A model for international spillovers to emerging markets

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Abstract

This paper develops a small open economy (SOE) dynamic stochastic general equilibrium (DSGE) model that helps to explain business cycle synchronization between an emerging market and advanced economies. The model captures the specificities of both economies (e.g. primary commodity, manufacturing, intermediate inputs, and credit) that are most relevant for understanding the importance as well as the transmission mechanisms of a wide range of domestic and foreign (supply, demand, monetary policy, credit, primary commodity) shocks facing an emerging economy. We estimate the model with Bayesian methods using quarterly data from South Africa, the US and G7 countries. In contrast to the predictions of standard SOE models, we are able to replicate two stylized facts. First, our model predicts a high degree of business cycle synchronization between South Africa and advanced economies. Second, the model is able to account for the influence of foreign shocks in South Africa. We are also able to demonstrate the specific roles these shocks played during key historical episodes such as the global financial crisis in 2008 and the commodity price slump in 2015. The ability of our framework to capture endogenous responses of commodity and financial sectors to structural shocks is crucial to identify the importance of these shocks in South Africa.

JEL classification: E3, E43, E52, C51, C33

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1 Introduction

The welfare gains to stabilizing macroeconomic fluctuations are larger in emerging and developing countries than in advanced economies.[1] Yet, substantially more effort has been put in developing such policies for advanced economies. A prerequisite for developing stabilization policies is to build structural models capable of explaining macroeconomic fluctuations.

In developed countries, estimated closed-economy DSGE models quantitatively match observed macroeconomic fluctuations (e.g. Christiano et al., 2005 and Smets and Wouters, 2007). The same is not true of open-economy models applied to advanced and emerging economies. These models have particular difficulty in explaining two stylized facts: *i)* the international business cycle synchronization; and *ii)* the importance of global shocks in driving macroeconomic fluctuations. For instance, the predictions of the SOE model in Justiniano and Preston (2010) suggest that US shocks only play a marginal role in macroeconomic fluctuations in Canada. This finding is counter-intuitive given the large degree of trade and financial linkages between the two countries and not consistent with the non-structural empirical literature. Moreover, Adolfson et al. (2005, 2007) and Christiano et al. (2011) find that foreign shocks play a small role in SOE models applied to the euro area and Sweden, respectively.[2] In a related study, Steinbach et al. (2009) apply Justiniano and Preston's model to South Africa and report that foreign shocks play no role in explaining fluctuations in GDP. However, structural vector autoregressive (SVAR) models show that (demand, supply, and credit) shocks originating from G7 countries and commodity price shocks account for more than 30% of macroeconomic fluctuations in South Africa (e.g. Houssa et al., 2013, 2015, hereafter HMO). Moreover, the work of Steinbach et al. (2009) fails to replicate the observed business cycle synchronization between South Africa and advanced economies.[3]

In this paper, we build and estimate a SOE model that is capable of explaining international business cycle synchronization as well as the quantitative roles of domestic and foreign shocks in macroeconomic fluctuations in emerging markets. We apply our model to South Africa. In comparison with other BRICS countries, South Africa has a higher degree of openness to trade (60 versus 36% of GDP) and finance (159 versus 96% of GDP) which should make the relative roles these two elements play in the transmission of foreign shocks

[1] e.g. Pallage and Robe (2003) and Houssa (2013).

[2] Two-country models also have difficulty in explaining business cycle synchronization. See for e.g. de Walque et al. (2017) for a model applied to the US and the euro area.

[3] The correlation coefficient between GDP year-on-year growth rates for South Africa and the group of G7 countries is 0.53 in 1994-2017. With the US, the corresponding number is 0.41.

more transparent.[4,5]

Our model consists of two blocks: a domestic block representing a SOE and a foreign block capturing its relation with advanced economies. The core of the domestic and foreign blocks draws on Adolfson et al. (2007) and Smets and Wouters (2007), respectively. We extend these works in a number of dimensions that allow to understand the transmission mechanisms of structural shocks originating from advanced economies to an emerging market. First, firms in the domestic and foreign blocks produce primary commodities and secondary products that are both traded. Domestic commodity supply is endogenous and fully exported. The primary commodity sector (essentially mining) is dominant in South Africa, accounting for about 40% of total exports in goods and services. In order to understand the role played by world commodity prices in South Africa, we assume that they are endogenously determined in the foreign block. The commodity price index balances an exogenous foreign commodity supply with an endogenous foreign demand for commodities driven by the business cycle. Second, we distinguish three categories of households to capture key differences among savers, entrepreneurs, and financially constrained (rule-of-thumb) households. In South Africa, 30% of the population (over 15 years) does not have an account at a financial intermediary.[6] Third, we introduce a financial sector comprising domestic and foreign banks allowing for financial accelerator effects (e.g. Bernanke et al., 1999). Foreign banks operate in the domestic and foreign markets (e.g. Kollmann, 2013) and transmit developments originating in the foreign credit market to the domestic economy. South Africa has a well developed and integrated banking sector with the rest of the world. Domestic credit to the private sector amounts to 145% of GDP (versus 91% for other BRICS) and the share of foreign bank assets among total bank assets in South Africa is similar to that of other OECD countries.[7]

Within this rich model we define two broad categories of structural shock. On the one hand, we have shocks whose origins - domestic or foreign - are clearly identified and have counterparts in the two blocks of the model: aggregate demand and supply, credit supply, monetary, and commodity supply shocks. On the other hand, shocks with origins that cannot

[4] Trade openness is defined as the sum of exports and imports in goods and services and financial openness is measured by the sum of trade in assets and liabilities. The data for trade is for 2016 and come from the World Bank whereas the figures for financial openness are for the year 2011 and they are taken from an updated version of Lane and Milesi-Ferretti (2007).

[5] Two other elements motivate the choice of South Africa. First, the South African Reserve Bank operates in an inflation-targeting framework making it possible to explicitly model its behavior. Second, South Africa is one of the very few emerging markets which possesses a large panel of macroeconomic series at quarterly frequency. These data are crucial for an accurate estimation of the model developed in this paper.

[6] The comparative figure for advanced economies is 9% (World Bank Financial Inclusion Database).

[7] 22% in 2006 in South Africa vs 27% for the OECD average but only 9% on average in other BRICS; see Claessens and Horen (2014). Domestic credit data refer to 2016 and are obtained from the World Bank.

be clearly identified are labelled SOE shocks. We estimate the model with Bayesian methods using quarterly data from South Africa and the US over the period 1994Q1 to 2017Q4. We provide a sub-period analysis and also experiment with different definitions of the foreign block using G7 data.

The results show that the new model is capable of replicating the importance of foreign shocks seen in the reduced-form empirical literature. In particular, these shocks explain 20 to 30% of the variability in real activity in South Africa. Historical decomposition also highlights specific roles played by foreign shocks during the global financial crisis in 2008 and the commodity price slump in 2015. Moreover, we show that the extended model can replicate the observed strong positive co-movement between business cycles in advanced economies and South Africa. Nevertheless, domestic shocks remain the most important driver of macroeconomic fluctuations in South Africa. As such, any appropriate stabilization policy should take into account both these domestic and foreign shocks.

Subsequently, we study the transmission channels of foreign shocks in South Africa in the new, quantitatively successful model. In particular, by shutting down channels one at a time in sequence, we find that the primary commodity sector plays an important role in the transmission of foreign shocks and the credit channel has contributed to amplifying fluctuations caused by these shocks. The ability of our model to capture endogenous responses of South African commodity and financial sectors to shocks originating from the foreign block is crucial to identifying the importance of foreign shocks. These results support the view that commodity prices are an important driver of economic fluctuations in small open emerging economies (e.g. Mendoza, 1995; and Kose, 2002). Recently, there has been a growing number of studies endorsing (e.g. Fernández et al., 2018; Drechsel and Tenreyro, 2018; and Fernández et al., 2017) or challenging this view (e.g. Schmitt-Grohé and Uribe, 2018; Aguirre, 2011; Lubik and Teo, 2005; and Broda, 2004). Our paper contributes to this debate by proposing a framework that models the interactions between the commodity sector and other sectors in the domestic and foreign blocks. In our model, commodity supply in the domestic block requires labor, capital and a fixed production factor (land). We use a CES production function and estimate the elasticity of substitution between production factors. These specificities control the elasticity of domestic commodity supply to world prices and could reconcile some of the discrepancies reported in the literature. Indeed, some of the papers reporting very large contributions of commodity price shocks use a classical Cobb-Douglas production function, thereby imposing sizeable domestic commodity supply responses to commodity price fluctuations.

Finally, we argue that endogenous commodity price responses to the global business cycle is key to replicating business cycle synchronization between advanced economies and South Africa. In existing SOE-DSGE studies, commodity prices (or terms of trade) are assumed to be exogenous. We depart from this literature and allow commodity prices to be driven both by demand and supply forces. We find that demand factors account for 31 to 52% of the variability in commodity prices, which echoes the SVAR literature pioneered by Kilian (2009). In our framework, a positive demand shock in advanced economies stimulates the demand for the commodity which implies a rise in commodity prices. In turn, this generates a boom in South Africa through higher export prices and volumes. Conversely, an exogenous contraction in commodity supply implies a negative co-movement between business cycles in South Africa and advanced economies because the rise in commodity prices discourages real activity in the foreign block, while at the same time generating a boom in South Africa. In a related empirical paper, Caldara et al. (2018) show in a SVAR model that oil price fluctuations driven by demand factors generate a positive co-movement between economic activity in advanced and emerging economies while oil supply shocks provoke a negative co-movement. Our paper contributes to this literature by developing the underlying mechanisms of these co-movments within a general equilibrium structural model.

The rest of the paper is arranged as follows. Section 2 presents the extended model. Section 3 discusses the empirical strategy. Section 4 discusses the empirical results and the last section concludes.

2 Model

The model comprises two blocks, each describing the structure of one type of economy: a block for an emerging economy (domestic); and a block for advanced economies (foreign) which could be interpreted as the global economy. The foreign block is modelled as an approximately closed economy that build on the work of Smets and Wouters (2007), henceforth denoted as SW.[8] The domestic block is an extension of the SOE-DSGE model proposed by Adolfson et al. (2007), henceforth denoted as ALLV.[9]

We extend ALLV and SW's models in a number of dimensions that are empirically relevant and allow to understand the transmission mechanisms of structural shocks originating

[8] SW build on the closed-economy DSGE model originally developed by Christiano et al. (2005). They assume a one final-good sector model that includes a number of real and nominal rigidities: price and wage stickiness, investment adjustment costs and habit formation in consumption.

[9] ALLV extend the work of Christiano et al. (2005) to a SOE. They introduce imperfect exchange rate pass-through in addition to the frictions in SW in their domestic block. Finally, they employ a SVAR model to capture the dynamics of the foreign block. The euro area is the domestic economy, whereas the foreign economy is an aggregate of four countries (US, UK, Japan and Switzerland).

from advanced economies to an emerging market. The main ingredients of our extensions can be summarized in three points. First, both domestic and foreign economies produce two sorts of goods that are traded: primary commodities and secondary goods. Commodity is an homogeneous good that is produced under perfect competition. Its price is endogenously determined in the global market based on demand for commodities by advanced economies and world commodity supply, which we assume to be exogenous. Domestic supply of commodities is also endogenous but it has no impact on world commodity prices given the SOE assumption. Second, we distinguish three categories of households to capture key differences among savers, entrepreneurs, and financially constrained (rule-of-thumb) households. The latter are only included in the domestic block, as a simplifying assumption. Third, we introduce a financial sector comprising domestic and foreign banks. Foreign banks are global players operating in the domestic and foreign markets.

The following sections describe our model in detail. The first-order conditions, its steady-state and observation equations are presented in the appendix.[10]

2.1 Households

The domestic economy is populated by three types of households: savers, entrepreneurs and rule-of-thumb consumers. Savers accumulate wealth in the form of domestic and foreign financial assets. Entrepreneurs manage domestic firms and invest to build physical capital used in the production sectors. Finally, rule-of-thumb households are excluded from the financial markets and they are unable to accumulate wealth. They mimic savers for their labor effort decisions and consume their entire income in each period. The household mass is normalized to 1 for each type of household.

Households derive utility from the consumption of a composite good (consisting of domestic and imported goods). Aggregate consumption $C_{j,t}$ for any household j is given by the CES index of domestic and imported goods

$$C_{j,t} = \left[(1 - \varepsilon_{m,t}\omega_c)^{1/\eta_c}(C^d_{j,t})^{(\eta_c-1)/\eta_c} + (\varepsilon_{m,t}\omega_c)^{1/\eta_c}\,(C^m_{j,t})^{(\eta_c-1)/\eta_c}\right]^{\eta_c/(\eta_c-1)}, \tag{1}$$

where $C^d_{j,t}$ and $C^m_{j,t}$ denote consumption of the domestic and imported goods, respectively, ω_c is the (steady-state) share of imports in consumption, and η_c is the elasticity of substitution between domestic and foreign consumption goods. The exogenous process $\varepsilon_{m,t}$ represents a preference shock on imported goods modeled as a time-varying home bias.

[10] The appendix is available upon request.

2.1.1 Savers

Household optimization problem The representative saver maximizes the inter-temporal utility by choosing his or her consumption level, labor effort, and domestic as well as foreign financial asset holdings.[11] The j^{th} household's preferences are given by

$$\mathrm{E}_0^j \sum_{t=0}^{\infty} \beta_S^t \left[\frac{\left(C_{j,t} - \mathbf{b} C_{t-1}^s\right)^{1-\sigma_c}}{1-\sigma_c} - A_h \frac{(h_{j,t})^{1+\sigma_h}}{1+\sigma_h} \right], \tag{2}$$

where E is the expectation operator, C_{t-1}^s is the previous period average level of consumption within the savers' group and $h_{j,t}$ denotes work effort. The parameters σ_c and σ_h denote the inverse of the inter-temporal elasticity of substitution for consumption and the inverse of the elasticity of work effort, respectively. A_h is the relative importance of labor in the utility, $\mathbf{b}$ is the exogenous habit parameter and β_S is the discount factor of savers.

They work, consume, and save in domestic and foreign risk-free financial assets. For any given period t, savers face the same budget constraint which is given, in nominal terms, by

$$\begin{aligned} B_{j,t+1} + S_t B_{j,t+1}^* + P_t^c C_{j,t}(1+\tau^c) = TR_t^s + SCS_{j,t} \\ + (1-\tau^y)\frac{W_{j,t}}{1+\tau^w} h_{j,t} + \varepsilon_{b,t-1} R_{t-1} B_{j,t} + \varepsilon_{b,t-1} R_{t-1}^* \Phi(\frac{A_{t-1}}{z_{t-1}}, \tilde{\phi}_{t-1}) S_t B_{j,t}^* \\ -\tau^k [(\varepsilon_{b,t-1} R_{t-1} - 1) B_{j,t} + (\varepsilon_{b,t-1} R_{t-1}^* \Phi(\frac{A_{t-1}}{z_{t-1}}, \tilde{\phi}_{t-1}) - 1) S_t B_{j,t}^* + B_{j,t}^*(S_t - S_{t-1})], \end{aligned} \tag{3}$$

where the subscript j indicators denote the household's choice variables, whereas the upper-case variables, without the subscript, are the economy-wide aggregates. B_t denotes the value of nominal domestic assets, S_t is the nominal exchange rate defined as the amount of local currency per unit of foreign currency and B_t^* is the value of foreign assets (expressed in foreign currency). TR_t^s denotes lump-sum transfers from the government, $SCS_{j,t}$ is the household's net cash income from participating in state-contingent securities at time t. P_t^c is the consumer price index and W_t represents the wage rate. The government finances its expenditure by collecting consumption tax τ^c, payroll tax τ^w, labor income tax τ^y, and capital income tax τ^k.[12] R_t and R_t^* are gross domestic and foreign policy rates determined by the domestic and foreign central banks, respectively. The exogenous process $\varepsilon_{b,t}$ creates a

[11] The domestic financial market is assumed to be complete, so each household can insure against any type of idiosyncratic risk through the purchase of the appropriate portfolio of securities. This prevents any frictions from causing households to become heterogeneous, so the representative agent framework is still valid for this economy.

[12] Tax rates are assumed to be constant. The government balances its budget with lump-sum transfers.

wedge between the monetary policy rate and the return on assets held by savers (e.g. SW).

Country risk premium In equation (3), the term $R^*_{t-1}\Phi(A_{t-1}/z_{t-1},\tilde{\phi}_{t-1})$ represents the risk-adjusted pre-tax gross interest rate paid by foreign bonds (in foreign currency). The term $\Phi(.,.)$ captures the country risk premium which is a function of the real aggregate net foreign asset position $A_t \equiv \frac{S_t B^*_{t+1}}{P_t}$.[13] It is made stationary using the price of the domestic secondary good P_t and the level of permanent technology z_t. The exogenous process $\tilde{\phi}_t$ is a time-varying shock to the risk premium.

