \frac{Y_t^G(j)}{N_t^G(j)} \quad (29)$$

$$(Y_t^{GX}(j)) : (1 - \alpha_G - \gamma_G) p_t^W \frac{Y_t^G(j)}{Y_t^{GX}(j)} = s_t p_t^{X^*} \quad (30)$$

$$(loan_t(j)) : 1 = \beta E_t \left(\frac{R_t prem_t}{\pi_{t+1}} \right) \quad (31)$$

Using Eq. (28) and (31), the demand for capital is

$$\frac{E_t \left[\alpha_G p_{t+1}^W \frac{Y_{t+1}^G(j)}{K_{t+1}^G(j)} + q_{t+1} (1 - \delta) \right]}{q_t} = E_t \left(\frac{R_t prem_t}{\pi_{t+1}} \right) \quad (32)$$

After aggregation, these demand equations can be rewritten as

$$E_t \left(\frac{R_t p_{rem_t}}{\pi_{t+1}} \right) = \frac{E_t \left[\alpha_G p_{t+1}^W \frac{Y_{t+1}^G}{K_{t+1}^G} + q_{t+1} (1 - \delta) \right]}{q_t} \quad (33)$$

$$w_t = \alpha_G p_t^W \frac{Y_t^G}{N_t^G} \quad (34)$$

$$s_t p_t^{X^*} = (1 - \alpha_G - \gamma_G) p_t^W \frac{Y_t^G}{Y_t^{GX}} \quad (35)$$

4.4 Sectoral goods

Sectoral goods retailer buys the inputs from entrepreneurs ($Y_t^G(j)$) at the price P_t^G and differentiates them slightly into $z_t^G(j)$ and sells at price $P_t^G(j)$. The final good of this sector or the retail output is

$$z_t^G = \left[\int_0^1 (Y_t^G(j))^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} \quad (36)$$

The price index that minimises the retailer's cost is

$$P_t^G = \left[\int_0^1 (P_t^G(j))^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}} \quad (37)$$

We assume that only a fraction $(1 - v_G)$ of retailers reset their prices, while the remaining retailers cannot re-optimize their prices and thus set their prices following the indexation rule $P_t^G(j) = (\Pi_{t-1}^G)^{\chi_G} P_{t-1}^G(j)$, where $\Pi_{t-1}^G = \frac{P_t^G}{P_{t-1}^G}$ and χ_G is the partial indexation coefficient. The retailer would choose $P_t^G(j)$ to maximise its present value of the expected future total profit over the periods during which its prices cannot be reoptimised again

$$E_t \sum_{i=0}^{\infty} (\beta v_G)^i \lambda_{t+i} [P_t^G(j) Y_{t+i}^G(j) - MC_{t+i} Y_{t+i}^G(j)], \quad (38)$$

where MC_t is the marginal cost and it is equal to the price of wholesale goods P_t^W . The optimal price chosen by all firms adjusting at time t

$$P_t^{G*} = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{i=0}^{\infty} (v_G \beta)^i \lambda_{t+i} MC_{t+i} Y_{t+i}^G \left(\frac{1}{P_{t+i}^G} \right)^{-\epsilon}}{E_t \sum_{i=0}^{\infty} (v_G \beta)^i \lambda_{t+i} Y_{t+i}^G \left(\frac{1}{P_{t+i}^G} \right)^{-\epsilon}} \quad (39)$$

Thus the aggregate price evolves according to

$$P_t^G = \left[v_G (\Pi_{t-1}^G)^{\chi_G (1-\epsilon)} (P_{t-1}^G)^{1-\epsilon} + (1 - v_G) (P_t^{G*})^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}. \quad (40)$$

The sectoral goods get exported and used in domestic demand so that

$$z_t^G = z_t^{GEX} + z_t^D \quad (41)$$

where the aggregate foreign demand for domestically produced exports is

$$z_t^{GEX} = \omega \left(\frac{P_t^G}{e_t P_t^*} \right)^{-v^*} Y_t^* \quad (42)$$

where Y_t^* is foreign output. The elasticity of demand for domestic goods is $-v^*$ and $\omega > 0$ is a parameter determining the fraction in foreign spending of domestic goods exported.

4.5 Imports Producer

For the imports sector, the sectoral goods producers buy foreign homogenous intermediate inputs z_t^{IM} and differentiate them slightly so that the sectoral final output is

$$z_t^{IM} = \left[\int_0^1 (Y_t^{IM}(j))^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} \quad (43)$$

and the price index is

$$P_t^{IM} = \left[\int_0^1 (P_t^{IM}(j))^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}} \quad (44)$$

We also assume that only a fraction $(1 - v_{IM})$ of importers reset their prices, while the remaining importers set their prices following the indexation rule $P_t^{IM}(j) = (\Pi_{t-1}^{IM})^{\chi_{IM}} P_{t-1}^{IM}(j)$, where $\Pi_{t-1}^{IM} = \frac{P_t^{IM}}{P_{t-1}^{IM}}$. The importer would choose $P_t^{IM}(j)$ to maximise its present value of the expected future total profit over the periods during which that price is effective

$$E_t \sum_{i=0}^{\infty} (v_{IM}\beta)^i \lambda_{t+i} [P_t^{IM}(j) Y_{t+i}^{IM}(j) - MC_{t+i}^{IM} Y_{t+i}^{IM}(j)], \quad (45)$$

where MC_t^{IM} is the marginal cost and it is equal the foreign price in domestic currency $e_t P_t^*$. The optimal price chosen by all importers that can adjust at time t is

$$P_t^{IM*} = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{i=0}^{\infty} (v_{IM}\beta)^i \lambda_{t+i} MC_{t+i}^{IM} Y_{t+i}^{IM} \left(\frac{1}{P_{t+i}^{IM}} \right)^{-\epsilon}}{E_t \sum_{i=0}^{\infty} (v_{IM}\beta)^i \lambda_{t+i} Y_{t+i}^{IM} \left(\frac{1}{P_{t+i}^{IM}} \right)^{-\epsilon}} \quad (46)$$

Thus the aggregate price evolves according to

$$P_t^{IM} = \left[v_{IM} (\Pi_{t-1}^{IM})^{\chi_{IM}(1-\epsilon)} (P_{t-1}^{IM})^{1-\epsilon} + (1 - v_{IM}) (P_t^{IM*})^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}. \quad (47)$$

4.6 Capital Producer

At the end of period $t - 1$, the capital producer sells capital stock, K_t^j (for $j = G, X$), to entrepreneurs and also the commodity producer respectively, to use in the period t production. After the wholesale goods output and commodity output have been sold, both entrepreneurs and commodity producer sell back to the capital producer the undepreciated stock of capital. The capital producer then builds new capital stock by consuming investment goods (I_t) and undepreciated capital $(1 - \delta) K_{t-1}$. The capital producer problem is to choose investment level to maximise its discounted revenue

$$\max_{I_t} E_t \sum_{t=0}^{\infty} \beta^t [q_t (K_t - (1 - \delta) K_{t-1}) - I_t] \quad (48)$$

subject to the capital evolution

$$K_t = (1 - \delta) K_{t-1} + \left[1 - \Phi \left(\frac{I_t}{I_{t-1}} \right) \right] I_t, \quad (49)$$

where we introduce the investment adjustment cost $\Phi(\cdot)$. The first order condition denotes the demand for investment and is as follows

$$q_t = \left[\left(1 - \Phi \left(\frac{I_t}{I_{t-1}} \right) - \Phi' \left(\frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} \right) + \beta \left(\frac{q_{t+1}}{q_t} \left(\frac{I_{t-1}}{I_t} \right)^2 \Phi' \left(\frac{I_{t-1}}{I_t} \right) \right) \right]^{-1} \quad (50)$$

4.7 Final goods

A representative firm acts in a perfectly competitive market and uses sectoral outputs to produce final consumption, investment goods and government spending. The production follows CES technology

$$Y_t = \left[\omega_{IM}^{\frac{1}{v}} (z_t^{IM})^{\frac{v-1}{v}} + (1 - \omega_{IM})^{\frac{1}{v}} (z_t^D)^{\frac{v-1}{v}} \right]^{\frac{v}{v-1}} \quad (51)$$

where ω_{IM} denotes the share of imported composite sectoral goods in the final goods and $v > 0$ denotes the elasticity of substitution between sectoral goods.

Given P_t, P_t^{IM} and P_t^G , the final good producer chooses z_t^{IM} and z_t^D to maximise its real profit. Its problem is as follows

$$\max_{z_t^{IM}, z_t^D} \frac{1}{P_t} (P_t Y_t - P_t^{IM} z_t^{IM} - P_t^G z_t^D) \quad (52)$$

subject to the CES technology, eq (51). This profit maximisation implies the following demand functions for domestically produced goods and imports

$$z_t^D = (1 - \omega_{IM}) \left(\frac{P_t^G}{P_t} \right)^{-v} Y_t; \quad (53)$$

$$z_t^{IM} = \omega_{IM} \left(\frac{P_t^{IM}}{P_t} \right)^{-v} Y_t \quad (54)$$

These demands are negatively related to their relative prices. The zero profit assumption implies that the final good price level (P_t), i.e. the consumer price index, is linked to the price of domestically produced goods and imported goods prices in the following manner

$$P_t = \left[\omega_{IM} (P_t^{IM})^{1-v} + (1 - \omega_{IM}) (P_t^G)^{1-v} \right]^{\frac{1}{1-v}}. \quad (55)$$

The final good is divided between consumption (of entrepreneurs and consumers), private investment in capital production sector and government spending

$$Y_t = C_t + ce_t + I_t + G_t \quad (56)$$

where the government is assumed to follow a balance budget and the government spending follows an AR(1) process $\log G_t = (1 - \rho_G) \log G + \rho_G \log G_{t-1} + \varepsilon_t^G$.

The real GDP, YY_t is defined as

$$YY_t = p_t^G \left(z_t^G - \frac{s_t p_t^{X*} Y_t^{GX}}{p_t^G} \right) + s_t p_t^{X*} Y_t^X. \quad (57)$$

Last but not least, net foreign asset holdings evolve according to

$$b_t^* = \frac{b_{t-1}^* R_{t-1}^*}{\pi_t^*} + p_t^{X*} (Y_t^X - Y_t^{GX}) + \frac{p_t^G}{s_t} z_t^{GEX} - z_t^{IM} \quad (58)$$

where $b_t^* = B_t^*/P_t^*$ is the stock of real foreign debt in the domestic economy.

4.8 Monetary policy

For the initial modelling and estimating purposes we assume that monetary behaviour in South Africa can be described by the standard Taylor rule. In extending the analysis to question whether alternative monetary regimes would change the macroeconomic outcomes, we consider the price level targeting (PLT) and nominal GDP targeting monetary regimes (NGDPT).

4.8.1 Taylor Rule

Monetary policy follows a simple Taylor rule

$$r_t^n = \rho_R r_{t-1}^n + (1 - \rho_R) \{ \rho_\pi \pi_t + \rho_{YY} y_t \} + \varepsilon_{Rt} \quad (59)$$

where ε_{Rt} is a monetary policy shock that follows the AR(1) process.

4.8.2 Price-level targeting regime

Under price-level targeting (PLT), inflation expectations adjust to stabilise the economy: if an unanticipated shock pushes the price level below the target, people will expect higher than average inflation in the future to bring the price level back to the target. PLT has two advantages over inflation targeting. First, due to the automatic adjustment in inflation expectations, the central bank does not need to move interest rates aggressively in response to shocks (Cover and Pecorino, 2005), thus it reduces the likelihood of hitting the zero bound. Second, the zero lower bound situation and the recession associated with it has renewed interest in PLT in that it can generate positive inflation expectations in a deflationary situation, lowering real interest rates even at the zero bound and so strengthen recovery. For instance, Wolman, 2005; Vestin, 2006; Nakov, 2008; and Dib et al, 2008; for a recent survey see Hatcher and Minford, 2014, have found PLT targeting as a better alternative monetary policy that can achieve price stability while also reducing the impact of the zero lower bound. While in the context of this paper, commodity exporting economies have been less frequented by the zero lower bound, yet, a commodity price boom is usually accompanied by a real exchange rate appreciation and hence deflationary pressures.

The PLT rule is specified as follows:

$$r_t^n = \rho_R r_{t-1}^n + (1 - \rho_R) \{ \rho_\pi (p_t - \bar{p}) + \rho_{YY} (y_t - y^*) \} + \varepsilon_{Rt} \quad (60)$$

where under the zero inflation steady state, the steady price level is assumed constant here and normalised as $\bar{p} = 0$.

4.8.3 Nominal GDP targeting

Market Monetarists who run a widely-accessed blog on monetary policy, have been calling for monetary policy to target the level of nominal GDP, i.e., nominal GDP Targeting (NGDPT), rather than either a monetary aggregate or inflation (Sumner 2011, Nunes and Cole 2013). A similar proposal was made some time ago in a series of papers by McCallum (1988) and McCallum and Nelson (1999) who suggested a rule setting interest rates in response to deviations of nominal GDP growth from a target rate. McCallum argued that this rule would be superior to monetary targeting because of the large and unpredictable changes in payments technology and financial regulations. Compared with the later Taylor Rule McCallum's rule has interest rates responding as strongly to output growth deviations as to inflation deviations. However, Market Monetarists argue for targeting the level of NGDP rather than its growth rate; the reasons are similar to those for PLT, except that in this case an expected future interest rate stimulus is triggered also by output falling below its trend (McCallum, 2011). The NGDP rule generates expectations of very strong monetary responses in conditions of prolonged recession – analogous to Roosevelt's 1930s abandonment of the Gold Standard (Krugman, 2011; Carney, 2012 and Woodford, 2012).

Implementing the NGDP target, the central bank would specify an intermediate target for the official interest rate. The rule might be written as follows:

$$r_t^n = \rho_R r_{t-1}^n + (1 - \rho_R) \{ \rho_{YY} (y_t + p_t - \bar{y}_t - \bar{p}) \} + \varepsilon_{Rt} \quad (61)$$

where $\bar{y}_t + \bar{p}$ is the target for NGDP, where $\bar{p} = 0$ and \bar{y}_t follows the trend path in real output generated by productivity.