This function $\Phi(.,.)$ illustrates the imperfect integration of the domestic economy into international financial markets.[14] Therefore, domestic households are charged a premium over the (exogenous) foreign interest rate R^*_t if the domestic economy is a net borrower ($B^*_t < 0$), and they receive a lower remuneration on their savings if the domestic economy is a net lender ($B^*_t > 0$).

Wage-setting Every household (except entrepreneurs) is a monopoly supplier of a differentiated labor service and sets its own wage $W_{j,t}$ with an adjustment rule following Erceg et al. (2000). Every saver sells its labor services ($h_{j,t}$) to a labor packer, which transforms it into a homogeneous input H^s using the following technology

$$H^s_t = \left[\int_0^1 (h_{j,t})^{\frac{1}{\lambda_{w,t}}} dj\right]^{\lambda_{w,t}},\ 1 \leq \lambda_{w,t} < \infty, \tag{4}$$

where $\lambda_{w,t}$ is a time-varying wage markup. This labor packer takes the input price of the j^{th} differentiated labor input as given, as well as the price of the homogeneous labor services.

Households have a probability $(1-\xi_w)$ og being allowed to re-optimize their wages. Those that cannot re-optimize their wages follow an indexation mechanism described by

$$W_{j,t+1} = \left(\pi^c_t \frac{\Delta y_t}{\Delta H_t}\right)^{\kappa_w} (\bar{\pi})^{1-\kappa_w} \mu_z W_{j,t},$$

so that they link their wages to a combination of factors including: the last period consumer price inflation $\pi^c_t = \frac{P^c_t}{P^c_{t-1}}$; the last period transitory labor productivity growth $\frac{\Delta y_t}{\Delta H_t}$ where $y_t = \frac{Y_t}{z_t}$ and Y_t is GDP; the inflation target rate $\bar{\pi}$; and permanent technology growth $\mu_z = \frac{z_{t+1}}{z_t}$.[15] The wage-indexation parameter κ_w determines the relative importance of past

[13] The function $\Phi(\frac{A_t}{z_t},\tilde{\phi}_t) = \exp(-\tilde{\phi}_A(\frac{A_t}{z_t} - \overline{A}) + \tilde{\phi}_t)$ is strictly decreasing in A_t and satisfies $\Phi(\frac{A}{z},0) = 1$.

[14] It also helps to make the model stationary; see Schmitt-Grohe and Uribe (2003).

[15] The indexation to transitory productivity growth ensures a standard response of consumption to stationary technology shocks in our model where rule-of-thumbs household consumption depends on labor market

consumer price inflation and labor productivity growth in the indexation process.

Foreign savers Foreign savers face a similar optimization problem. However, the closed-economy assumption implies that they only consume foreign goods and only accumulate foreign bonds.

2.1.2 Rule-of-thumb households

There is a continuum of rule-of-thumb households of mass 1 indexed by $j \in (0, 1)$. They are similar to non-Ricardian households put forward in Mankiw (2000), Coenen and Straub (2005), Erceg et al. (2006) and Galí et al. (2007) and introduced in DSGE models applied to developing countries (Medina and Soto, 2007; and Céspedes et al., 2013, for example). They do not have access to credit and capital markets. They consume their entire labor income in every period. Their budget constraint is given by

$$(1 + \tau_t^c) P_t^c C_{j,t} = \frac{1 - \tau_t^y}{1 + \tau_t^w} W_{j,t} h_{j,t} + TR^r \ , \tag{5}$$

where TR^r are government transfers.[16] Those households mimic savers in setting their wages.[17] Each rule-of-thumb household also sells its labor $h_{j,t}$ to a labor packer which transforms it into a homogeneous labor input H_t^r using a technology analogous to equation (4). There are no rule-of-thumb households in the foreign economy.

2.1.3 Hours aggregation and labor mobility

Hours worked by each category of households are perfect substitutes. Therefore, the aggregate labor effort H_t available to the economy is simply given by

$$H_t = H_t^s + H_t^r \tag{6}$$

We assume imperfect labor mobility between primary and secondary sectors like Horvath (2000) and Dagher et al. (2010).[18] The labor aggregator allocates labor between primary and secondary sectors. Total labor effort is given by a CES aggregation of hours worked in

incomes. We assume that the permanent technology growth rate is constant and calibrated to μ_z.

[16] These transfers only serve to reach a consumption target at steady-state.

[17] Each rule-of-thumb household pairs with a saver and always sets an identical wage.

[18] Using a panel of OECD countries, Cardi and Restout (2015) argue that sector-specific productivity shocks generate wage differentials incompatible with perfect labor mobility. They show that Horvath's labor allocation function can replicate this wage gap.

the primary and secondary sectors

$$H_t = \left[(1-\omega_h)^{-1/\eta_h}(H_t^f)^{(1+\eta_h)/\eta_h} + \omega_h^{-1/\eta_h}(H_t^p)^{(1+\eta_h)/\eta_h}\right]^{\eta_h/(1+\eta_h)}, \tag{7}$$

where H_t^p and H_t^f denote labor effort in the primary and final sectors, respectively; ω_h is the share of primary sector employment in total employment; and η_h is the elasticity of substitution between labor services provided in the two sectors. The intuition behind this specification is that there are costs associated with labor mobility such as sector-specific skills.[19] In the foreign economy, households only work in the final good sector.

2.1.4 Entrepreneurs

Optimization problem There is a continuum of entrepreneurs of mass 1, indexed by $j \in (0, 1)$, which attain utility from consumption. Their inter-temporal utility is given by

$$\mathrm{E}_0^j \sum_{t=0}^{\infty} \beta_E^t \left[\frac{\left(C_{j,t} - \mathbf{b}C_{t-1}^e\right)^{1-\sigma_c}}{1-\sigma_c}\right], \tag{8}$$

where C_{t-1}^e is the past average consumption level of entrepreneurs and $\beta_E < \beta_S$ ensures that entrepreneurs are more impatient than savers. Entrepreneurs consume, borrow in domestic-currency assets (from the bank), and manage firms. They pay wages to savers and rule-of-thumb households, purchase foreign inputs, manage capital stocks and sell (primary and final) output. Entrepreneurs maximize this utility under a budget constraint presented below after a discussion on investment and capital accumulation.

Investment and capital accumulation Capital and investment are assumed to be sector-specific. The investment (I^q) in each sector $q \in (p, f)$ -p for primary sector and f for secondary sector- is given by a CES aggregate of domestic ($I_t^{d,q}$) and imported investment goods ($I_t^{m,q}$) in each sector

$$I_t^q = \left[(1-\varepsilon_{m,t}\omega_i)^{1/\eta_i}(I_t^{d,q})^{(\eta_i-1)/\eta_i} + (\varepsilon_{m,t}\omega_i)^{1/\eta_i}\,(I_t^{m,q})^{(\eta_i-1)/\eta_i}\right]^{\eta_i/(\eta_i-1)}, \tag{9}$$

where ω_i is the steady-state share of imports in investment and η_i is the elasticity of substitution between domestic and imported investment goods.

[19] Fedderke (2012) argues that the South African labor market is rigid. It is segmented (between unionised and non-unionised workers and between the formal and informal sector) and suffers from a skills mismatch.

The capital accumulation rule is subject to investment adjustment costs and follows

$$\overline{K}_{t+1}^{q} = (1-\delta)\overline{K}_{t}^{q} + \Upsilon_t F(I_t^q,\ I_{t-1}^q)\ , \tag{10}$$

where δ is the depreciation rate. Υ_t is a stationary investment-specific technology shock common to both sectors and $F(I_t, I_{t-1})$ represents a function which turns investment into physical capital. The $F(I_t, I_{t-1})$ function is specified following Christiano et al. (2005) as

$$F(I_t,\ I_{t-1}) = (1-\tilde{S}(I_t/I_{t-1}))I_t\ , \tag{11}$$

where the function $\tilde{S}(I_t/I_{t-1})$ is defined by

$$\tilde{S}(I_t/I_{t-1}) = \phi_i \left\{ exp\left(\frac{I_t}{I_{t-1}} - \mu_z\right) + exp\left(-\frac{I_t}{I_{t-1}} + \mu_z\right) - 2\right\}, \tag{12}$$

with $\tilde{S}(\mu_z) = \tilde{S}'(\mu_z) = 0$ and $\tilde{S}''(\mu_z) \equiv \tilde{S}'' = 2\phi_i > 0$.

Entrepreneurs also set the rate of capital utilization such that the effective capital stock available to firms in each sector q is given by

$$K_t^q = u_t^q \overline{K}_{t-1}^q\ . \tag{13}$$

In equation (15), the function $a(u_t^q)$ represents the cost of varying capital utilization rate and follows Christiano et al. (2005). It is defined as

$$a(u_t^q) = \frac{(1-\tau_k)r_k}{\sigma_a}\left(\exp\left(\sigma_a(u_t^q - 1)\right) - 1\right), \tag{14}$$

with $a'(u) = (1-\tau_k)r_k$ and $a''(u) > 0$.

Budget constraint Entrepreneurs face the following budget constraint

$$\begin{aligned}(1+\tau^c)P_t^c C_{j,t} + P_t^i\left(I_{j,t}^p + I_{j,t}^f\right) + \varepsilon_{b,t-1}R_{t-1}^L B_{j,t}^e + P_t\left(a(u_{j,t}^p)\bar{K}_{j,t}^p + a(u_{j,t}^f)\bar{K}_{j,t}^f\right)\\ = (1-\tau^k)\varPi_{t,j} + \tau^k(\varepsilon_{b,t-1}R_{t-1}^L - 1)B_{j,t}^e + B_{j,t+1}^e + TR_t^e + SCS_{j,t}^e\ ,\end{aligned} \tag{15}$$

with

$$\varPi_{t,j} = P_t\left(Y_{j,t}^f - (1-\omega_x)X_{j,t}^f\right) + \left(S_t P_t^x - \omega_x P_t^m\right)X_{j,t}^f + \left(S_t P_t^{*p} - \omega_x P_t^m\right)X_{j,t}^p$$

$$- R^L_{t-1} \left(W^p_t H^p_{j,t} + W^f_t H^f_{j,t} + P^m_t N^m_{j,t} \right) - z_t \phi_t. \qquad (16)$$

In equation (15), the term P^i_t represents the price of the investment good. Entrepreneurs are charged a lending rate R^L_{t-1} (discussed in the financial sector section below) on credit B^e_t carried over from the previous period. The terms TR^e_t and $SCS^e_{j,t}$ represent transfers and state-contingent securities. The exogenous process $\varepsilon_{b,t}$ creates a wedge between the lending rate and cost of entrepreneurs liabilities.[20]

In equation (16), entrepreneurs' profits $\Pi_{t,j}$ depend on sales and production costs. The first term represents the income from domestic sales of final goods (total final good output not used for exports). The second and third terms represent the income from final good and primary commodity exports (net of an import content share ω_x), respectively. These terms are presented in the firms section below. Entrepreneurs use intra-period loans to finance their wage bill ($W^p_t H^p_{j,t} + W^f_t H^f_{j,t}$) and expenditure on imported inputs ($P^m_t N^m_{j,t}$), which is expressed in domestic currency. The term $z_t \phi_t$ defines fixed costs (paid in monetary terms) that ensures that the free entry condition holds in the secondary sector.[21]

Foreign entrepreneurs Foreign entrepreneurs face a similar optimization problem. Because commodity supply is exogenous in the foreign economy, they only invest in final capital goods and pay wages to foreign households working in the final good sector. Because the foreign economy is closed, they sell all their production in the foreign market and do not purchase inputs abroad.

2.2 Firms

There are two categories of goods in this model: primary commodity (essentially mining); and secondary goods.

[20] In SW, this shock only affects one type of bond. However, in our context, restricting this shock to bonds held by savers would fail to generate the positive correlation between consumption and investment that wedge shocks typically produce. We therefore apply this shock to both the returns on savers' assets and costs of entrepreneurs' liabilities. The IRFs presented in the appendix show that this shock behaves as a typical aggregate demand shock.

[21] We assume that $\phi_t = (1 - \frac{1}{\lambda_{d,t}}) Y^f_0$. It ensures that the free entry condition holds in the long run for a given markup $\lambda_{d,t}$ with Y^f_0 denoting the steady-state value of the production discussed in the firms' section. It enables the fixed costs to adjust to changes in the final goods distributors' market powers and therefore prevents dramatic changes in firms' profits after a markup shock, which would otherwise transmit to entrepreneurs' balance sheets and risk premiums.

2.2.1 Commodity sector

The primary commodity is produced under perfect competition in the two blocks of the model.

Domestic commodity producers The domestic commodity supply is assumed to be entirely exported abroad allowing to capture the dominant role it plays in the exports of this emerging economy. It is produced in two stages. First, firms combine capital, labor and land to produce a commodity input Y_t^p with a CES technology

$$Y_t^p = Y_0^p \left[\alpha_p \left(\frac{K_t^p}{K_0^p} \right)^{\frac{\sigma_p - 1}{\sigma_p}} + \beta_p \left(\frac{L_t^p}{L_0^p} \right)^{\frac{\sigma_p - 1}{\sigma_p}} + (1 - \alpha_p - \beta_p) \left(\frac{z_t \varepsilon_{h,t} \varepsilon_{hp,t} H_t^p}{H_0^p} \right)^{\frac{\sigma_p - 1}{\sigma_p}} \right]^{\frac{\sigma_p}{\sigma_p - 1}}, \quad (17)$$

where K_t^p is capital stock and H_t^p represents labor services used in the mining sector. L_t^p is amount of land used for commodity production. Land is assumed to be exogenous.[22] α_p and β_p are income shares of capital and land in the primary sector, respectively; σ_p is the elasticity of substitution between production factors in the primary sector. The exogenous process $\varepsilon_{h,t}$ is an economy-wide labor-augmenting productivity shock, while $\varepsilon_{hp,t}$ is specific to the primary sector.

In the second step, commodity producers use a Leontief technology to combine the commodity input Y_t^p with an imported input (capturing the import content of exports)

$$X_t^p = \min \left(\frac{Y_t^p}{1 - \omega_x}, \frac{N_t^p}{\omega_x} \right), \quad (18)$$

where X_t^p represents domestic commodity exports and N_t^p is the import content of commodity exports. Domestic commodity is entirely exported abroad at the world price of commodity P_t^{*p} which is determined by foreign demand and supply for commodities.[23] It should be noted that the domestic commodity supply is allowed to respond to world commodity prices. This

[22] Exogenous land helps to control the transmission of highly volatile commodity prices to the domestic economy (e.g. Kose, 2002). Here, land follows the permanent labor productivity level: $L_t^p = z_t L_0^p$.

[23] In line with the SOE assumption, the domestic economy supply is too small to influence world commodity prices. This assumption is likely to hold looking at South African shares in commodity exports such as gold (3.3% in 2015, OEC), diamonds (8.7%), coal briquettes (7.7 %), iron ore (5%) and aluminium (2.6%), with the exception of platinum (41%). Broda (2004) tests the terms of trade exogeneity assumption on a sample of 1000 goods in 75 developing countries including South Africa. He finds that only 22 goods from 9 countries violate this assumption, none of which originate from South Africa.

is an important channel through which foreign shocks impact on the domestic economy. Endogenous domestic commodity production is also assumed in the literature (e.g. Kose, 2002; and Hove et al., 2015) but our framework is distinctive in the use of a CES production function and in the inclusion of intermediate inputs. The former controls the price elasticity of commodity supply, while the latter accounts for the empirical relevance of the import content of exports.

Foreign commodity producers The world commodity price is determined endogenously through the confrontation of foreign supply (Y_t^{pS*}) and demand (Y_t^{pD*}) for commodities. Foreign commodity supply is modeled as an exogenous AR(1) process

$$Y_t^{pS*} = (1 - \delta_p^*) Y_{t-1}^{pS*} + \delta_p^* Y^{pS*} + \epsilon_{p,t}^*, \tag{19}$$

where Y^{pS*} is the steady-state value of foreign commodity production and $\epsilon_{p,t}^*$ is the foreign commodity supply shock which is assumed to be an IID process. This shock could be also interpreted as a pure commodity price shock hitting the world commodity prices for reasons that are unrelated to world commodity demand. The foreign demand for commodity is determined by the foreign secondary goods sector where it serves as an input (see the following section).

2.2.2 Secondary sector

Domestic and foreign secondary goods are used for domestic and foreign consumption and investment as imperfect substitutes. In addition, foreign secondary goods enter the domestic production function as inputs.[24] The structure of the secondary sector can be arranged in three steps: *i)* Secondary goods firms produce undifferentiated secondary goods; *ii)* Distributors (in the domestic, import, export and foreign markets) differentiate secondary goods with brand-naming technology. They enjoy monopoly power which we model as the Calvo (1983) price-setting; and *iii)* Aggregators assemble the undifferentiated goods into consumption and investment goods as well as inputs.

Domestic secondary goods producers The secondary good is produced under perfect competition. Firms use capital K^f, purchase foreign inputs N^m and hire labor H^f to produce undifferentiated secondary goods denoted by Y^f. Two steps are involved. First, firms

[24] However, by the SOE assumption, the share of the domestic good in foreign consumption and investment is virtually zero.

combine labor and capital to produce a domestic input using a CES technology following Cantore et al. (2014)

$$N_t^d = N_0 \left[\alpha \left(\frac{K_t^f}{K_0} \right)^{\frac{\sigma_d - 1}{\sigma_d}} + (1-\alpha) \left(\frac{z_t \varepsilon_{h,t} H_t^f}{H_0} \right)^{\frac{\sigma_d - 1}{\sigma_d}} \right]^{\frac{\sigma_d}{\sigma_d - 1}}, \tag{20}$$

where z_t is a unit-root technology process growing at a constant rate μ_z representing labor productivity; $\varepsilon_{h,t}$ represents a labor-augmenting technology shock which is assumed to be common to the primary and secondary sectors. The parameter σ_d represents the elasticity of substitution between labor and capital. If $\sigma_d = 1$, this functional form leads to the standard Cobb-Douglas production function. The CES function is written in its normalized form as in Temple (2012) and Cantore and Levine (2012). N_0, K_0 and H_0 are normalizing constants defined in the steady-state appendix. This specification ensures that the coefficient α is the true labor income share.

In the second step, secondary producers combine domestically-produced inputs with imported inputs to create the secondary good using the following CES function:

$$Y_t^f = Y_0^f \left[\omega_n \left(\frac{N_t^m}{N_0^m} \right)^{\frac{\sigma_n - 1}{\sigma_n}} + (1-\omega_n) \left(\frac{N_t^d}{N_0^d} \right)^{\frac{\sigma_n - 1}{\sigma_n}} \right]^{\frac{\sigma_n}{\sigma_n - 1}}, \tag{21}$$

where σ_n is the elasticity of substitution between domestic and foreign inputs (Burstein et al., 2008), Y_0^f is a scaling parameter.

Foreign secondary good producers Two steps are involved in the production of foreign secondary goods (similarly to Bodenstein et al., 2011).[25] First, foreign firms combine capital and labor to produce foreign intermediate goods using a CES technology

$$N_t^* = N_0^* \left[\alpha^* \left(\frac{K_t^*}{K_0^*} \right)^{\frac{\sigma_d^* - 1}{\sigma_d^*}} + (1-\alpha^*) \left(\frac{z_t \epsilon_{h,t}^* H_t^*}{H_0^*} \right)^{\frac{\sigma_d^* - 1}{\sigma_d^*}} \right]^{\frac{\sigma_d^*}{\sigma_d^* - 1}}, \tag{22}$$

where H_t^* is hours worked and K_t^* is capital. The parameter σ_d^* is the elasticity of substitution between labor and capital and $\epsilon_{h,t}^*$ is a labor efficiency shock. In the second step, foreign firms combine intermediate goods with their demand for commodities to obtain secondary

[25] They consider endogenous oil prices in a two-country model with one oil importer and one oil exporter. Oil enters both countries' production functions with a similar two-step CES function.

foreign goods

$$Y_t^* = Y_0^* \left[\beta^* \left(\frac{Y_t^{pD*}}{Y_0^{pD*}} \right)^{\frac{\sigma_p^*-1}{\sigma_p^*}} + (1-\beta^*) \left(\frac{N_t^*}{N_0^*} \right)^{\frac{\sigma_p^*-1}{\sigma_p^*}} \right]^{\frac{\sigma_p^*}{\sigma_p^*-1}}, \tag{23}$$

where Y_0^{pD*} and N_0^* are normalizing constants; β^* is the (income) share of commodity in foreign secondary goods sector; and σ_p^* is the elasticity of substitution between commodity and foreign intermediate goods. Equation (23) shows how foreign (supply, demand, credit, and monetary policy) shocks could be transmitted to the domestic economy through commodity prices. A boom in the foreign economy causes an increase in commodity demand which eventually raises commodity prices. The elasticity σ_p^* is a key parameter that determines the strength of commodity price responses to changes in foreign demand for commodities.

Domestic distributors There are two types of domestic distributors (intermediate and final). There is a continuum of intermediate distributors, indexed by $i \in [0, 1]$. Each intermediate distributor buys a homogeneous secondary good Y^f; turns it into a differentiated intermediate good (using a brand-naming technology) and then sells it to a final distributor at price $P_{i,t}$. Every intermediate distributor is assumed to be a price taker in the secondary goods market (it purchases secondary goods at their marginal costs) and a monopoly supplier of its own variety (it sets its own price). The final distributor is an aggregator which uses a continuum of differentiated intermediate goods to produce the final homogeneous good, which is then used for consumption and investment by domestic households and sold at price P_t.

The intermediate distributor follows a price adjustment rule along the lines of Calvo (1983). At every period t, with probability $(1-\xi_d)$, any intermediate distributor i is allowed to re-optimize its price by choosing the optimal price P_t^{new}.[26] With probability ξ_d, it cannot re-optimize, and it simply indexes its price for period $t+1$ according to the following rule:

$$P_{i,t+1} = (\pi_t)^{\kappa_d} (\overline{\pi})^{1-\kappa_d} P_t,$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is last period's inflation, $\overline{\pi}$ is the inflation target and κ_d is an indexation parameter.

The final distributor is assumed to have the following CES production function:

[26] Since all distributors are virtually identical and will always choose the same price, the index i is dropped to simplify the notation.

$$J_t^d = \left[\int_0^1 \left(J_{i,t}^d\right)^{\frac{1}{\lambda_{d,t}}} di\right]^{\lambda_{d,t}}, \; 1 \leq \lambda_{d,t} < \infty, \tag{24}$$

where $J \in (C, I)$ refers to the consumption or investment good and $\lambda_{d,t}$ is a stochastic process determining the time-varying markup in the domestic goods market.

Foreign distributors Foreign distributors face a similar optimization problem when distributing foreign goods to foreign households and entrepreneurs.

Exporting distributors The intermediate exporting firm buys a homogeneous domestic good Y^f from domestic secondary producers as well as a foreign input (from importing firms at price P_t^m) to account for the import content of exports. It combines these goods using a Leontief technology, turns them into a type-specific differentiated good using a brand-naming technology and then sells it in the foreign market to an aggregator at price $P_{i,t}^x$ expressed in foreign currency. The aggregator produces final exported consumption and investment goods sold at price P_t^x to foreign households.

The final, composite, exported good aggregates a continuum of i-differentiated exported goods, each supplied by a different firm, according to

$$\tilde{X}_t = \left[\int_0^l (\tilde{X}_{i,t})^{\frac{1}{\lambda_x}} di\right]^{\lambda_x}, \; 1 \leq \lambda_x < \infty. \tag{25}$$

where λ_x is the steady-state markup in the exporting sector.

Domestic intermediate exporting firms follow a Calvo price-setting rule and can optimally change their price only when they receive a random signal. In any period t, each exporting firm has a probability $(1-\xi_x)$ of re-optimizing its price by choosing $P_{new,t}^x$.[27] With probability ξ_x the importing firm cannot re-optimize at time t and, instead, it indexes its price according to the following rule: $P_{i,t+1}^x = (\pi_t^x)^{\kappa_x} (\overline{\pi})^{1-\kappa_x} P_{i,t}^x$ where $\pi_t^x = \frac{P_t^x}{P_{t-1}^x}$. This foreign currency price stickiness assumption implies short-run incomplete exchange rate pass-through to the export price.

Assuming that aggregate foreign consumption and investment follow a CES function,

[27] All exporting firms that are allowed to re-optimize their price, in a given period, will choose the same price, therefore it is not necessary to use a firm index.

foreign demand for the aggregate final exported good is defined by

$$X_t^f = \left(\frac{P_t^x}{P_t^*}\right)^{-\eta_f} X_t^*, \tag{26}$$

$$X_t^* = X^* \left(\frac{\nu C_t^* + (1-\nu) I_t^*}{\nu C^* + (1-\nu) I^*}\right) \varepsilon_{x,t}, \tag{27}$$

where P_t^* is the price of the foreign good and P_t^x is the export price (denominated in foreign currency). X_t^* captures foreign aggregate demand which depends on foreign aggregate consumption and investment and where ν is the share of consumption in final good trade. $\varepsilon_{x,t}$ is an export-specific shock capturing changes in foreign households' home bias. The coefficient η_f is the foreign elasticity of substitution between foreign and domestic goods allowing for short-run deviations from the law of one price.

Importing distributors The (foreign-owned) intermediate importing firm buys a homogeneous foreign good in the world market. It turns it into a type-specific good using a differentiating technology (brand-naming) and then sells it in the domestic market to an aggregator at price $P_{i,t}^m$. The aggregator produces final imported consumption, investment and input goods sold at price P_t^m to households and firms.

The final imported consumption and investment goods are aggregated using a continuum of i differentiated imported goods. Each are supplied according to

$$J_t^m = \left[\int_0^l (J_{i,t}^m)^{\frac{1}{\lambda_{m,t}}} di\right]^{\lambda_{m,t}}, \ 1 \leq \lambda_{m,t} < \infty, \tag{28}$$

where $\lambda_{m,t}$ is the time-varying markup common to all sectors J and $J \in (C, I, N)$ is an indices referring to the imported consumption, investment and input goods. We assume that this markup is affected by both foreign markup shocks (common to all foreign distributors) as well as by a specific import price push shock.

Foreign intermediate importing firms follow a Calvo price-setting rule and can optimally change their price only when they receive a random signal. In any period t, each importing firm has a probability $(1-\xi_m)$ of re-optimizing its price by choosing $P_{new,t}^m$[28]. With probability ξ_m, the importing firm cannot re-optimize at time t and, instead, it indexes its price according to the following scheme: $P_{i,t+1}^m = (\pi_t^m)^{\kappa_m} (\overline{\pi})^{1-\kappa_m} P_{i,t}^m$ where $\pi_t^m = \frac{P_t^m}{P_{t-1}^m}$. This local currency price stickiness assumption implies incomplete exchange rate pass-through to the consumption and investment import prices.

[28] All importing firms that are allowed to re-optimize their price, in a given period, will choose the same price, therefore it is not necessary to use a firm index.

We depart from ALLV by assuming that the imported good price is the same for both investment and consumption. We also assume that a share of imports is used by domestic producers and exporting firms. In addition, the importing distributor purchases the foreign input at its marginal production cost.

2.3 Financial sector

There are two types of banks: domestic and foreign.[29] Domestic banks operate in the domestic market. Foreign banks are global players (similarly to Kollmann, 2013) operating in the domestic and foreign markets. Entrepreneurs take loans denominated in domestic currency at aggregate rate R_t^L given by

$$R_t^L = (1-\omega_b)R_t^{L,d} + \omega_b R_t^{L,f} \ , \tag{29}$$

where ω_b is the share of foreign banks operating in the domestic economy. $R_t^{L,d}$ and $R_t^{L,f}$ are the lending rates charged by domestic and foreign banks to domestic borrowers, respectively. We assume that entrepreneurs borrow a fixed share ω_b of their credit needs from foreign banks and they cannot take advantage of arbitrage opportunities. We define these lending rates below.

Domestic financial market Domestic banks collect deposits from savers and have access to the central bank to finance any liquidity shortages. The deposit rate is equal to the central bank rate R_t. Banks give loans to entrepreneurs. Following Bernanke et al. (1999), we assume the existence of an agency problem (not modeled here) between banks and borrowers. The domestic bank determines the domestic lending rate $R_t^{L,d}$ and charges an external financing premium over the deposit rate to finance monitoring costs by setting

$$R_t^{L,d} = R_t \exp\left[\phi_{nw}\left(\frac{B_t^e}{V_t} - \frac{B^e}{V}\right)\right] + \varepsilon_{R_L,t} \ , \tag{30}$$

where B_t^e is the entrepreneur nominal debt and V_t is its collateral such that $\frac{B_t^e}{V_t}$ represents leverage. Therefore, the domestic bank spread between lending and deposit rates follows the endogenous evolution of domestic entrepreneurs' balance sheets. $\varepsilon_{R_L,t}$ is a pure domestic

[29] Cetorelli and Goldberg (2011) show that both domestic and foreign banks contributed to the transmission of the financial crisis to emerging countries in Europe, Asia and Latin America. Cross-border lending and local loans by foreign affiliates were cut while domestic banks also reduced their loans due to adverse balance sheet effects resulting from the financial crisis. Although no African countries are considered, it justifies the introduction of domestic and foreign banks in the model.

credit supply shocks.[30]

We depart from Bernanke et al. (1999) by considering an alternative definition of collateral. We draw on Mendoza (2002) and define the value of collateral as a claim on entrepreneurs' output

$$V_t = P_t Y_t^f + S_t P_t^{*p} X_t^p \ , \tag{31}$$

where $P_t Y_t^f$ is nominal output in the final sector, $S_t P_t^{*p}$ is the commodity price expressed in domestic currency and X_t^p represents commodity exports. This specification has been widely used in the sudden-stop literature applied to developing countries subject to terms of trade shocks. Arellano and Mendoza (2002) argue that it reflects actual practice in the credit markets.[31]

Foreign financial market Foreign banks determine the lending rates they charge on loans denominated in domestic and foreign currencies. They consider global (the sum of domestic and foreign) entrepreneurs' balance sheets to set an identical premium over the domestic and foreign deposit rates.[32] Foreign banks set the lending rate

$$R_t^{L,f} = R_t \ \exp\left[\phi_{nw}^* \left(\frac{B_t^{e*}}{V_t^*} - \frac{B^{e*}}{V^*}\right)\right] + \varepsilon_{R_L,t}^* \ , \tag{32}$$

for borrowing in domestic currency and

$$R_t^{L,*} = R_t^* \ \exp\left[\phi_{nw}^* \left(\frac{B_t^{e*}}{V_t^*} - \frac{B^{e*}}{V^*}\right)\right] + \varepsilon_{R_L,t}^* \ , \tag{33}$$

[30] In spirit, the pure credit supply shock identification is similar to Helbling et al. (2011) and Meeks (2012): it is an increase in the credit spread unrelated to default risks. It generates a gap between the lending and deposit rates. It differs from the wedge shock $\varepsilon_{b,t}$ which causes gaps between the central bank policy rate and the return on savers' assets and between the lending rate and the costs of borrowers' liabilities. We interpret this latter shock as an aggregate demand shock (see IRFs in the appendix).

[31] Arellano and Mendoza (2002) argue that a higher current income to credit ratio "reduces the likelihood of observing situations in which the current income of borrowers falls short of what is needed to pay for existing debts". Although we do not introduce sudden-stops (none were observed in South Africa over the estimation period, see Smit et al., 2014), we use this argument in order to link credit spreads to a similar ratio. In the empirical literature, Min et al. (2003) describe a negative link between export earnings and the spread. Bastourre et al. (2012), Shousha (2016), Fernández et al. (2018) and Drechsel and Tenreyro (2018) document negative links between commodity prices and spreads in emerging markets.

[32] This is equivalent to assuming that foreign banks cannot discriminate between domestic and foreign borrowers and that each category of agent has access to domestic currency loans.

for borrowing in foreign currency. B_t^{e*} is the global entrepreneur nominal debt and $\varepsilon_{R_L,t}^*$ is a pure foreign credit supply shock.[33] V_t^* is the value of collateral defined as

$$V_t^* = P_t^{k*} \bar{K}_t^* \ , \tag{34}$$

where $\bar{K}_t^*$ is capital in the world economy and P_t^{k*} is its price.

Foreign banks therefore introduce contagions from developments in the global market into the domestic economy through the interest rate $R_t^{L,f}$ they charge in the domestic economy. When lending funds to domestic entrepreneurs, they charge a premium over the domestic deposit rate function of global entrepreneurs balance sheets and foreign credit supply shocks.[34] Developments in the financial sector have repercussions on both aggregate demand (through entrepreneurs consumption and investment) and supply (through firms' working capital paid in advance) sides of the model.

2.4 Public authorities

The public sector consists of a central bank and a fiscal authority.