5 Model calibration and estimated parameters

We use Bayesian estimation method to estimate the model with the data sample period from 1999.04 until 2017.01. The start date is chosen to account for the large structural break post 1994 when the economy

acceded to democratic independence and hence the veto on trade were lifted and the date is chosen when sectoral data for commodity production and prices became available. The description of the dataset are provided in the Appendix. All the data with the exception of interest rates is logged and detrended using the first difference method.

In this section we first analyze the calibrated and estimated parameters of the model since these are used in the next section’s model’s estimated impulse response functions. We calibrate some parameters to match long run moments of the data, such as government spending share to GDP while we estimate the remaining parameters by Bayesian maximum likelihood so as to ensure that the model provides an empirically realistic fit to observed data. The estimated model is the model with the inflation targeting regime (i.e., Taylor rule that targets the inflation rate) which is the adopted regime of the South African Reserve Bank.

The calibrated parameters and their values are listed in Table 4 and they follow to a large extent the same values as in studies conducted for South Africa, viz., Steinbach et al. (2009), Alpanda et al. (2010, 2011), Jooste et al. (2013) and Gupta and Hollander (2016) and these values are in line with prominent studies on SoEs, as in for instance, Adolfson et al. (2007), Medina and Soto (2007) and Fornero and Kirchner (2014) for commodity exporting economies such as Chile and Drechsel and Tenreyro (2018) for Argentina.

[Insert Table 4 here]

We use a quarterly frequency for the model. The discount factor is set to $\beta = 0.995$, which implies an annualized risk-free interest rate of two percent which is in line with estimations for the neutral interest rate in South Africa. The Frisch labor supply elasticity is set to one-third, implying $\psi = 3$. The intertemporal elasticity of substitution is fixed at 1.5. The elasticity of substitution between domestic and imported consumption goods in aggregate demand is set to 3.0, which is consistent with values used for studies in South Africa. The share of domestic produced goods in aggregate demand ($1 - \omega_{IM}$) is 74%, which is consistent with the average fraction of domestic goods in the CPI basket since 2009. The annual depreciation rate of capital is 10%. Producers of commodities have a constant return technology the share of capital and labor are respectively 10% and 29% in production given the use of land in this industry. The production of wholesale goods have the share of capital and labor at 29% and 63% in production. The elasticity of the international external premium to foreign debt, ψ^{B^*} , is set to 0.01, a standard calibrated value in the literature. The steady-state external finance premium, S , is set to 1.008, corresponding to an annual risk spread of 300 basis points, equal to the sample average spread between the business prime lending rate and the three-month Treasury bill rate in South Africa. Following Bernanke et al. (1999), we set the steady-state ratio of capital to net worth, $\frac{K^G}{NW}$, equal to 1.7. This implies a firm leverage ratio, defined as the ratio of debt to assets, of 0.41, close to the leverage ratio of the manufacturing sector in South Africa. We also use Bernanke et al. (1999) value of 0.9728 for the survival rate of entrepreneurs, η , implying an expected working life for entrepreneurs of 36 years. Finally, we set the steady-state ratio of government spending to output at 18%, which is roughly in the data. We set the persistence to land to 0.8 on the ground that land ownership has been pretty stagnant in South Africa.

In Table 5, we report the prior and posterior distributions of the estimated parameters. These results are broadly consistent with previous literature on estimation of DSGE models in South Africa and the literature in general. The parameter, ς , the elasticity of the external premium with respect to commodity price implies an estimate of -0.0325 , in line with our regression result in the empirical section. The estimates obtained by Drechsel and Tenreyro (2018) for Chile is higher and in the vicinity of -0.2 . The investment adjustment cost parameter, ϕ , implies significant real inertia. The estimated value of the key parameter of the financial accelerator mechanism, κ , the elasticity of the external finance premium with respect to firm leverage is 0.23 and statistically different from zero and much larger than previous literature of 0.05 value often used to calibrate this parameter for the US (see for example, Bernanke et al., 1999; Bernanke and Gertler, 2000; Fukunaga, 2002; and Gilchrist, 2004). This value tends to suggest that changes in the premia has negligible effects on amount borrowed or vice-versa, an increase in credit carries a rather abrupt increase in the credit premia, a feature which is in line with the highly non-competitive credit system in South Africa that has a few large banks.⁷ There is ample rigidity in both domestic good producer prices and imported good prices, together with moderate indexation. These are consistent with evidence on product markets competition presented in Fedderke and Schaling (2005) for South Africa. The foreign demand for domestic traded goods

⁷See evidence in for example, Okeahalam & Maxwell (2001), Falkena et al. (2004) and Simbanegavi et al. (2014).

has an elasticity of 3.6175, which is quite high and in line with recent aggregate estimation for the export demand in South Africa (Gupta and Hollander, 2016) and higher than studies in Chile (see Monfort, 2008 and Fornero and Kirchner, 2014). The estimated monetary policy parameters show a response to inflation which is in line with the Taylor rule principle and a somehow modest response to the output gap. Finally, the persistence of the autoregressive processes follow a beta distribution with prior mean 0.8 and standard deviation of 0.1 and their posterior distribution suggest relatively high persistence and the standard errors of the innovations follow an inverse-gamma distribution with prior mean 0.1 and a standard deviation of 2.

[Insert Table 5 here]

6 The Dynamics and Evaluation of Estimated Model

In this section, we first use the estimated model with the inflation targeting regime which is the adopted regime of the South African Reserve Bank to analyse the dynamic behaviour of the model in response to different macroeconomic shocks, viz., unanticipated shocks to monetary policy, risk premiums (banking shock) and world interest rate. This set of shocks is relevant for understanding the behaviour of the South African economy over recent decades and allows us to compare our model to others in the literature. These are also shocks that illustrate how aggregate disturbances can have differing implications for the various sectors of the economy. Secondly, we study the estimated model implications for the business cycles characteristics we have found in the data by first focussing on shocks to the commodity price and using the benchmark model with a Taylor rule targeting inflation to investigate the three channels of a commodity price shock, viz., the ‘competitiveness’, the ‘borrowing cost’ and the ‘financial market’ channels. Lastly, we focus on the main issue of the paper which is to analyse the choice of monetary regimes amongst different specifications of Taylor rule with targeting inflation (Taylor rule), price-level targeting (PLT) and nominal GDP targeting (NGDPT), in responding to the commodity price shock. In order to do the policy analysis, we plot the IRFs to commodity price shocks for the three different Taylor rule, where the estimated coefficients used are those for inflation targeting since the other two regimes are hypothetical rules, so we can use the same estimated coefficients for the momentary policy but with new targets. We then evaluate the three policy regimes and their implications for the theoretical variance of key variables.