Central bank The monetary authority is assumed to follow a simple Taylor-type rule

$$R_t = \rho_r R_{t-1} + (1-\rho_r) \left(R + \tau_\pi \left(\pi_t^c - \bar{\pi} \right) + \tau_{\Delta y} \left(\frac{y_t - y_{t-1}}{y_{t-1}} \right) + \tau_{\Delta s} \left(\frac{S_t}{S_{t-1}} - 1 \right) \right) + \varepsilon_{R,t}, \tag{35}$$

where ρ_r is the interest rate smoothing parameter, τ_π is the response to current consumer price inflation, $\tau_{\Delta y}$ to (real) GDP growth deviation from its trend and $\tau_{\Delta s}$ to the change in exchange rate. The exogenous process $\varepsilon_{R,t}$ is a monetary policy shock. Similar policy rules include Lubik and Schorfheide (2007), Ortiz and Sturzenegger (2007), Hove et al. (2015), Alpanda et al. (2011) and Liu et al. (2009) for models applied to South Africa. It is also consistent with the adoption of inflation-targeting which formally started in February 2000. The foreign central bank follows a similar rule (but does not respond to the exchange rate by the closed-economy assumption).

[33] The global entrepreneurs' debt includes both domestic and foreign entrepreneurs. However, by the SOE assumption, domestic entrepreneurs are too small to have an impact on this ratio.

[34] The foreign credit supply shock is identified based on foreign variables: from equation (32), it is a shock that raises the spread between the lending and deposit rates for reasons unrelated to foreign entrepreneurs balance sheets.

Government The government collects taxes on consumption, labor and capital and follows a simple spending rule

$$g_t = \rho_g g_{t-1} + (1 - \rho_g)\bar{g} + \varepsilon_{g,t}, \tag{36}$$

where $g_t = \frac{G_t}{z_t}$ and $\bar{g}$ is the steady-state stationary value of government spending and $\varepsilon_{g,t}$ is a government spending shock. We assume that government consumption is composed of domestic goods only. The foreign government follows a similar rule.

2.5 Closing market conditions

In equilibrium, the domestic final goods market, the loan market and the foreign bond market have to clear. The final goods market is in equilibrium when demand from domestic households, the government and foreign households equals the domestic supply of final goods. The aggregate resource constraint therefore has to meet the following condition on the use of domestic goods:

$$C_t^d + I_t^d + G_t + (1 - \omega_x)X_t^f \leq Y_t^f - a(u_t^p)\overline{K}_t^p - a(u_t^f)\overline{K}_t^f. \tag{37}$$

In the same way, we define the idendity on GDP by

$$Y_t = C_t + I_t + G_t + X_t - M_t \ , \tag{38}$$

where $I_t = I_t^p + I_t^f$, $X_t = X_t^f + X_t^p$ and $M_t = C_t^m + I_t^m + N_t^m + \omega_x X_t$.

The loan market clears when the demand for liquidity from firms and entrepreneurs equals the supply of liquidity including savers' deposits and monetary injections by the central bank. Since the central bank liquidity supply is perfectly inelastic at its policy rate, we can disregard money supply.

The foreign asset market clears when the positions of the exporting and importing firms equal the households' choice of foreign bond holdings. Foreign assets evolve according to:

$$S_t B_{t+1}^* = R_{t-1}^* \Phi\left(a_{t-1}, \tilde{\phi}_{t-1}^a\right) S_t B_t^* + S_t P_t^x X_t^f + S_t P_t^{*p} X_t^p - P_t^m M_t. \tag{39}$$

Finally, the aggregate resource constraint in the foreign economy implies that total final output is used for private and public consumption and investment. The supply of commodities in the foreign economy is equal to the demand for commodities by foreign firms in the secondary sector.

3 Empirical strategy

We start by summarizing the driving forces in our model. Thereafter, we present the data and estimation technique used. Finally, we discuss the calibration of some parameters that were not estimated.

3.1 Structural shocks classification

Table 1 summarizes the different innovations analyzed in the paper. We define three broad categories of structural shocks: domestic, foreign, and SOE shocks. Domestic and foreign shocks are disturbances that are unambiguously identified from domestic and foreign origins, respectively. SOE shocks, on the other hand, are disturbances that may have both domestic and foreign origins. Our primary interest is to understand the role of foreign shocks in South Africa.

Domestic and foreign shocks are classified into five groups: aggregate demand shocks (AD) including wedge shocks[35], investment-specific shocks, and government consumption shocks; aggregate supply shocks (AS) including productivity shocks, cost-push shocks and wage push shocks; monetary policy shocks (MP); credit supply shocks (Cred); and commodity supply shocks (Com).

We analyze three SOE shocks: trade volume shocks (simultaneous changes in domestic and foreign households' home biases), import price shocks, and the country risk premium shock. SOE shocks might be caused by internal as well as external factors. For example, trade volumes shocks could be driven by internal factors such as changes in domestic import/export policies or changes in the quality of domestic products. In the same way, trade volumes shocks could be explained by external factors such as changes in foreign taste for domestic goods or shocks originating from the rest of the world but outside the G7 countries. The country risk premium could also be explained by changes in domestic country risk (beyond what is captured by the net foreign asset position) or by a change in foreign risk aversion leading to a revision of the price of exchange rate risks. Given the lack of any clear-cut identification of the origins of these shocks, we label them as SOE shocks. Note also that these SOE shocks are restricted so as not to have any impact on foreign variables.

[35] Wedge shocks could also be interpreted as financial shocks and as a result they could be grouped together with credit supply shocks. However, considering that their main impact is on consumption and investment, we decided to label it as a real demand shock.

Table 1: Overview of structural shocks

	Symbol	Process	Group	Description
Foreign shocks				
Wedge	$\varepsilon^*_{b,t}$	AR(1)	AD*	Wedge between the monetary policy rate and the return on households' assets and liabilities (affecting consumption and investment)
Investment-specific	Υ^*_t	AR(1)	AD*	Investment-specific shock[a]
Government demand	$\varepsilon^*_{g,t}$	AR(1)	AD*	Government consumption shock
Mark-up	$\lambda^*_{d,t}$	AR(1)	AS*	Distributors markup shock
Wage-push	$\lambda^*_{w,t}$	IID	AS*	Wage markup shock
Productivity	$\varepsilon^*_{h,t}$	AR(1)	AS*	Aggregate labor-augmenting productivity shock
Monetary policy	$\varepsilon^*_{R,t}$	AR(1)	MP*	Deviation from Taylor rule
Credit supply	$\varepsilon^*_{R_L,t}$	AR(1)	Cred*	External financing premium (spread) shock
Commodity supply	$\varepsilon^*_{p,t}$	IID	Com*	Exogenous shock to global commodity supply
SOE shocks				
Trade volume	$\varepsilon_{x,t}$, $\varepsilon_{m,t}$	ARMA(1,1)	Trade	Correlated shocks to domestic and foreign trade preferences
Import markup	$\lambda_{m,t}$	AR(1)	Trade	Importing distributors markup shock
Country risk premium	$\tilde{\phi}_t$	AR(1)	UIP	Country risk premium shock (affecting UIP condition)
Domestic shocks				
Wedge	$\varepsilon_{b,t}$	AR(1)	AD	Wedge between the monetary policy rate and the return on households' assets and liabilities (affecting consumption and investment)
Investment-specific	Υ_t	AR(1)	AD	Investment efficiency shock (in primary and secondary sectors)
Government demand	$\varepsilon_{g,t}$	AR(1)	AD	Government consumption shock
Mark-up	$\lambda_{d,t}$	AR(1)	AS	Domestic distributors markup shock
Wage-push	$\lambda_{w,t}$	IID	AS	Wage markup shock (note: not used in the baseline estimation)
Productivity	$\varepsilon_{h,t}$	AR(1)	AS	Aggregate labor-augmenting productivity shocks hitting the primary and secondary sectors
Monetary policy	$\varepsilon_{R,t}$	IID	MP	Deviation from Taylor rule
Credit supply	$\varepsilon_{R_L,t}$	AR(1)	Cred	External financing premium (spread) shock
Commodity supply	$\varepsilon_{hp,t}$	AR(1)	Com	Labor augmenting productivity shock in the primary sector

[a] The investment-specific shock in the foreign economy differs from the usual investment efficiency shock. A favourable investment efficiency shock has a negative impact on the real price of capital. This generates an increase in the spread driven by a drop in the value of collateral (equation 34). We replaced this shock with a shock to the discount rate applied to capital returns. The latter creates similar dynamics but better captures the negative correlation between the spread and investment in US data.

3.2 Estimation

We estimate the model with Bayesian methods (e.g. DeJong et al., 2000; Otrok, 2001; and Schorfheide, 2000) in DYNARE.[36] In the baseline analysis, we estimate domestic and foreign parameters jointly with endogenous priors following Christiano et al. (2011). The priors (described in section 3.4) are updated based on the standard deviation of observed variables to avoid a common problem of over-predicting the variances implied by the structural model. In a robustness exercise, we experiment with independent priors. We also experiment with estimating the model in two steps. First, foreign parameters are estimated using only data from the foreign economy. Second, domestic parameters are estimated on the full dataset, calibrating foreign parameters at their mode values obtained from the first step. Our main results remain qualitatively unchanged with these alternative estimation procedures.

3.3 Data

We estimate the model using quarterly data on 13 domestic and 9 foreign variables over the period 1994Q1 to 2017Q4. The start date has been selected to avoid the apartheid period in South Africa (which was characterized by instability and relatively low trade and financial linkages with the rest of the world). We also experiment with estimating the model over different time spans but our main empirical results remain qualitatively unchanged. For instance, we end the sample period in 2009Q1 in order to isolate the zero lower bound period in advanced economies such as the US and the euro area. In the same way, we start the sample period in 2000Q1. This period corresponds to the formal implementation of inflation-targeting in South Africa.

The following domestic variables are used: GDP, consumption, investment, total imports, total exports, employment, consumer and import price indexes, labor compensation, risk-free rate, and nominal effective exchange rate. In addition, we build a South African spread proxy using the predicted values obtained from regressing an emerging market spread index on South African variables.[37] Moreover, commodity exports are proxied by sales in the mining sector (about 70% is exported). As just mentioned, we use employment as an observed variable. However, in the model, there is no unemployment, only hours worked. We therefore

[36] See Adjemian et al. (2011).

[37] The emerging market spread considered is the Option-Adjusted Spread for the ICE BofAML Emerging Markets Corporate Plus Index obtained from the Federal Reserve Bank of St. Louis database. The South African variables used as independent variables are the number of insolvencies, the yield on EKSOM bonds, the spread between domestic and US 10-year government bond yield, the OECD-MEI manufacturing business confidence indicator and the MSCI mid- and large-cap equity return index.

follow ALLV and introduce an ad-hoc equation linking employment to hours with a labor-hoarding parameter. Finally, we allow for estimated measurement errors on exports and imports (to compensate for the fact that there is only one trade volume shock) and calibrated measurement errors for other variables.[38] More details on data construction and observation equations are provided in the appendix.

Foreign variables include GDP, consumption, investment, consumer price index, wages, risk free rate, spread, hours worked and commodity price. We use US data in the baseline estimation and G7 data as a robustness check. We use aggregate G7 data obtained from the OECD or the first principal component of series on the 7 countries. Commodity price is measured as a simple average of world prices of the main miming exported by South Africa (with the exception of gold): coal, platinum, silver and aluminum. The foreign spread is measured as the difference between BBB and government bond 5 years yields. Finally, we replace the Fed funds rate by the shadow rate (proposed by Wu and Xia, 2016) in order to better capture monetary policy in the US at the zero lower bound.

3.4 Priors

The prior distributions are described in Tables 7 and 8 at the end of the paper. We now discuss some of the key priors.

Commodity sector Here, we describe our priors governing foreign demand and domestic supply commodity price elasticities. We build our prior based on the well-developed literature focusing on oil markets. The elasticity of substitution between production factors in the domestic primary sector production function (σ_p) has a determining impact on the domestic commodity supply price elasticity. The literature generally supports a low elasticity of substitution. We therefore set the prior mean for σ_p to $1/2$. The mean of the prior governing the foreign commodity demand elasticity of substitution (σ_d^*) is set to 0.13 following the literature review in Caldara et al. (2016) on oil demand elasticity.[39]

Financial sector The prior means for the financial accelerator in the domestic (ϕ_{nw}) and foreign (ϕ_{nw}^*) economies are set to 0.05 following Bernanke et al. (1999). This value is very close to the estimate in Christensen and Dib (2008) for the US. Our choice for the prior mean of the share of foreign banks in domestic credit (ω_b) follows Claessens and Horen

[38] They are calibrated to explain 1% of the variance in observed variables.

[39] Bodenstein et al. (2011) calibrate the oil demand elasticity of substitution in the production function to 0.4. However, the evidence presented in Caldara et al. (2016) supports lower demand elasticities.

(2014). They estimate the share of foreign banks' assets among total bank assets to 22% for South Africa. We also estimate the correlation between domestic and foreign credit supply shocks. This captures the fact that domestic and foreign banks are exposed to similar risks. We refer to two key statistics to describe this correlation in bank risks. First, foreign currency loans and advances account for 6.6% of banks' total assets in South Africa (SARB data). Second, the claims on non-residents to domestic assets ratio averages 17% over the 2001-2015 period (data from the IMF-IFS). We therefore set the prior to an intermediate value of 0.14.

3.5 Calibrated parameters

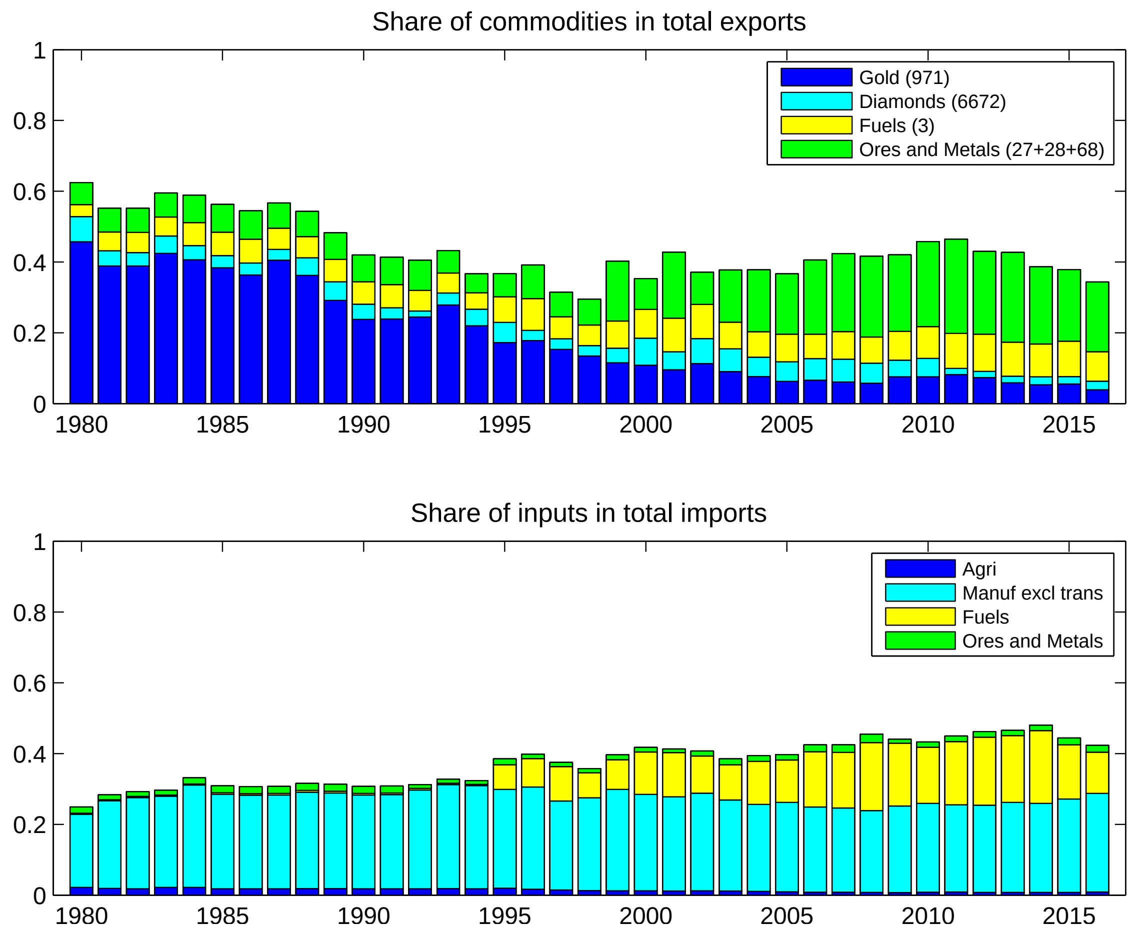
The values of calibrated parameters are given in Table 6 at the end of the paper. We briefly discuss a number of important calibrated parameters in this section. For more details, we refer to the appendix.

Households The share of rule-of-thumb households (which are excluded from financial markets) is set to 1/3. This proportion is consistent with the data: only about 70% of adults (aged 15 and above) have an account in South Africa (World Bank Financial Inclusion database, 2014). The share of entrepreneurs is set to 1/3 as in Gerali et al. (2010). The discount factors for savers β_S and entrepreneurs β_E are set at 0.994 and 0.986 in order to match average risk-free interest rate and spread, respectively.

Commodity sector The mining exports-to-GDP ratio is set to 11%, which implies that mining represents about 38% of total exports. Figure 1 shows the evolution of South African commodity exports. The data indicate that the share of mining exports fell from well above 50% in the 1980s to between 30% and 45% over the 1994-2016 period. The overall decline in the share of commodity exports was caused by a large drop in gold exports partially compensated by an increase in fuel, ores and metals exports. We set the capital share in the mining sector α_p at 0.3. The land share β_p is then calibrated to 0.29 to ensure that households devote 6.7% of their labor efforts to the mining sector on average. This value corresponds to the mining sector's share in total non-agricultural employment as reported by the South African Chamber of Mines.

Imports We fix the shares of imports in household consumption ω_c, investment ω_i, domestic production ω_n and the additional import content of exports ω_x, based on the methodology proposed by Kose (2002) and the calibration proposed by du Plessis et al. (2014) on South Africa. Following the methodology proposed by Kose (2002), we find that the input share

Figure 1: Input import and commodity export shares in South African trade



fluctuated around 40% over the estimation period. Considering the broad input categories presented in equation (21) and the additional import content of exports, calibrating ω_n to 0.07 and ω_x to 0.16 implies that together, those inputs account for about 40% of South African imports. The total import content of exports is then also equivalent to the 20% reported by the OECD (data for 2014).[40] We further calibrate ω_c and ω_i to 0.15 and 0.45, respectively (du Plessis et al., 2014 also assign a larger share of imports in the investment than in the consumption basket). Moreover, machinery and transport equipment represent a substantial (30%) share of imports (World Bank database). Taken together, those values imply an import-to-GDP ratio of about 28% as observed in the data.

Financial sector The sum of entrepreneurs' debt stock and their wage bill and inputs financed in advance ensures that the credit provided to the private sector to GDP ratio

[40] The total import content of exports is based on the foreign inputs entering the secondary goods production function plus the additional 16% of imports entering the exportation process.

averages 150%.[41]

Foreign economy The commodity income share in final goods production is calibrated to 0.08. Entrepreneurs credit-to-GDP ratio is set to 200%. The share of investment goods in world trade ν is set to 0.7 following Engel and Wang (2011). They propose a model where trade consists of durables goods and justify their choice with the fact that durable goods account for 70% of exports and imports in OECD countries. The elasticity of substitution between labor and capital (σ_d^*) is set to one. For simplicity, most other calibrated parameters in the foreign economy are set at their domestic counterparts' values.

4 Empirical results

We begin by discussing the estimated parameter values. Subsequently, we use variance decomposition and historical decomposition to identify the driving forces of macroeconomic fluctuation in South Africa. Thereafter, we study the transmission mechanisms of the structural shocks and demonstrate the importance of commodity and financial channels in the transmission of foreign shocks. Finally, we undertake a number of robustness exercises.

4.1 Estimated parameters

Table 8 reports the parameter values (including the prior mean and standard deviation; as well as the estimated posterior mode and 90 % credible intervals), whereas Table 7 presents the persistence coefficients and the standard deviation of exogenous disturbances. The prior and posterior distributions of all estimated parameters are presented in the appendix.

In the foreign block, a parameter of interest is the elasticity of substitution σ_p^* between commodity and other (labor and capital) inputs. We estimate this parameter value to be low at 0.19. A low elasticity of substitution implies that commodity prices respond relatively strongly to the foreign business cycle through firms demand. The persistence of commodity supply shocks $(1 - \delta_p^*)$ is relatively large: the mode of δ_p^* is estimated at 0.07. We estimate a low value for the spread elasticity to borrower net worth ratio (fixing its prior mean to 0.05; e.g. as in Bernanke et al., 1999) to about 0.026. Other parameters are estimated to values which are fairly standard in the literature.

For the domestic block, we estimate the elasticity of substitution between production factors in the primary sector (σ_p) and find a value of 0.43. The use of a CES production

[41] Credit provided to the private sector to GDP ratio fluctuated between 100 and 160% over the estimation period, World Bank database.

function with decreasing returns to scale (due to the introduction of a fixed production factor) and a low factor elasticity of substitution imply a short-run domestic commodity supply price elasticity of 0.19.[42] By contrast, a standard Cobb-Douglas production function with labor and capital would have generated a much larger commodity supply elasticity (0.67, holding all other parameters constant) that would lie outside the range of reasonable parameters for commodity markets (see, for example, the literature review in Caldara et al., 2016) and would generate excess commodity supply volatility. We also estimate the elasticity of substitution of foreign inputs in the domestic final goods production function (σ_n) to 0.24 which supports the view that those inputs are crucial for domestic supply conditions in South Africa. The mode of the elasticity of substitution between labor and capital in the final goods sector (σ_d) is also low: 0.38. These results support the use of CES production functions advocated for in Cantore et al. (2015).

The estimated share of foreign banks in domestic credit is 0.32 (larger than its prior mean of 0.22) and the estimated correlation in credit supply shocks is 0.2 (also larger than its prior of 0.14). We estimate the domestic bank spread elasticity to borrower net worth ratio to a low value of 0.016, suggesting that the financial accelerator is relatively modest in this economy. However, considering the relative volatility of the value of collateral (in equation 31) driven by volatile commodity prices, this low value could potentially generate a significant response of the spread to business cycle fluctuations.

We assume that domestic elasticities of substitution of consumption and investment are identical ($\eta_c = \eta_i$) due to the lack of identification (we do not have quarterly data on the composition of imports). The domestic η_c and foreign η_f elasticities are estimated to be small (about 0.36 and 1.05 respectively). We also note that the investment adjustment cost is large (6.36 in the baseline) and that variable capital utilization is estimated to be irrelevant (and therefore a posteriori calibrated to 10).

Finally, the estimated values of the monetary policy rule suggest that the South African Reserve Bank (SARB) has responded more aggressively to inflation (1.85). This result is consistent with the inflation-targeting regime. The coefficients on the change in the NEER and the growth rate of GDP are 0.11 and 0.43, respectively. These findings suggest that authorities at SARB are primarily concerned with inflation stabilization but they do not completely neglect fluctuations in real activity and the exchange rate.

[42] We compute this short-run commodity supply elasticity based on the IRFs to a foreign commodity supply shock simulated at the mode of estimated parameters. We divide the response of domestic commodity output on impact (in percentage deviation from steady-state) by the response of real commodity prices (also in deviation from steady-state).

4.2 Variance decomposition

Variance decomposition is computed at the posterior mode for the baseline model. Table 2 shows foreign shocks contribution to the variation of foreign variables (lower panel) and domestic variables (upper panel).[43]

Foreign shocks contribution to foreign variables The most important drivers of economic fluctuations in US GDP are demand shocks (41% summing wedge, investment-specific and public consumption shocks), followed by aggregate supply shocks (28% summing productivity, cost-push and wage-push shocks), monetary policy shocks (20%), commodity supply shocks (6%) and credit supply shocks (4%). The most important drivers of price fluctuations in the US are aggregate supply shocks. Aggregate demand shocks have the largest impact on the monetary policy rate, followed by aggregate supply and commodity supply shocks. Business cycle shocks in the foreign block such as demand, supply, monetary policy and credit capture about 31% of fluctuations in commodity prices. In our robustness exercises, we find values in the range of 29 to 52% which are consistent with the 35% reported in Caldara et al. (2018). Foreign credit shocks explain 93% of the variance in the spread reflecting the large spike in US spread data during the financial crisis.

Foreign shocks contribution to domestic variables The estimation confirms the finding obtained with SVAR analysis in HMO that foreign shocks are important drivers of economic fluctuations in South Africa. Together, foreign shocks explain about 20% of the fluctuations in South African macroeconomic variables over the 1994 to 2017 period. They account for a large share of fluctuations in GDP (24%), consumption (21%), investment (22%), mining exports (18%) and the risk-free rate (17%). The largest shares are observed for labor compensations (26%) and the spread (37%) while we report lower contributions for imports (6%), exports (12%), the consumer price index (14%) and the nominal exchange rate (11%).

Going through specific foreign shocks, we can see that commodity supply shocks play a dominant role in South Africa: they explain 9% of the fluctuations in GDP, 10% for consumption, 10% for investment, 12% for mining exports, and 15% for the spread. Altogether, these findings are in line with the view that commodity prices have a large impact on commodity-exporting countries and that these shocks generate considerable volatility in consumption and investment.

[43] Note that the sum of variances does not add up to 100 due to the inclusion of small calibrated measurement errors allowed in the estimation.

Table 2: Foreign shocks contribution to foreign and domestic variables

	AD*	AS*	MP*	Com*	Cred*	All*
GDP	5.31	5.33	2.61	8.99	1.61	23.85
Employment	3.96	3.84	2.29	6.82	1.35	18.26
Consumption	1.51	6.29	2.30	9.84	1.01	20.95
Investment	1.21	7.17	2.07	10.38	0.80	21.63
Exports	5.33	1.16	0.84	3.95	0.50	11.78
Imports	0.42	2.49	0.90	2.07	0.28	6.16
Mining exports	3.13	2.07	0.88	12.02	0.30	18.40
CPI	5.69	5.03	0.76	2.01	0.38	13.87
MPI	1.14	13.09	1.75	1.18	0.03	17.19
Labor comp.	2.68	7.32	3.14	11.22	1.29	25.65
Risk-free rate	8.50	2.78	0.74	4.52	0.60	17.14
Spread	6.26	2.91	1.28	14.90	11.92	37.27
NEER	0.34	2.00	5.92	2.53	0.07	10.86
US GDP	40.88	27.94	19.72	6.06	4.45	99.05
US Consumption	37.41	31.30	23.33	3.94	3.08	99.06
US Investment	53.78	18.86	11.98	8.56	5.93	99.11
US Hours	40.34	31.05	19.42	3.92	4.43	99.16
US CPI	26.65	50.56	15.07	6.41	0.63	99.32
US Wage	22.23	57.08	16.32	2.82	0.73	99.18
US Risk-free rate	50.16	21.70	13.95	10.26	1.42	97.49
US Spread	1.81	0.84	0.41	3.14	92.68	98.88
Commodity Price	13.45	10.66	5.99	67.51	1.19	98.80

Note: Risk-free rate and spread in levels; NEER in Q/Q growth rate; all other variables in Y/Y growth rates. Stars stand for foreign shocks. See Table 1 for a description of the shocks classification. The last column is the total contribution of all foreign shocks. South Africa data in the upper panel, US data in the lower panel.

Foreign aggregate demand shocks have a relatively large impact on exports (5%), the spread (6%), the CPI (6%), interest rates (8%) and GDP (5%). Foreign supply shocks have a notable impact on consumption (6%) and investment (7%) through their impact on the import price index (13%). They are also important contributors to labor incomes (7%), CPI (5%) and GDP (5%). Foreign monetary policy shocks are important for the exchange rate (6%). The impact of foreign credit supply shocks is modest. They explain 2% of fluctuations in output (but 12% for the spread) which reflects the relatively moderate direct exposure of South African banks to the global economy.

Table 3: SOE and domestic shocks contribution to domestic observed variables

	Trade	UIP	SOE	AD	AS	MP	Com	Cred	Domestic
GDP	5.79	3.97	9.76	26.84	22.37	4.17	11.30	1.12	65.80
Employment	25.27	1.10	26.37	14.92	34.53	3.08	1.48	0.91	54.92
Consumption	9.19	4.60	13.79	35.72	20.83	4.13	2.61	1.27	64.56
Investment	7.50	4.62	12.12	47.57	6.63	0.97	9.02	1.38	65.57
Exports	64.05	4.86	68.91	2.20	2.64	0.27	14.19	0.01	19.31
Imports	81.18	1.73	82.91	6.31	1.24	0.26	2.89	0.23	10.93
Mining exports	0.75	4.01	4.76	0.88	1.27	0.29	69.37	0.02	71.83
CPI	17.89	16.98	34.87	19.43	22.52	6.60	2.06	0.08	50.69
MPI	45.15	25.78	70.93	2.76	2.09	1.69	4.38	0.02	10.94
Labor comp.	13.22	2.39	15.61	16.29	35.67	1.40	2.13	0.95	56.44
Risk-free rate	8.16	19.94	28.10	29.18	13.19	5.53	4.93	0.16	52.99
Spread	5.65	3.42	9.07	4.49	1.97	0.54	6.49	37.42	50.91
NEER	0.14	77.23	77.37	1.33	1.91	3.02	4.55	0.00	10.81

Note: Risk-free rate and spread in levels; NEER in Q/Q growth rate; all other variables in Y/Y growth rates. See Table 1 for a description of the shocks classification. The third column is the total contribution of all SOE shocks. The last column is the total contribution of all domestic shocks.

SOE shocks Table 3 reports the variance decomposition for domestic and SOE shocks.[44] The data show that SOE shocks matter for a number of key macroeconomic variables in South Africa (such as the exchange rate, trade volume, GDP, and import prices). In particular, these shocks explain about 77% of the fluctuations in the exchange rate (compared to 88% for the UIP shock alone in Alpanda et al., 2010). They also explain the vast majority of the fluctuations in imports (83%) and exports (69%). Data on exports and imports are very volatile and correlated. Trade shocks, which include correlated export and import shocks, can replicate this large volatility without having any dramatic impact on other variables and are therefore given a heavy weight in the estimation. Although foreign demand shocks also have an economically significant impact on exports, they are unable to explain the bulk of large fluctuations in this variable.

Domestic shocks Domestic shocks remain important drivers of economic fluctuations (see Table 3). Pure domestic shocks explain about two-third of fluctuations in GDP, consumption and investment. They also contribute to about half of the fluctuations in CPI and the risk-free rate. They are particularly important for the fluctuations in mining output (72%) explained by domestic commodity supply shocks. On the contrary, domestic shocks only offer

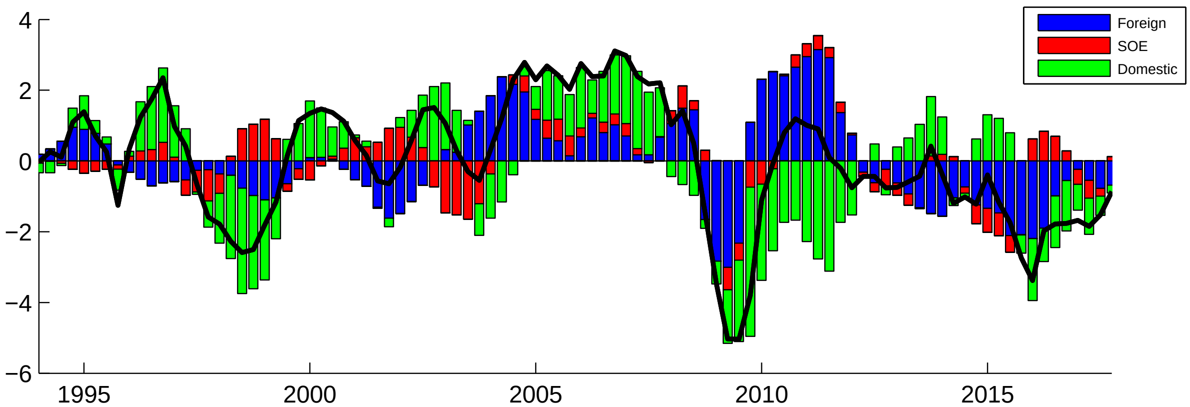
[44] Remember that SOE cannot affect foreign variables.

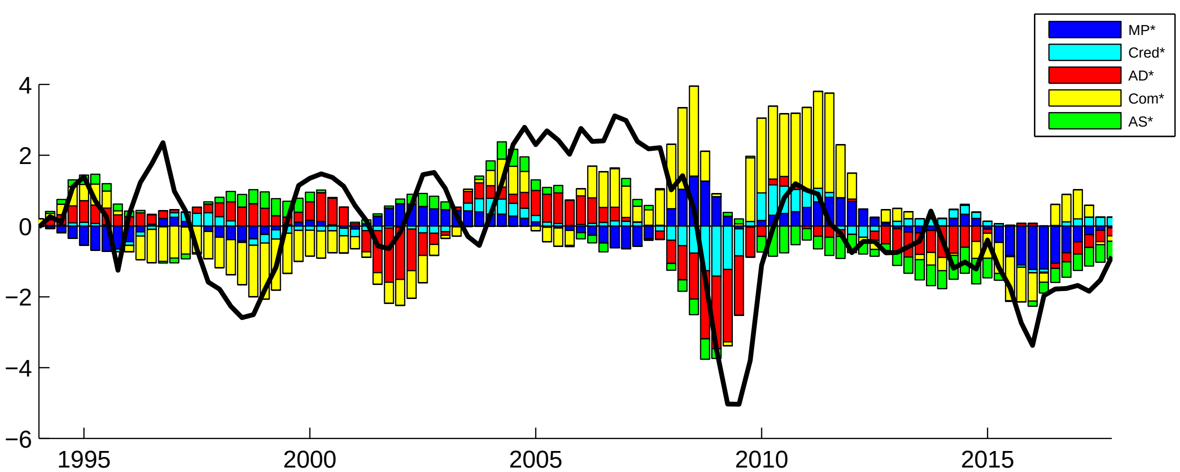
a weak explanation for the fluctuations in imports (11%), exports (19%) and the exchange rate (11%).