We now show the dynamic behaviour of the estimated model IRFs under the inflation targeting regime in response to different macroeconomic shocks, viz., unanticipated shocks to monetary policy, risk premiums (banking shock) and world interest rate

Monetary policy shock registers responses in domestic variables⁸ consistent with economic theory and similar to most New Keynesian models. Figure 2 shows the effects of an increase in the nominal interest rate. The real interest rate rises, discouraging both consumption and investment. This reduces output and real wages. It also lowers entrepreneurs’ net worth for goods producers which contributes to the further drop in investment by goods producers. In the calibrated IRF version of the model, the risk premium increases. However the estimated model provides different result concerning this variable. Overall the aggregate domestic demand decreases. This means the production of final goods decreases, thus they would demand less of domestically produced intermediate goods and imports. CPI Inflation decreases and real interest rate increases leads to real appreciation, thus demand for goods exports decreases. With less demand for goods exports and goods intermediate for the final production, there is less demand for goods overall. Thus production of goods decreases. Demand for labour, capital and commodity inputs decrease in the goods sectors. Since there is an increase in real interest rate, there is real appreciation and real depreciation is expected. The commodity producer who sells their product at foreign price will want to produce as much now and sell in this period. Thus their production increases and demand for inputs in this sector, labor and capital increase. With more demand for resources and the supply being fixed means that price of resources, i.e., price of land increases. There is more production, but less demand for commodity at home and commodity exports increases, though overall export falls. The overall impact on local financial market is translated into lower credit growth.

⁸Trade balance is scaled by GDP as is commonly done in the literature.

[Insert Fig. 2 here]

Credit premium shock The effects of a financial crisis are approximated here by a credit premium shock. Figure 3 shows that a higher credit premium results in lower output, consumption, investment, net worth and capital. The goods sector contracts tremendously due to higher credit cost and the amount of debt contracts as well. The commodity sector also depresses overall together with exports. It is clear from these impulse responses that macro-prudential policy is feasible in principle. However we do not pursue it here as a potential reform because for it to operate as a stabilisation tool regulative policy needs to be set at a distortionary level, so that its tightness can be both raised and lowered (see Le et al. (2017) for a discussion). Inflation rate increases due to the negative supply effect on output hence calling for an increase in the nominal interest rate.

[Insert Fig. 3 here]

Foreign interest rate shock Figure 4 shows that an increase in foreign nominal interest rate leads to consumers prefer buying more foreign bonds at the expense of lower consumption. This increases the marginal utility of consumption and thus increases the real interest rate. This decreases the demand for capital and investment and decreases the price of existing capital. As the goods producers has to buy capital, they would demand more of it but lower capital price means that their networth is less and the premium is higher (the risk premium initially increases slightly), overall hence they demand less capital. Domestic demand decreases overall. A higher nominal interest rate causes a real depreciation, thus goods exports increases and import inflation rises as imports are now more expensive and demand for imports is lower. The commodity input, sold in foreign currency, is cheaper. However with higher price of capital together with a depreciation, the supply side of commodity production is affected and hence a real depreciation means the commodity producer produces less. They demand less capital, labour, but substitute by using more resources, since these firms still need to satisfy an increasing domestic demand for its output. Hence resources price go up.

[Insert Fig. 4 here]

For the second exercise, we study how a positive commodity price shock translates into the economy via the three channels we have outlined above, the ‘competitiveness’, the ‘borrowing cost’ channel and the ‘financial market’ channels. Fig. 5 depicts three models using the estimated parameters of the benchmark inflation-targeting Taylor rule. The ‘benchmark’ case is the model that includes all three effects, The ‘competitiveness effect’ case is the model that has the term ς in equation (1) set to zero ($\varsigma \neq 0$) by shutting off the channel through the interest rate and the ‘financial market effect’ case is the model that has financial friction set equal to zero, i.e., the non-commodity goods sector does not face a credit premium with $prem_t = 0$ in equation (25). First, we note that the benchmark model (including the ‘financial market effect’) registers an increase in investment response which is the strongest, and the consumption response is larger in magnitude than the output response and there is a negative total trade balance with total net exports being countercyclical, hence replicating pervasive factual evidence for commodity exporting and emerging market economies. There is a real exchange rate appreciation. To obtain these effects, we need the double-role of commodity prices as noted by Drechsel and Tenreyro (2018). They term the two effects as the ‘competitiveness’ channel which is increasing the output in the commodity sector, hence increasing the country’s revenue, however it also depresses the other sector, the Dutch disease effect, by a sectoral re-allocation in terms of factor inputs and also increasing the input cost of the non-commodity sector since it uses commodity as a factor input. However the commodity boom outweighs the other effects, increasing output and total exports, hence creating a positive trade balance. Hence this effect alone does not generate a countercyclical total trade balance, which is a salient feature in emerging economy business cycle data as in Schmitt-Grohe and Uribe (2003) for instance. Hence the second effect, the ‘borrowing cost’ channel which does not cause any effect on output in either sector, however decreases the economy’s borrowing rate and the world interest rate. This effect is governed by the negative sensitivity of the interest spread $r_{F,t} - r_t^*$ to commodity prices present in the term ς in equation (1) and based on the empirical evidence in Section 3. This exogenous fall in borrowing rates allows households and firms in the present to increase consumption and investment, hence inducing the increase in domestic absorption that causes the countercyclical total net export effects.

[Insert Fig. 5 here]

In this paper, we coin a third channel as the ‘financial market’ effect. In the benchmark case, the Dutch-disease problem is less pronounced since the booming commodity price causes the networth of the entrepreneur to increase and the credit premium to fall and hence the sectoral re-allocation that causes output and factor inputs (capital) in this sector to fall is less pronounced. A comparison with the model without the credit premium, i.e., the ‘financial market effect’ case shows that the sectoral downturn is more pronounced since without a fall in credit premium, the non-commodity sector registers a more sizeable fall in output. The presence of the financial accelerator in this model hence causes a bigger boom. Nevertheless, the commodity price boom effect opens the scope for policy stabilization due to the Dutch disease sectoral re-allocation and the fall in entrepreneur credit.

In this last part, we investigate the choice of monetary regimes amongst different specifications of Taylor rule with targeting inflation (Taylor), price-level targeting (PLT) and nominal GDP targeting (NGDPT), in response to the commodity shock.

Commodity price shock is of particular importance to the dynamics of the SoE since commodities are main exports and are also used as factor inputs in the production of domestic goods. The higher commodity prices raise domestic revenues together with demand. The booming commodity sector registers a competitiveness effect. The real exchange rate appreciation lowers the cost of imported goods. In the Dutch disease literature, this is called the spending effect. In South Africa, an important share of imported goods goes into household consumption. As the borrowing cost falls via the effect of commodity prices on external finance premium, consumption and investment, mainly driven by the investment in commodity market. In terms of sectoral re-allocation, the other sector, the wholesale good sector contracts, the Dutch disease issue. Consistent with the patterns of production, the increase in investment is concentrated in the commodity sector while investment in the other sectors experiences a fall. This is further reiterated by the fall in credit as shown in Fig. 6. The real exchange rate appreciation and lower cost of imported goods are in line with a fall in inflation. Comparing across the three policy regimes, we see that in line with previous evidence, PLT, due to the faster adjustment in higher inflation expectations, calls for the central bank not to move interest rates aggressively in response to commodity price shocks and altogether entails lesser disinflationary pressures, whereas inflation targeting regime causes an abrupt cut in the policy rate due to the current appreciation of the real exchange rate and deflation. The higher increase in the real interest rate is also translated into a bigger fall in credit.