4.3 Historical decomposition

Figure 2: Historical Decomposition: South African GDP

Upper Panel: Total contribution of structural shocks to SA GDP YoY growth rate (re-centered around zero). Lower Panel: Selected foreign shocks (Monetary Policy, Credit, Commodity Supply and Aggregate Demand) contribution to SA GDP

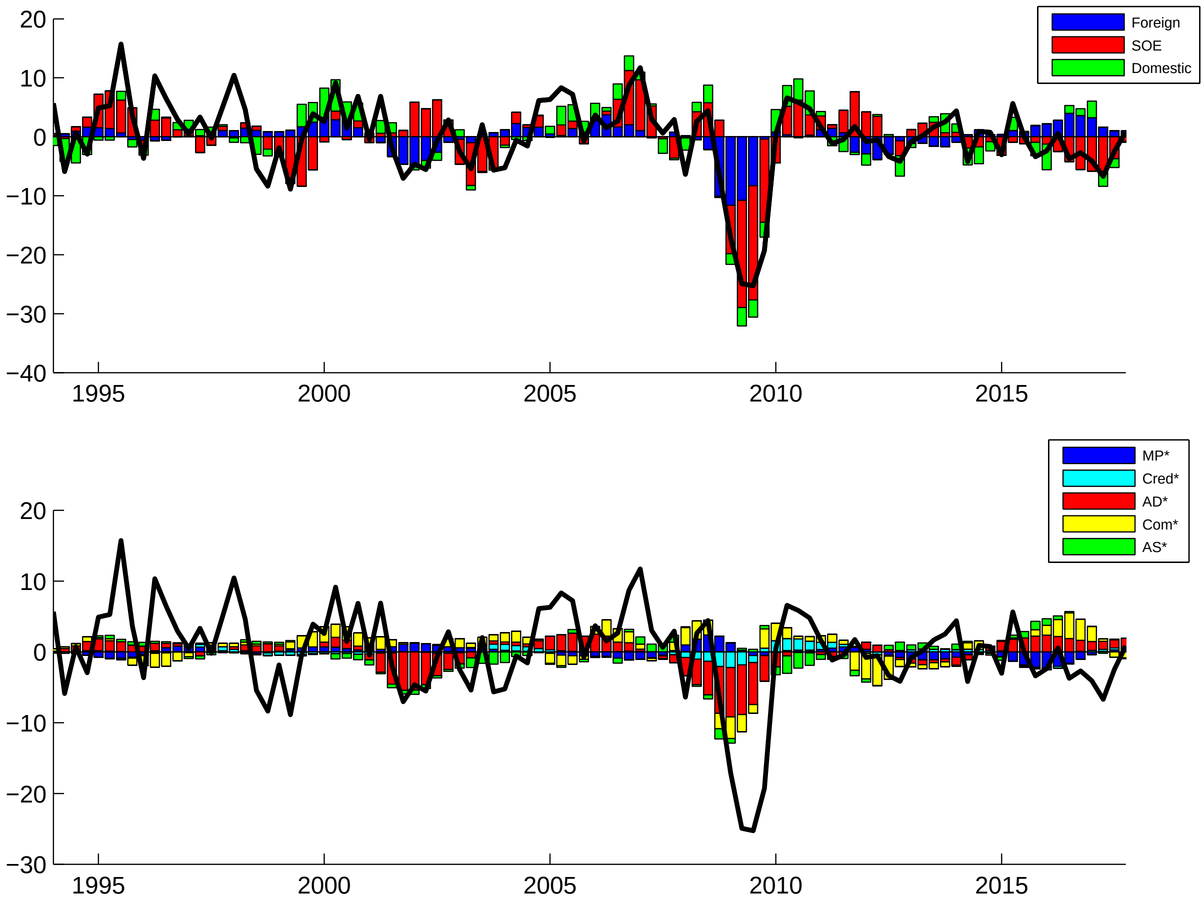




Historical decomposition is employed to study the role that structural shocks have played during key historical episodes such as the Rand crises in 1996, 1998 and 2001; the 2004-2007 growth period; the 2007/08 global financial crisis; the commodity price collapse of 2015 and the recent monetary policy tightening in the US. Figures 2 to 5 display the historical decomposition for world commodity prices and three macroeconomic series for South Africa: GDP,

Figure 3: Historical Decomposition: South African Export Volume

Upper Panel: Total contribution of structural shocks to SA Export Volume YoY growth rate (re-centered around zero). Lower Panel: Selected foreign shocks (Monetary Policy, Credit, Commodity Supply and Aggregate Demand) contribution to SA Export Volume

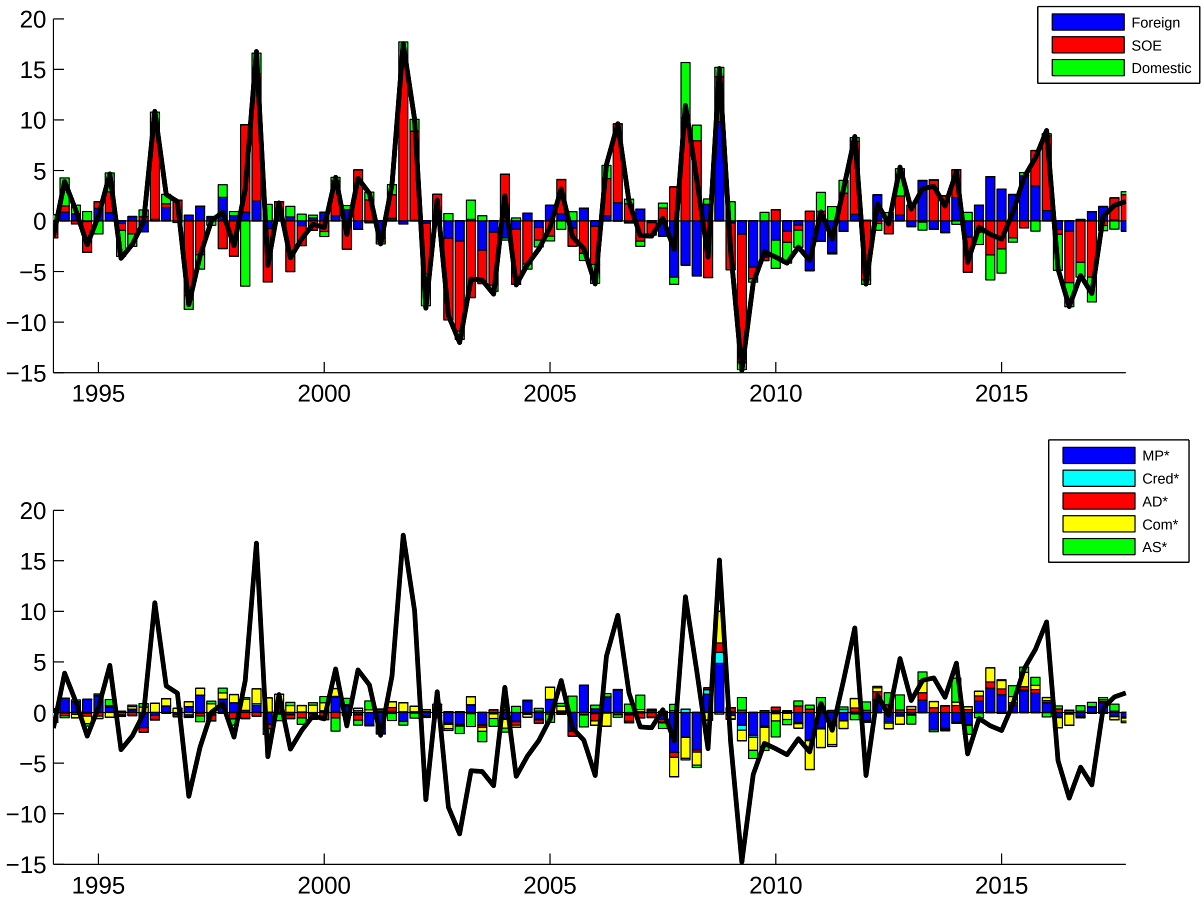


export volume, and the NEER. The upper panel in each figure highlights the contributions of domestic, foreign, and SOE shocks whereas in the lower panel we present a detailed analysis across foreign shocks.

Adverse commodity prices shocks of the late 1990s (that coincided with the Asian financial crisis of 1997) had a major impact during the 1998 South African Rand crisis. The SARB responded to the Rand depreciation by tightening its monetary policy where the policy rate increased by almost 700 basis points in the space of six months. This drastic interest rate increase was another (domestic) factor that contributed to amplifying the crisis. It is interesting to compare the 1998 Rand crisis to two other Rand crises that South Africa experienced in 1996 and 2001. The 1996 Rand crisis occurred following US monetary policy

Figure 4: Historical Decomposition: South African NEER

Upper Panel: Total contribution of structural shocks to SA NEER QoQ growth rate (re-centered around zero). Lower Panel: Selected foreign shocks (Monetary Policy, Credit, Commodity Supply and Aggregate Demand) contribution to SA NEER

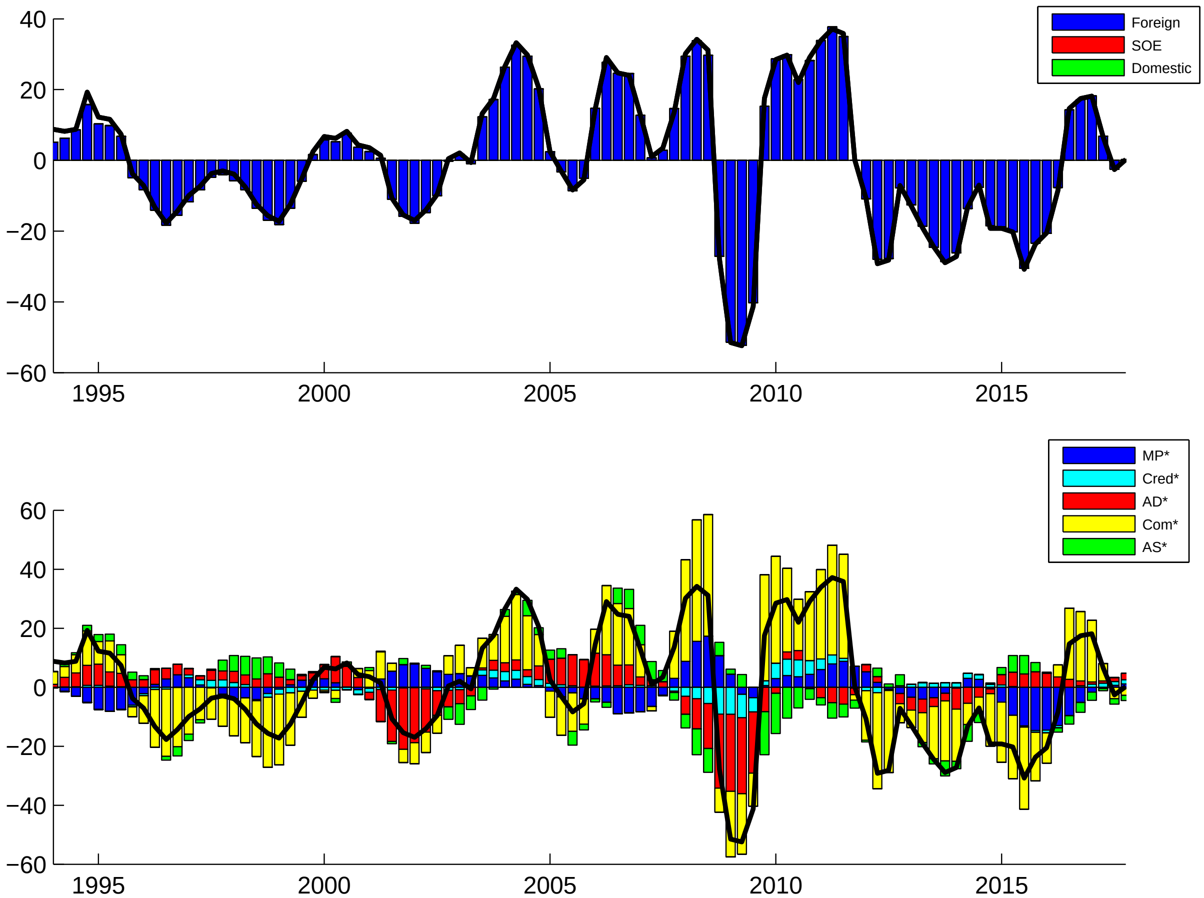


tightening in 1994/95 whereas the 2001 Rand crisis happened after the dot-com bubble burst in 2000, which translated into a negative contribution of foreign demand shocks in 2001/02. However, neither of these two Rand crises were accompanied by major changes in domestic monetary policy or commodity prices and their impact on South African GDP was modest.

Is it also interesting to see other historical events. For instance, the data in Figure 2 show that commodity supply and strong foreign demand as well as SOE shocks contributed to the sustained growth in South Africa in 2005-2007. The 2007/2008 and the great recession episodes translated into the largest drop in South African GDP growth via adverse foreign aggregate demand and credit shocks and their associated effects on commodity demand. Negative foreign aggregate supply and SOE shocks also contributed (to a lower extent) to the

Figure 5: Historical Decomposition: Real world commodity price for mining

Upper Panel: Total contribution of structural shocks to world commodity price YoY growth rate (re-centered around zero). Lower Panel: Selected foreign shocks (Monetary Policy, Credit, Commodity Supply and Aggregate Demand) world commodity price



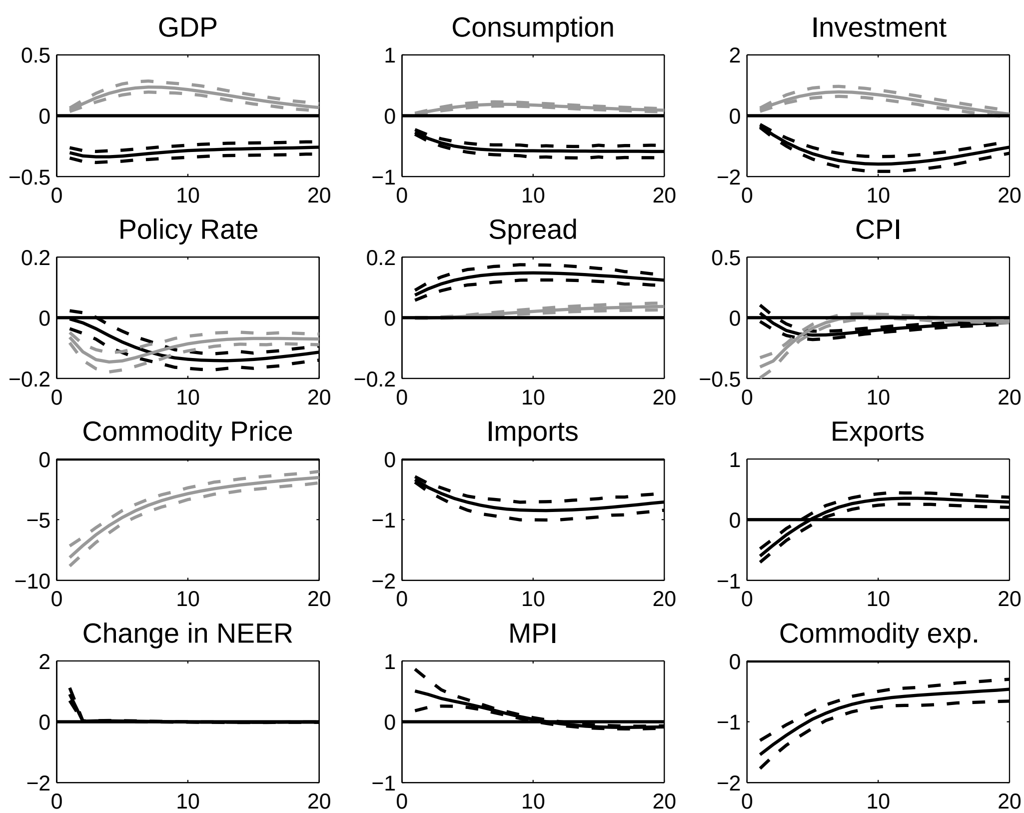
recession in South Africa. Finally, positive commodity supply shocks (together with positive credit supply shocks that possibly capture the impact of quantitative easing) contributed to the 2011 recovery before the recent commodity price reversal (with the contribution of foreign commodity supply shocks reaching a trough in 2015). The contribution of foreign monetary policy, which was accommodative during the crisis, later turned into negative effects at the end of the estimation period. Among domestic factors, adverse supply shocks (labor-augmenting productivity, wage-push and cost-push shocks) contributed to the low GDP growth between 2015 and 2017.