[Insert Fig. 6 here]

We next evaluate the theoretical variance of key variables for the three policy regimes.⁹ We have already seen that the model with PLT induces less variance in inflation and financial market variability than inflation targeting (Taylor) and partly NGDPT mainly due to its ability to control inflation expectations and hence leading to less variability in real interest rate and credit premium. As can be seen in Table 6, the results are mixed with the inflation-targeting Taylor rule regime producing slightly lower variances for output, consumption and investment at the cost of much higher variance in inflation and the nominal interest rate. Importantly, PLT and NGDPT produce way much lower inflation variance together with greater stability for financial markets variables, especially risk premium and credit growth. Hence though the inflation-targeting Taylor rule regime outperforms both PLT and NGDPT with output variance if one uses either output variance or consumption variance as a standard welfare cost measure, yet, PLT outperforms all regimes in terms of inflation variance and NGDPT seems to be doing much better than IT regime in that instance. If one wishes to minimise inflation variance the best way to increase stability is the straight PLT regime on its own, but with NGDPT on its own the central bank needs to assess a forecast of output correctly, which may cause difficulties as has been discussed in the literature. Hence while an inflation-targeting Taylor rule performs somewhat better for some real variables, namely output and consumption, we can confirm that PLT provides better inflation stability and lower variance for financial market variables in line with NGDPT in a model with sticky prices, commodity and financial markets.

[Insert Table 6 here]

⁹Since we estimate the log-linearized version of the model, we defer welfare computation of the models which can be interesting for future research. Using theoretical variances of the models as done in this paper is a rather sound alternative since output and consumption variances are approximate measures of welfare.

7 Conclusion

In this paper, we attempt to shed light on the channel that exists between commodity price shocks and financial markets in South Africa and highlight the role of monetary policy in stabilising the economy. In our model, booming commodity prices increase the country's competitiveness and lower their borrowing costs, however the Dutch-disease problem registers a fall in credit in the non-commodity sector due to the sectoral re-allocation and despite falling credit premium. This means that policy stabilization has a role to play.

We show that the implications from our estimated model with the inflation-targeting regime are in line with previous results in literature and theory. We also show that the model predictions are in line with the data in South Africa which is broadly in line with similar commodity exporting economies business cycles. In particular, we see that a commodity price shock entails both a competitiveness and borrowing cost effects with procyclicality in main macro variables and a countercyclical trade balance, together with a sectoral downturn in the non-commodity sector which faces lower credit. We also show that a model with financial accelerator exacerbates the commodity price boom due to falling credit premium.

Lastly, we analyze the performance for three monetary regimes in terms of their IRFs and implications for the variance of main macro variables. We suggest that price-level targeting can substantially stabilize inflation. Due to its adjustment expectations mechanism in New Keynesian models because an increase in expected inflation raises current inflation, it can lead to smaller changes in inflation following commodity price shocks which usually appreciate the real exchange rate leading to deflationary pressures which are more pronounced under inflation-targeting regime. Under price-level targeting, a real exchange rate appreciation entails higher future expected inflation and hence dampen disinflationary pressures altogether. Moreover greater financial market stability is achieved due to smoother changes in policy rates compared to inflation targeting.

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Appendix: Data Description

All data used in this paper is of quarterly frequency. The data covers the period from 1999Q4 until 2017Q1. These data comprise of data for South Africa on population (working age population, ages 15-65) from FRED database. Data for South Africa on real GDP, investment, consumption, commodity output, real exchange rate comes, net exports and government debt come from the IMF database and are seasonally adjusted.

We use the quarterly 3-month treasury bill rate (IMF database), the domestic lending rate and deposits rate for South Africa and these are sourced from FRED database and we deflate these series using the corrected inflation measure.

Data on commodity price for South Africa are based on a real commodity price index computation of our own and closely follows Deaton and Miller (1996) and Chen and Rogo (2003) through 5 steps: (i) We find the equivalence between SITC level 4 groups and the IMF commodities database (ii) We calculate the country's value of each primary commodity exports using the UN COMTRADE database, which provides annual trade data for SITC level 4 groups, and take the average; (iii) We calculate the weights for each commodity by dividing its average value of exports for each commodity by the average total value of primary commodity exports; (iv) We use the weights to compute a geometric weighted-average of (US-dollar based) monthly nominal commodity export prices; and (v) We calculate the real commodity price index by dividing the nominal price index by the U.S. CPI index.

For the rest of the world, we use the US real GDP, inflation rate and quarterly 3-month treasury bill rate obtained from the IMF database.

	P^{X*}	Y	C	I	TB	R
P^{X*}	1.00	0.54	0.57	0.18	-0.10	-0.027
Y	0.54	1.00	0.89	0.71	-0.10	0.09
C	0.57	0.89	1.00	0.59	-0.15	-0.095
I	0.18	0.71	0.59	1.00	-0.07	0.27
TB	-0.10	-0.10	-0.15	-0.07	1.00	0.81
R	-0.027	0.09	-0.095	0.27	0.81	1.00

Note. The variables P^{X*} , Y , C , I , TB , R denote, respectively, commodity price, real output, real consumption, real investment, real trade balance and nominal central bank rate of interest. The variables P^{X*} , Y , C , I , are in growth rate, the variable TB is scaled by output, Y , the nominal rate of interest, R , is in percentage rate. The sample is for the period 1999-2017 and at quarterly frequency.

Table 1: Business Cycles Correlations in South Africa

RHS variable	Real spread (3-mth TB real rate)
Commodity price	-0.0148** (.007)
Output growth	0.168 (0.243)
Trade balance	0.0000 (0.001)
Debt-to-GDP ratio	-0.017 (0.011)
Constant	0.69*** (0.232)
Observations	68

Note: The real spread is calculated by deflating the domestic 3-month treasury bill rate, provided by the IMF database, with a corrected inflation measure, and then subtracting the US 3-month treasury bill real rate of interest. The commodity price is in log deviations from mean. Appendix A provides details on the sources of the other regressors. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2: Regression results: Country Spread

LHS variable	Real spread (loan premia)
Commodity price	-0.017** (0.014)
Output growth	-0.243 (0.240)
Trade balance	0.0000 (0.001)
Debt-to-GDP ratio	-0.018* (0.014)
Constant	0.658*** (0.293)
Observations	68

Note: The real spread is calculated by deflating the domestic loan rate, obtained at the FRED database, with a corrected inflation measure, and then subtracting the 3-month US treasury bill real rate of interest. The commodity price is in log deviations from mean. Appendix A provides details on the sources of the other regressors. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3: Regression results: Credit Premium