4.4 Impulse response functions

This section analyses the IRFs to foreign shocks. Its main message is that typical foreign business cycle shocks (such as aggregate demand, supply, credit and monetary policy) generate a positive co-movement between real activities in South Africa and USA. Foreign commodity supply shocks, on the contrary, provoke a negative co-movement between business cycles of these two economies. In what follows, we detail on each foreign shock one at a time. Analysis on SOE and domestic shocks is presented in the appendix.

Figure 6: IRFs - Foreign commodity supply shock

Note: Variables expressed in percentage deviation from steady-state, inflation, spread and interest rates annualized. Horizon in quarters. Baseline model with SA variables in black and US variables in grey and 90% confidence bands.



Commodity supply Figure 6 shows the IRFs of domestic (in black) and foreign (in grey) variables to a foreign commodity supply shock. This shock is modeled as an exogenous increase in global commodity production. It lowers their relative prices and acts as a positive supply shock in the foreign economy by reducing firms' marginal costs. Foreign prices fall and output expands in the final goods sector. The central bank responds by easing its monetary policy and banks tighten their credit conditions (because the higher credit demand dominates the increase in collateral value).

The contraction in mining prices causes a drop in mining production in South Africa. Revenues from mining activities collapse, damaging the trade balance (in nominal terms) and leading to a build-up of foreign debt. This increases the risk associated with the domestic currency. In addition, anticipations of lower output and inflation rates (from lower aggregate demand) resulting in lower domestic interest rates further acts against the domestic currency. The exchange rate surges. Lower export revenues and higher import prices depress imports, consumption and investment. Banks react to the worsening of borrowers' collateral value by increasing the spread which further exacerbates the impact of the shock. On impact, aggregate export volumes suffer from the drop in commodity trade. However, the depreciation encourages final goods sales abroad and aggregate exports turn positive after about one year.

A commodity supply shock is a good candidate to explain the excess volatility in consumption relative to output as well as the large fluctuation in investment in emerging economies.[45] Indeed, the magnitude of the drop in consumption exceeds the decline in output and the magnitude of the drop in investment is large. This is explained by the depreciation of the Rand: a large share of the decrease in domestic absorption translates to a decrease in the demand for foreign consumption and investment goods. Moreover, our foreign commodity supply shock reproduces the positive co-movement between GDP, CPI and the policy rate reported in HMO after a gold price shock in the inflation targeting period (although the results are not statistically significant in HMO).

Foreign aggregate demand Figure 7 shows the IRFs of foreign and domestic variables to foreign wedge shocks.[46] In line with intuition, a positive foreign demand shock stimulates real activity and prices in the US economy. As a result, the central bank responds by raising its policy rate. This shock also increases demand for commodities whose prices surge. The spread narrows since the borrowers' net worth improves.

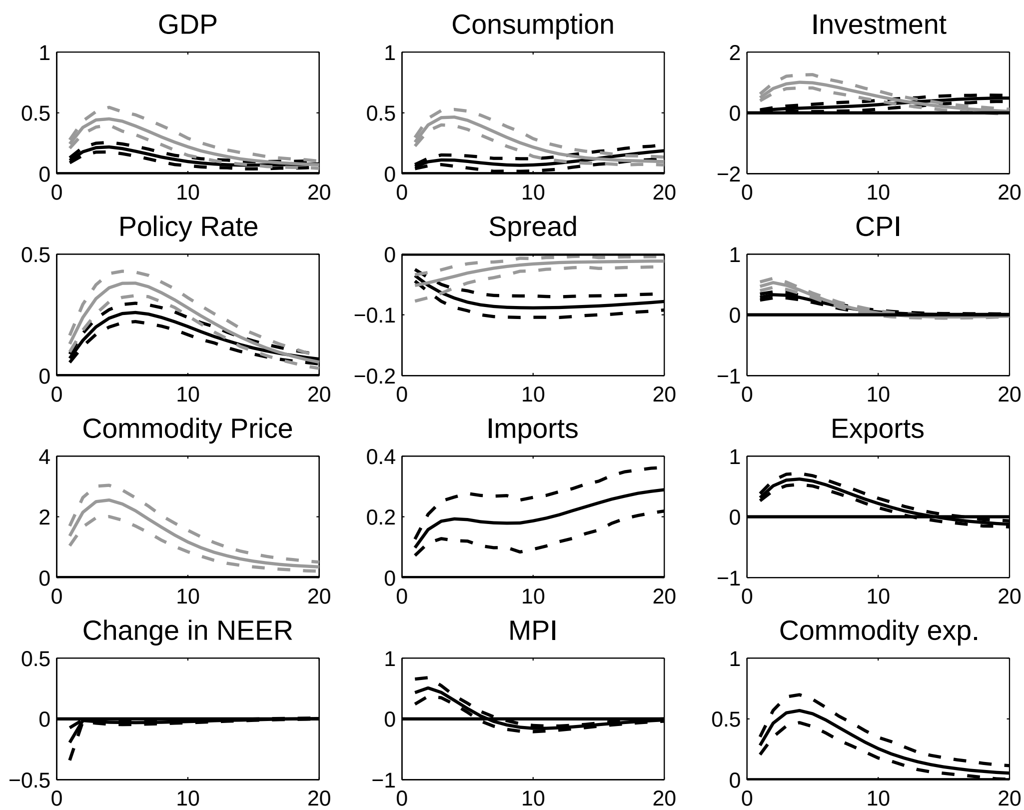
This surge in foreign demand and the associated commodity price increase stimulate domestic mining and manufacturing exports and as a consequence real activity and con-

[45] For a description of business cycle stylized facts in emerging economies, see Neumeyer and Perri (2005), Aguiar and Gopinath (2007) and García-Cicco et al. (2010).

[46] Foreign demand shocks also include investment-specific and public consumption demand shocks, which are presented in the appendix of the paper.

Figure 7: IRFs - Foreign demand shock (wedge shock)

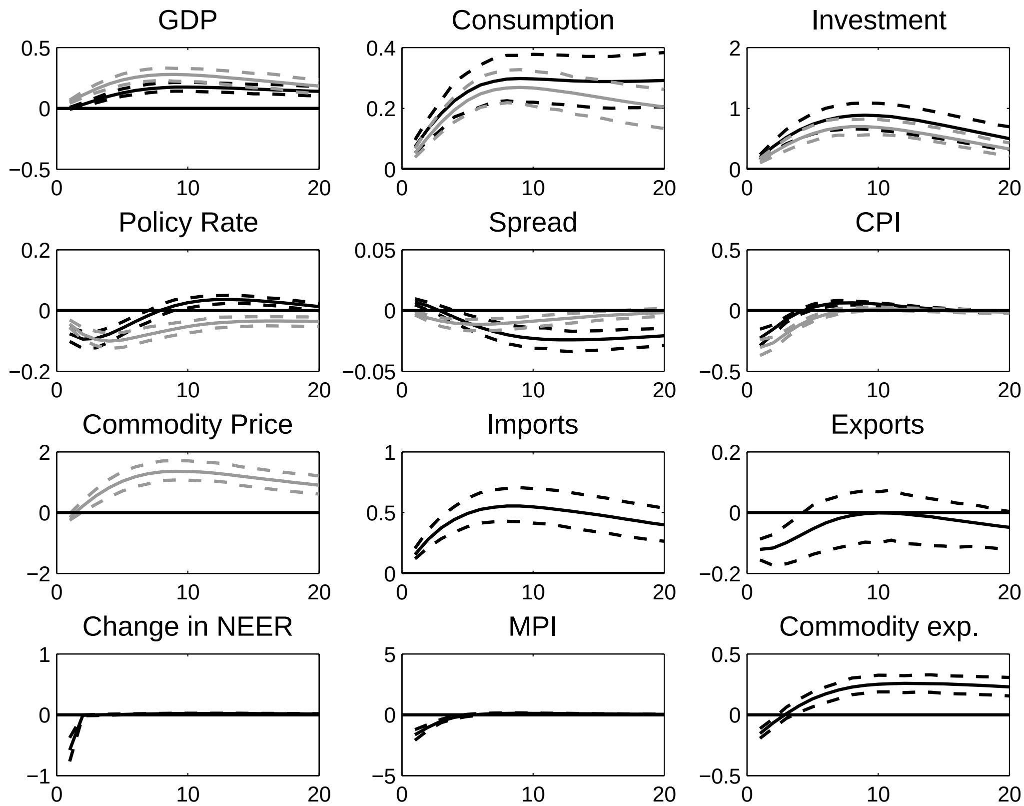
Note: Variables expressed in percentage deviation from steady-state, inflation, spread and interest rates annualized. Horizon in quarters. Baseline model with SA variables in black and US variables in grey and 90% confidence bands.



sumer prices rise in South Africa. The import content of exports generates a small positive co-movement between exports and imports. The central bank reacts by tightening its monetary policy stance in order to stabilize output and inflation. These effects are consistent with the VAR evidence in HMO. The rise in activity and mining prices have a positive impact on borrowers' net worth which generates a drop in the spread. The responses of consumption and investment are initially moderate. The rise in economic activity generates more labor incomes, which rule-of-thumbs households spend immediately. However, optimizing households are encouraged to save by higher interest rates and delay consumption and investment plans. In contrast to HMO, we document a small appreciation. Although, the foreign interest rate increases, its impact is compensated by a rise in the domestic policy rate and by an improvement in the net foreign asset position.

Figure 8: IRFs - Foreign supply shock (Productivity shock)

Note: Variables expressed in percentage deviation from steady-state, inflation, spread and interest rates annualized. Horizon in quarters. Baseline model with SA variables in black and US variables in grey and 90% confidence bands.



Foreign aggregate supply Figure 8 shows the IRFs of foreign and domestic variables to an increase in foreign productivity.[47] Foreign supply increases, leading to the traditional drop in prices and rise in GDP. The central bank cuts its interest rate in order to stabilize the inflation rate. Additional production gradually boosts the demand for commodities, which in turn pushes up their prices. Higher capital prices and investment boost the collateral value of the firm and lead to a drop in the spread.

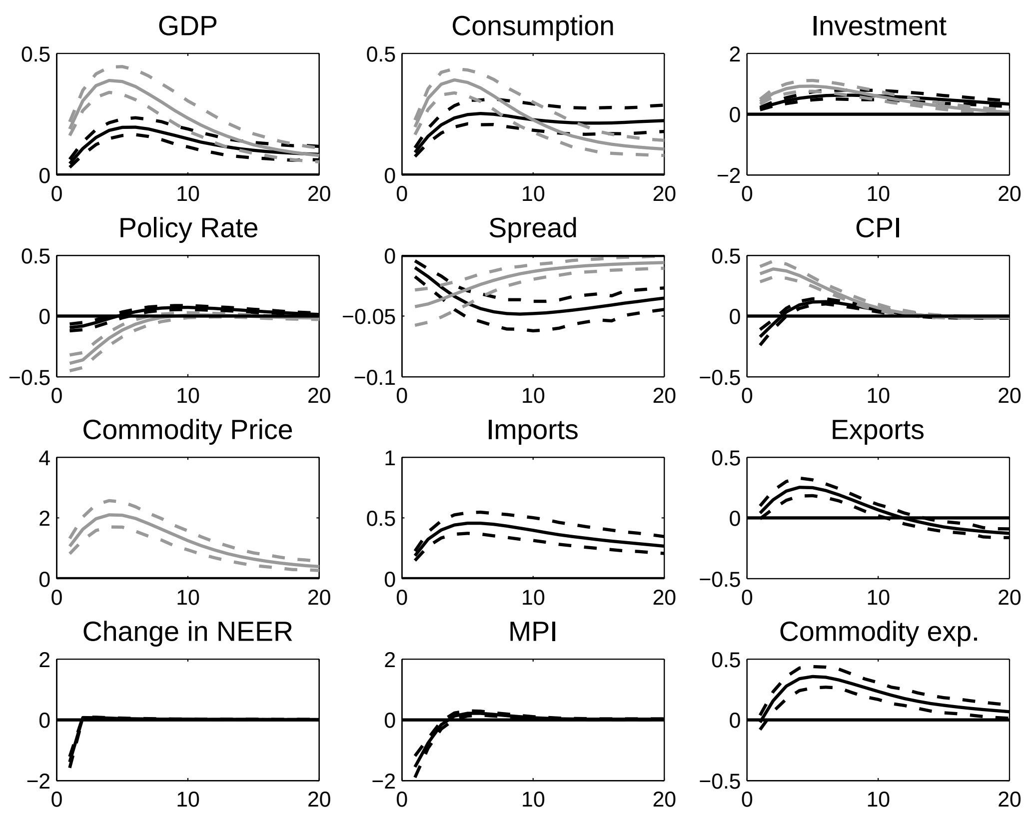
Foreign favourable supply shocks reduce foreign import prices and provoke an appreciation of the Rand originating in the fall in foreign interest rates. Households imported consumption and investment increase. The drop in import prices also generate an initial decline in domestic CPI, which in turn leads to an initial decrease in the risk-free rate. The

[47] Foreign supply shocks also include cost-push and wage-push shocks, which are presented in the appendix of the paper.

appreciation of the Rand depresses exports. However, the increase in investment and consumption demand also favors domestic firms. This later effect occurs since the elasticity of substitution between domestic and imported consumption and investment inputs is low. Therefore, the increase in imports also generate an expansion of demand for domestic inputs by domestic households. Output expands. After a few periods, CPI-inflation turns positive, driven by the expansion in aggregate demand, and the interest rate follows. With the exception of exports, these results coincide with the dynamic response of macroeconomic variables to the foreign productivity shock reported in HMO.

Figure 9: IRFs - Foreign monetary policy shock

Note: Variables expressed in percentage deviation from steady-state, inflation, spread and interest rates annualized. Horizon in quarters. Baseline model with SA variables in black and US variables in grey and 90% confidence bands.



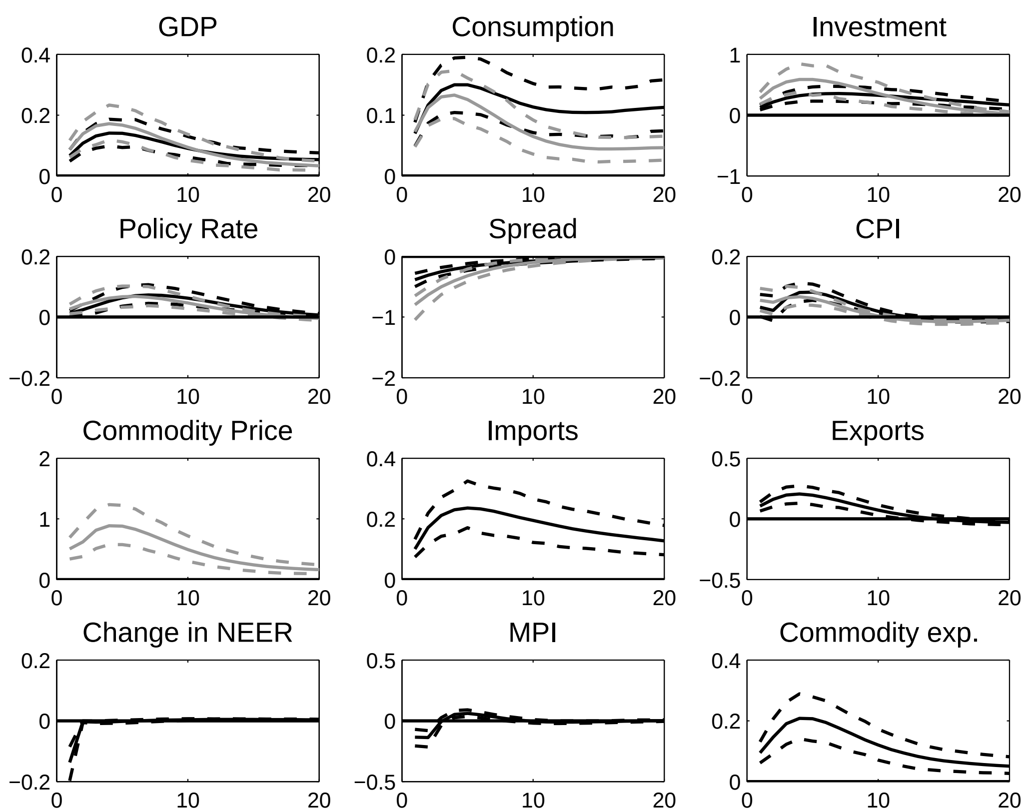
Foreign monetary policy Figure 9 shows the IRFs of domestic and foreign variables to a foreign monetary policy shock. After an unexpected cut in the foreign policy rate, foreign

GDP and inflation increase. This boosts the collateral value of the firms and prompts banks to ease credit conditions. The real mining price follows the surge in global demand.