Parameter	Description	Value
<i>Household preferences</i>		
β	Discount rate	0.99
σ	Elasticity of intertemporal substitution in consumption	1.5
ψ	Inverse of the elasticity of labor supply	3.0
<i>Demand baskets</i>		
ω_{IM}	Share of imported goods in aggregated demand	0.26
v	CES btw domestic and imported goods	3.0
<i>Capital accumulation</i>		
δ	depreciation rate	0.025
<i>Commodity production technology</i>		
α_X	Capital share in commodity production	0.10
γ_X	Labour share in commodity production	0.29
<i>Entrepreneur (wholesale) good production technology</i>		
α_G	Capital share in wholesale good production	0.29
γ_G	Labour share in wholesale good production	0.63
ψ^{B^*}	elasticity of external premium to foreign debt	0.01
S	Gross steady-state risk premium	1.008
$\frac{K^G}{NW}$	Steady-state ratio of capital to net worth	1.7
G^*/Y^*	Steady-state government spending	0.18
η	Survival rate of entrepreneurs	0.973
ρ^l	Persistence land process	0.8
ρ^{IM}	Persistence to imported good PC	0.8

Table 4: Value of Calibrated Parameters

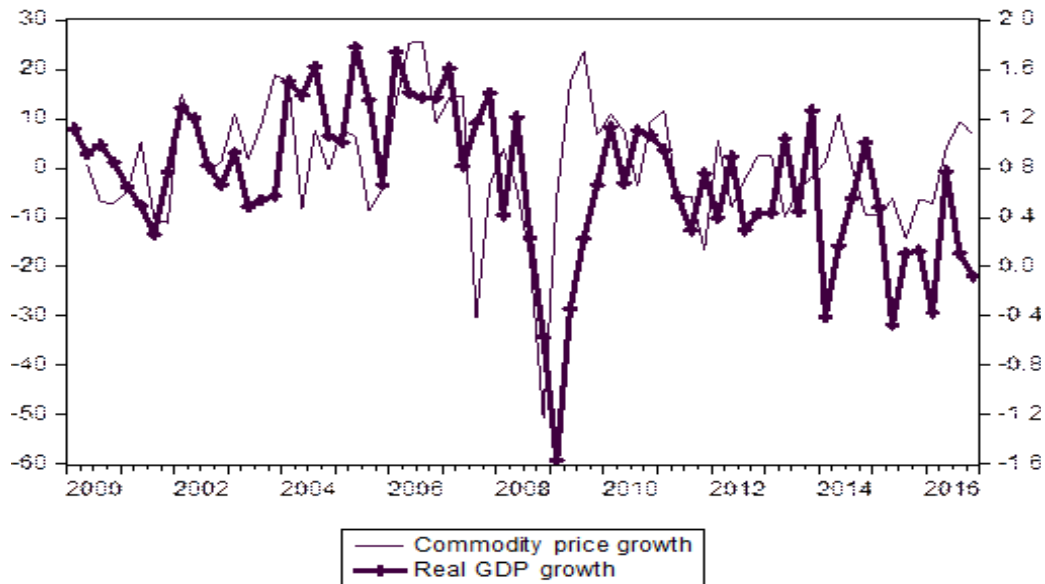


Figure 1: Commodity price growth and Real GDP growth

Name	Description	Prior			Posterior	
		Mean	Prior SD	Dist.	Mean	90% Probability Interval
ζ	elasticity of external premium to comm. price	-0.09	0.1	Inv Gamma	-0.0325	[-0.0424, -0.0226]
ϕ	capital adjustment costs	4.0	1.5	Gamma	4.8629	[4.2371, 5.4961]
v^*	CES of foreign demand for domestic goods	4.0	0.1	Gamma	3.6175	[3.5265, 3.7187]
κ	external finance premium elasticity	0.02	0.1	Inv Gamma	0.2271	[0.1818, 0.2894]
ρ_π	reaction to inflation deviation (Taylor rule)	1.5	0.2	Gamma	1.1588	[1.1008, 1.2169]
ρ_{YY}	reaction to output gap (Taylor rule)	0.5	0.2	Beta	0.1357	[0.0897, 0.1779]
χ_G	indexation of home good inflation	0.5	0.1	Beta	0.3476	[0.2655, 0.4360]
χ_{IM}	indexation of imported good inflation	0.5	0.1	Beta	0.2890	[0.2381, 0.3353]
v_G	calvo prob in home good inflation	0.5	0.1	Beta	0.7551	[0.7256, 0.7847]
v_{IM}	calvo prob in imported good inflation	0.5	0.1	Beta	0.2969	[0.3334, 0.4229]
ρ_R	interest rate smoothing parameter	0.8	0.1	Beta	0.7750	[0.7424, 0.8218]
ρ_a	persistence entr. productivity shock	0.8	0.1	Beta	0.9736	[0.9655, 0.9826]
ρ_a^x	persistence comm. productivity shock	0.8	0.1	Beta	0.8952	[0.8526, 0.9367]
ρ^{p^*}	persistence comm. price shock	0.8	0.1	Beta	0.7810	[0.7541, 0.8080]
ρ^{B^*}	persistence foreign debt risk premium	0.8	0.1	Beta	0.3685	[0.3038, 0.4292]
ρ^{rp}	persistence to external finance premium	0.8	0.1	Beta	0.5647	[0.4487, 0.6867]
ρ^G	persistence to domestic good PC	0.8	0.1	Beta	0.9874	[0.9806, 0.9945]
ρ^g	persistence to government expenditure	0.8	0.1	Beta	0.9230	[0.8900, 0.9566]

Name	Description	Prior			Posterior	
		Mean	SD	Dist.	Mean	90% Probability Interval
ρ^{y^*}	persistence foreign output	0.8	0.1	Beta	0.9737	[0.9535, 0.9963]
ρ^{π^*}	persistence foreign inflation	0.8	0.1	Beta	0.6725	[0.6401, 0.7038]
ρ^{r^*}	persistence foreign interest rate	0.8	0.1	Beta	0.9591	[0.9403, 0.9819]
σ_R	st dev monetary shock	0.1	2.0	Inv Gamma	0.0105	[0.0089, 0.0121]
σ_a	st dev entr. productivity shock	0.1	2.0	Inv Gamma	0.0266	[0.0216, 0.0322]
σ_a^x	st dev comm. productivity shock	0.1	2.0	Inv Gamma	0.0355	[0.0289, 0.0413]
σ_{p^*}	st dev comm. price shock	0.1	2.0	Inv Gamma	0.1453	[0.1248, 0.1655]
σ_{B^*}	st dev foreign debt risk prem. shock	0.1	2.0	Inv Gamma	0.1038	[0.0842, 0.1213]
σ_{rp}	st dev external finance premium	0.1	2.0	Inv Gamma	0.0587	[0.0347, 0.0796]
σ_G	st dev domestic good PC	0.1	2.0	Inv Gamma	0.0195	[0.0160, 0.0233]
σ_{y^*}	st dev foreign output	0.1	2.0	Inv Gamma	0.0116	[0.0102, 0.0132]
σ_{π^*}	st dev foreign inflation	0.1	2.0	Inv Gamma	0.0128	[0.0108, 0.0148]
σ_{r^*}	st dev foreign interest rate	0.1	2.0	Inv Gamma	0.0100	[0.0086, 0.0115]
σ_g^*	st dev govt spending	0.1	2.0	Inv Gamma	0.0258	[0.0214, 0.0302]

Notes: Posterior statistics are computed using 20,000 draws from the posterior distribution of model's parameters. For brevity, we report the estimated parameters for the benchmark Taylor rule model.

Table 5: Estimated Parameters

	IT	PLT	NGDPT
<i>var</i> (output gap)	0.4414	0.5477	0.5196
<i>var</i> (inflation)	0.3201	0.0013	0.0040
<i>var</i> (nominal interest rate)	0.3058	0.0008	0.0003
<i>var</i> (consumption)	1.0800	1.3281	1.2667
<i>var</i> (investment)	0.6129	0.5582	0.5597
<i>var</i> (real exchange rate)	0.1147	0.1225	0.1239
<i>var</i> (real wage)	5.6537	6.4419	6.2866
<i>var</i> (risk premium)	0.0047	0.0039	0.0041
<i>var</i> (credit growth)	0.4668	0.1650	0.1464

Notes: The table contains the theoretical variances of the main variables under three different monetary regimes. The variances are based on commodity shock.

Table 6: Theoretical Variances from Different Monetary Regimes

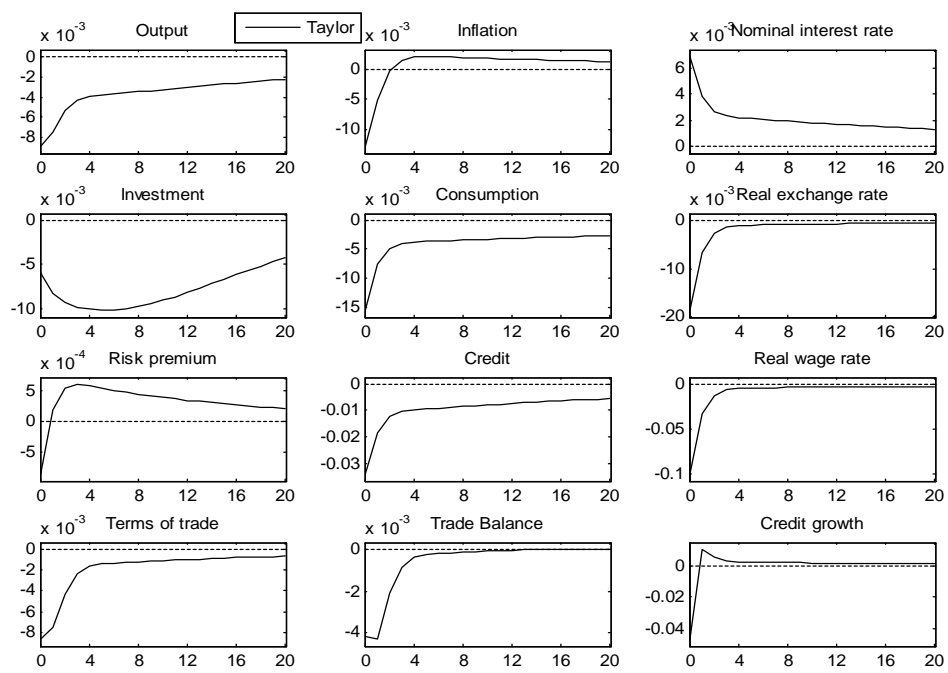


Figure 2: Estimated IRFs for a monetary shock

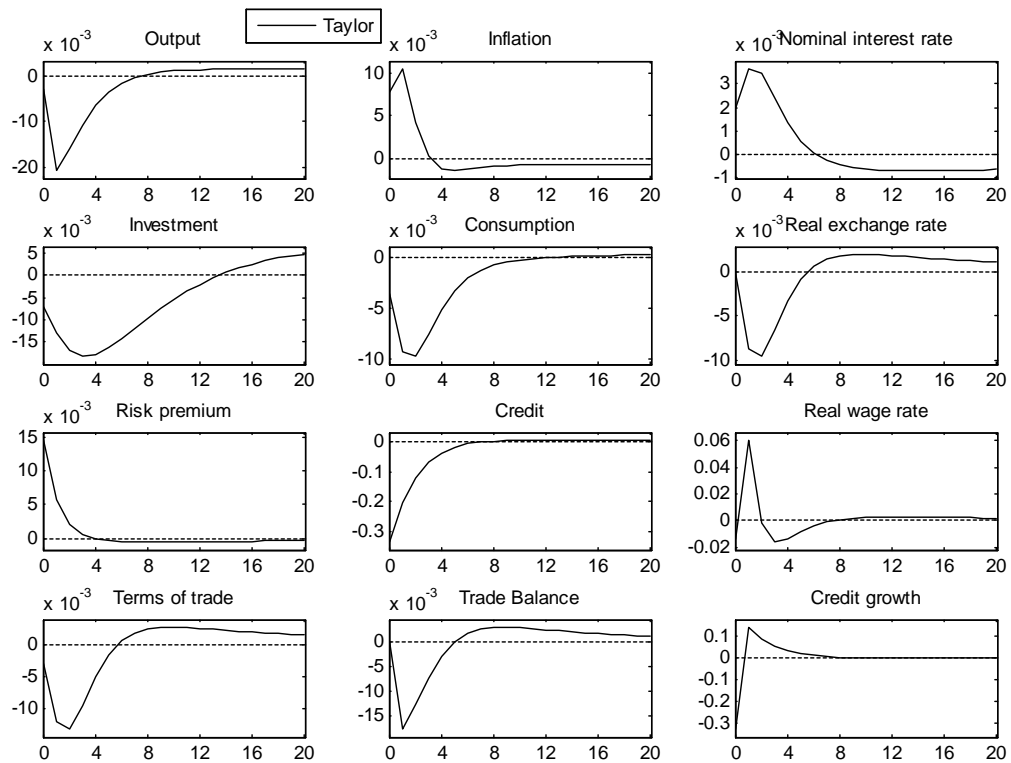


Figure 3: Estimated IRFs for a premium shock

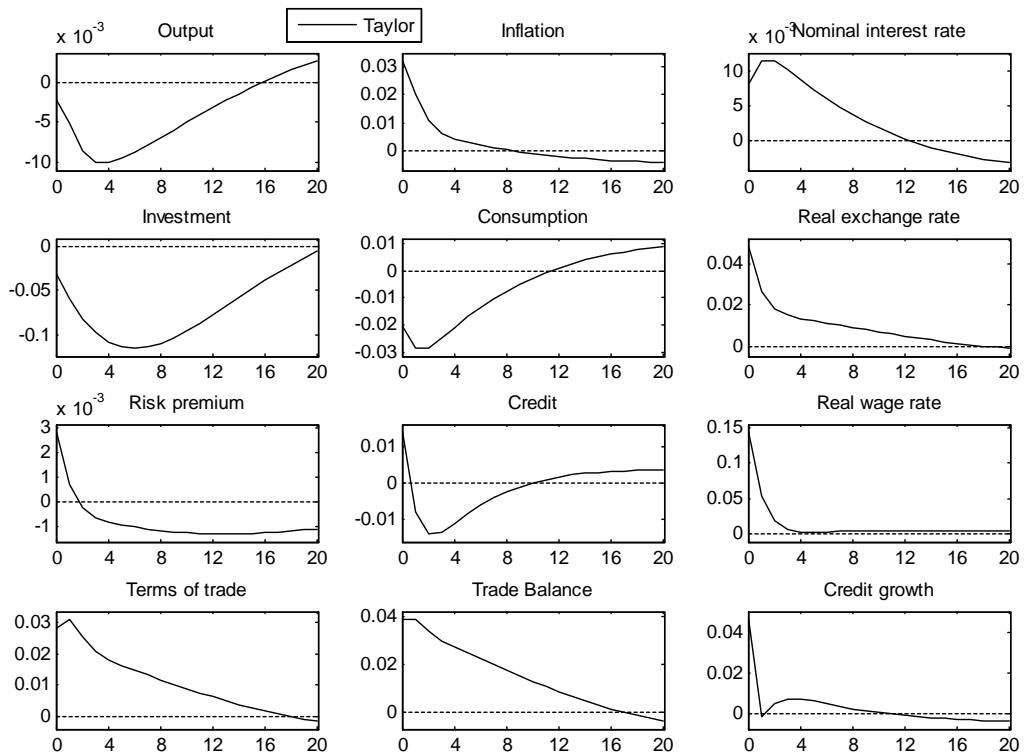


Figure 4: Estimated IRFs for a foreign nominal interest rate shock

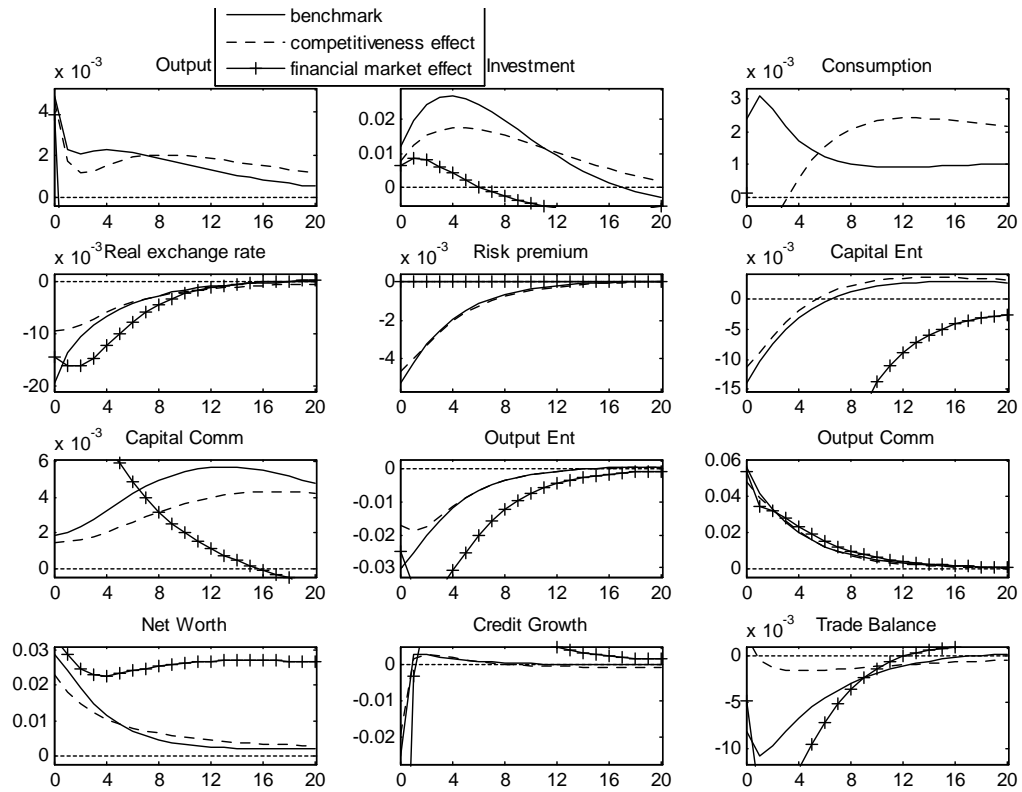


Figure 5: Estimated IRFs and three channels of commodity price shock.

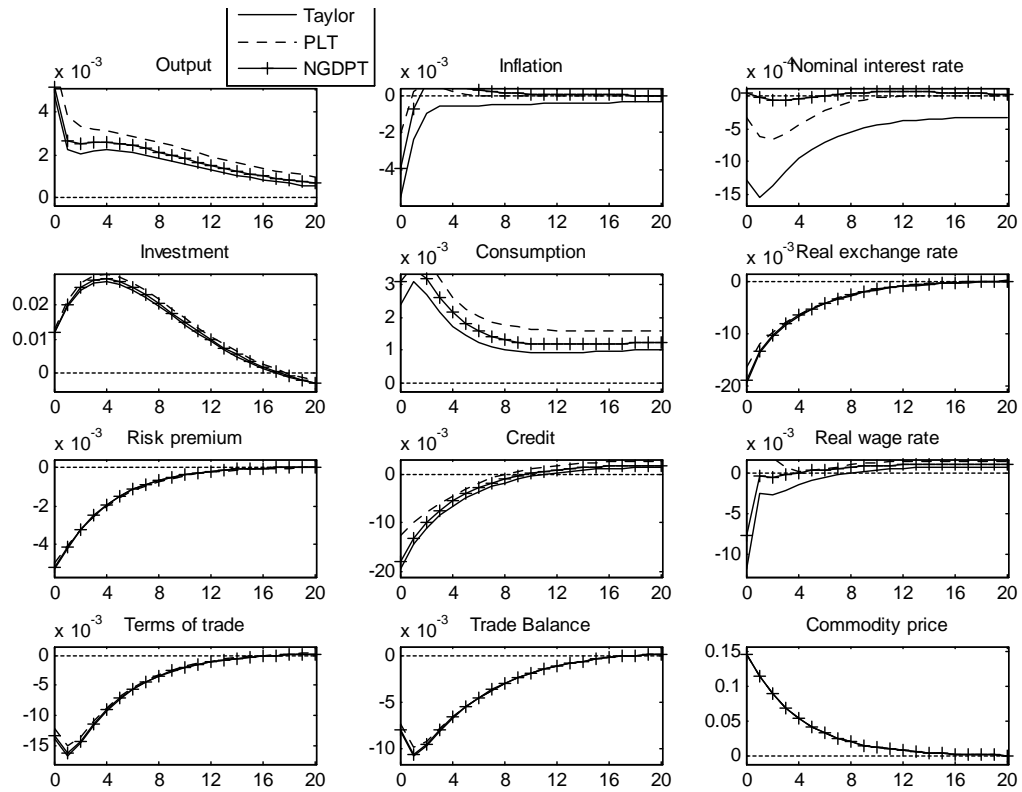


Figure 6: Comparison of three monetary regimes IRFs to a commodity price shock