The contraction in foreign risk-free rates provokes a strong appreciation of the Rand which stimulates imports and reduces domestic prices on impact. The SARB responds by lowering its policy rate. Together with cheaper foreign inputs, domestic monetary policy easing stimulate consumption and investment. Exports also respond favourably to this shock benefiting from higher mining prices and foreign demand (but mitigated by the currency appreciation). Higher collateral value and the ease in foreign credit conditions lead to a drop in the domestic spread which further amplifies this boom. After a few periods, aggregate demand peaks which results in a rise in the consumer price inflation rate and in a tightening of monetary policy.

Figure 10: IRFs - Foreign credit supply shock

Note: Variables expressed in percentage deviation from steady-state, inflation, spread and interest rates annualized. Horizon in quarters. Baseline model with SA variables in black and US variables in grey and 90% confidence bands.



Foreign credit supply Figure 10 shows the IRFs of foreign and domestic variables to a foreign credit supply shock. This shock is simulated through an exogenous (and therefore unrelated to collateral) decrease in the risk premium. It causes a decrease in firms' marginal production costs as well as an increase in consumption and investment demand from entrepreneurs. As a result, GDP increases while inflation and risk-free rates slightly increase (the demand effect dominates). The upswing in foreign production leads to an increase in demand for commodities that is transmitted to commodity prices.

Foreign banks operating in the domestic economy reduce the spread applied to South African firms and households. This easing in credit conditions causes a rise in domestic consumption and investment demand. The boom in the foreign economy increases foreign demand and therefore exports increase and the Rand appreciates. The appreciation of the Rand stimulates imports and together with the drop in financing cost they have a lowering impact on firms marginal costs. However, we report a moderate increase in consumer prices because these effects are dominated by the upward pressure on prices caused by the increase in domestic and foreign demand. The impact of this shock on domestic variables is similar to the foreign demand shock presented in Figure 7. As in HMO, this shock generates a positive co-movement between GDP, trade variables, inflation and the policy rate. These facts support the view that, due to the moderate direct exposure of South African banks to the foreign economy, adverse foreign credit supply shocks in 2007/08 were mainly transmitted to the South African economy through the trade channel.

4.5 Transmission channels

We now investigate the relative importance of our different extensions to ALLV's model. We proceed in four steps.

Commodities, finance and imports First, we completely remove all of our extensions in the domestic economy. We estimate a model similar to ALLV[48] while leaving the foreign economy unchanged as in our baseline analysis presented in the previous sections. Looking at variance decomposition presented in Table 4, we can see that the contribution of foreign shocks to macroeconomic fluctuations in South Africa is low in ALLV's model. For instance, the contribution of foreign shocks to the variability of GDP decreases sharply from 24 to 6%. Similar results hold true for other macroeconomic variables. This finding demonstrates that our extensions are necessary to capture the role of foreign shocks in South Africa. The

[48] This version is a bit different from the original ALLV framework because in their analysis the dynamics of the foreign block is represented by a VAR model.

problems that standard SOE models have in accounting for the influence of foreign shocks is well known in the literature (e.g. Justiniano and Preston, 2010).

Commodity sector Second, we only remove the domestic commodity sector from our baseline model and we re-estimate the model (while leaving the domestic export-to-GDP ratio and the foreign economy again unchanged as in our baseline analysis). Results are reported in Table 4. Closing the commodity channel generates a dramatic decrease in foreign shocks contribution to domestic real variables such as GDP (24% to 13%). We find a larger drop for consumption (from 21 to 6%) and investment (22 to 6%). We also document a drop in the contribution to other variables such as labor compensation (which declines from 26% to 7%), the spread (37 to 18%) and NEER (11 to 5%). These findings indicate that commodity plays a key role in the transmission of foreign shocks in South Africa.

Financial sector Third, we study the role of our extensions on the domestic credit sector (while again leaving the foreign economy unchanged). We remove the financial accelerator mechanism (the spread is always equal to zero in the domestic economy) and we assume that all households are patients (no households are excluded from financial markets). This experiment reduces the contribution of foreign shocks to domestic GDP from 24 to 16% (see Table 5). The impact of foreign shocks on other variables such as CPI (which declines from 14% to 9%), risk-free rate (17 to 9%) and NEER (11% to 9%) also declines in this case. Consistent with the fact that the financial accelerator is particularly important for investment decisions, we observe a decrease from 22 to 10% in the contribution of foreign shocks to this variable. Consumption is also affected: the variance decomposition drops from 21 to 14%. The specific structure of the financial sector has therefore amplified the effect of foreign shocks on domestic variables through the financial channel and through the inability of some households to smooth consumption when facing large foreign shocks. In particular, the price of commodities and the financial sector interact through the value of collateral (equation 31): an increase in the price of commodities raises the value of collateral and eases credit condition, which further stimulates consumption and investment.[49]

[49] Note that the effect of the financial sector could be underestimated in this model. Indeed, as reported in Table 9, the model underestimates the correlation between the domestic spread and activity measures such as GDP. This could indicate that the financial accelerator mechanism is underestimated. Moreover, there is no binding constraint on the amount of credit as in Iacoviello (2005) which could reinforce the importance of the financial sector for the transmission of foreign shocks. However, direct exposure to foreign financial assets was limited and could justify the view that foreign credit supply shocks were transmitted through the trade channel.

Table 4: Variance decomposition under different models

Foreign shocks	Baseline	No Mining	No Fin	No Inputs	ALLV	Exo CS	Exo CP*
GDP	23.85	13.27	15.82	21.90	6.11	9.61	19.32
Employment	18.26	6.46	11.95	21.13	4.87	7.70	14.94
Consumption	20.95	6.40	13.50	20.34	3.21	14.64	16.73
Investment	21.63	6.28	10.07	21.28	5.98	17.81	17.49
Exports	11.78	13.27	13.27	13.92	12.49	4.49	9.14
Imports	6.16	3.71	4.25	8.27	4.08	4.40	4.42
Mining exports	18.40	0.00	16.77	14.84	0.00	0.03	19.48
CPI	13.87	14.08	8.87	12.88	5.01	13.00	12.78
MPI	17.19	14.67	14.14	17.66	5.81	15.35	15.79
Labor comp.	25.65	6.93	18.54	25.34	4.66	11.87	20.62
Risk-free rate	17.14	15.45	9.35	15.52	6.29	15.04	16.18
Spread	37.27	17.75	0.00	36.82	0.00	40.58	36.32
NEER	10.86	4.53	9.18	9.96	3.12	8.55	8.26
SOE shocks	**Baseline**	**No Mining**	**No Fin**	**No Inputs**	**ALLV**	**Exo CS**	**Exo CP***
GDP	9.76	18.20	13.36	12.32	10.33	7.61	10.30
Employment	26.37	34.69	24.27	19.20	24.82	30.97	29.64
Consumption	13.79	21.74	18.46	16.29	22.31	14.08	15.86
Investment	12.12	23.26	18.26	10.62	20.71	14.43	14.64
Exports	68.91	79.92	67.72	48.12	75.57	65.13	71.29
Imports	82.91	83.13	82.26	79.07	71.44	85.13	85.53
Mining exports	4.76	0.00	4.62	3.96	0.00	0.01	5.78
CPI	34.87	43.67	36.49	34.45	46.05	37.98	36.15
MPI	70.93	77.80	73.52	72.11	78.71	74.51	73.44
Labor comp.	15.61	29.33	17.65	18.95	36.46	18.45	18.30
Risk-free rate	28.10	39.22	29.77	26.64	35.66	30.28	31.00
Spread	9.07	19.19	0.00	6.86	0.00	9.36	11.45
NEER	77.37	88.13	76.90	81.04	85.16	81.54	80.94
Domestic shocks	**Baseline**	**No Mining**	**No Fin**	**No Inputs**	**ALLV**	**Exo CS**	**Exo CP***
GDP	65.80	67.90	70.14	65.23	82.67	82.18	69.79
Employment	54.92	58.30	63.21	59.18	69.64	60.83	54.90
Consumption	64.56	71.08	67.08	62.64	73.29	70.56	66.69
Investment	65.57	69.78	70.93	67.36	72.58	67.06	67.20
Exports	19.31	6.82	19.00	37.97	11.93	30.38	19.57
Imports	10.93	13.16	13.50	12.67	24.47	10.47	10.03
Mining exports	71.83	0.00	73.69	76.40	0.00	95.22	69.76
CPI	50.69	41.65	53.99	52.12	48.43	48.39	50.48
MPI	10.94	6.62	11.56	9.07	14.52	9.22	9.82
Labor comp.	56.44	61.30	61.23	53.29	56.63	67.24	58.64
Risk-free rate	52.99	43.34	58.78	56.13	55.80	52.80	51.14
Spread	50.91	60.02	0.00	53.61	0.00	47.33	49.70
NEER	10.81	6.48	13.00	7.98	10.91	9.00	9.84

Note: This table shows the total contribution of foreign, SOE and domestic shocks on domestic variables. No Mining = No mining production in SA. No finance = closing the financial sector in SA. No Inputs = No inputs in the domestic production function. ALLV = Domestic economy modeled following ALLV. Exo CS = domestic commodity supply is exogenous (modeled as an AR(1) process). Exo CP* = commodity prices exogenous to developments in the domestic and foreign economy blocks.

Import structure Finally, we remove our extensions on the import structure. We now assume that there are no foreign inputs used in the domestic production function and also no import content of exports is allowed. We recalibrate the shares of imports in consumption and investment to 0.19 and 0.4, respectively, in order to account for the fact that some foreign inputs would finally enter domestic consumption or investment (after being processed by domestic firms). In this case, we do not observe any large drop in the contribution of foreign shocks on domestic variables. In a related paper, Hollander et al. (2018) introduced oil inputs in the production function in a SOE-DSGE model applied to South Africa. While we focus on commodity exports, they show that commodities can also be an important driver of business cycle fluctuations through the import channel.[50]

4.6 The role of an endogenous commodity sector

This section focuses on the importance of an endogenous commodity sector in the domestic and foreign economy blocks to capture the contribution of shocks originating from advanced economies in the emerging economy and to generate business cycle synchronization. First, we compare the baseline model to an alternative version where the domestic commodity supply (equation 17) is replaced by an exogenous AR(1) process, hence imposing a zero commodity supply elasticity in the domestic economy. The next-to-last column in Table 4 reports a big drop in the contribution of foreign shocks to South African GDP (from 24 to 10%) and labor compensation (from 26 to 12%) when domestic commodity supply is exogenous. We also observe a (smaller) reduction in the contribution of foreign shocks to investment and consumption.[51] Moreover, the correlation between domestic and foreign GDP growth rates decreases from 0.3 to 0.2 in the alternative version. Second, we contrast the baseline to an alternative assumption governing commodity prices. In the alternative, we assume that commodity prices are fully exogenous to development in the domestic and foreign economies. We model commodity prices as an exogenous AR(1) process which replaces equation (19) in the model. Therefore, commodity prices do not respond to foreign demand shocks but are fully explained by commodity specific shocks. The last column in Table 4 documents a small reduction in the contribution of foreign shocks to domestic real variables such as GDP, consumption and investment but the alternative model is capable to reproduce similar variance decompositions. However, this alternative model would not be able to explain

[50] An other difference is that they model oil prices as fully exogenous, while our commodity price index is endogenously determined in the foreign block.

[51] Commodity price fluctuations, through their wealth effects, are still able to substantially affect South African investment and consumption even if commodity export volumes do not respond to prices.

business cycle synchronization as the correlation in domestic and foreign GDP growth rates drops from 0.3 to 0.13. In fact, as described by the IRFs in Figure 6, changes in commodity prices driven by commodity specific factors generate a negative co-movement between the emerging commodity exporter and advanced economies. The empirical relevance of this latter result is also discussed in Caldara et al. (2018) within a SVAR framework applied to oil prices. These results demonstrate the importance of an endogenous commodity sector to reproduce both the contribution of foreign shocks and business cycle synchronization between a small open emerging commodity producer and advanced economies.

4.7 Model validation and robustness checks

Moments of the estimated model Looking at moments observed in the data and generated using the mode of parameters (Table 9), we can see that our model successfully reproduces some key moments such as the correlation between: domestic and foreign GDP (data: 0.41 vs DSGE: 0.30); mining exports and commodity prices (0.62 vs 0.39); domestic GDP and commodity prices (0.51 vs 0.42); foreign and domestic interest rates (0.77 vs 0.29); and foreign and domestic spreads (0.55 vs 0.41). Note, however, that we overestimate the correlation between foreign GPD and commodity prices (0.27 vs 0.45) while we miss the correlation between commodity prices and the CPI (0.68 vs 0.09). In the foreign block, we introduced commodities as a production input, which fits the type of commodities exported by South Africa, but abstract from other commodities that are also used as consumption inputs, such as oil.

Correlation between shocks We compute the correlations between shocks (when parameters are set at their modes, see Table 11).[52] Although the model (as most DSGE models) still implies a number of correlated shocks, we find that domestic and foreign shocks of the same type (e.g. foreign and domestic aggregate demand shocks) tend to display a modest and positive correlation.[53] This indicates that the strength of transmissions channels are not over- or under-estimated. Moreover, there is no correlation between domestic and foreign commodity supply shocks. This finding suggests that the magnitude of the responses of domestic commodity exports to foreign commodity supply shocks is well identified. Also note that it is the study of shocks correlation that justifies our choice to introduce import

[52] We assume that shocks are independent in the estimation and after the estimation we check to which extent this assumption was maintained.

[53] Note that we estimate the correlation between domestic and foreign supply shocks. See section 3.4 for its prior, and section 4.1. for its estimated value.

content of exports, to allow for correlated import and export shocks (called trade shocks) and to introduce wedge shocks (generating a positive co-movement between consumption and investment) instead of the consumption demand shock originally present in ALLV.

Commodities in the foreign consumption basket In the foreign block of the model, commodities are used as production inputs. They, however, do not enter the consumption basket. Here, we relax this assumption. We calibrate the share of commodities in consumption to 4% and estimate an additional parameter: the elasticity of substitution between commodities and other consumption goods. The prior mode is set to 0.4, which is the value used in Bodenstein et al. (2011). We find a mode of 0.43 for this parameter and the elasticity of substitution between commodities and other production inputs adjusts from 0.19 to 0.07. This experiment allows us to better match the correlation between commodity prices and foreign CPI and GDP. However, we underestimate the variance in a few foreign variables (such as commodity prices and GDP) which accounts for a small drop in the contribution of foreign shocks to domestic variables (see Table 5).

Identification of foreign shocks We check the robustness of results to different datasets and strategies used in order to estimate foreign parameters and foreign shocks. Our baseline analysis uses US data over the 1994Q1-2017Q4 period. Domestic and foreign parameters are estimated jointly. We now experiment with different strategies using G7 data and estimating domestic and foreign parameters separately (see Table 5). When using G7 data, the contribution of foreign shocks to South African GDP remains high although it has decreased a bit in comparison with the baseline analysis. This small decrease is due to the fact that aggregating over G7 countries reduces the variance of foreign variables (and therefore lead to smaller shocks). On the contrary, when estimating parameters in two steps, we document an increase in the contribution of foreign shocks. Some foreign parameters are affected by domestic data when the estimation is performed in a single step (e.g. the elasticity of substitution of commodities is lower in the two steps procedure).

Identification of SOE shocks We re-estimate the model with two trade volume shocks: domestic trade preferences (ε_m capturing a shock to import volumes) and foreign trade preference (ε_x capturing a shock to export volumes). In that case, estimated measurement errors for imports and exports are not necessary and we estimate the correlation between those two trade volume shocks. We use a beta distribution with mean equals to 0.5 and standard deviation equals to 0.2 as prior. We find a posterior mode of 0.75, not too far from

Table 5: Foreign Shocks Contribution to Domestic Variables: Sensitivity

Foreign shocks	Baseline	2-steps	G7	Spread	Mining exp.	Com. in C^*
GDP	23.85	29.02	20.32	24.07	23.58	21.95
Employment	18.26	21.00	15.76	18.71	18.18	22.54
Consumption	20.95	32.59	20.59	20.28	20.74	19.22
Investment	21.63	30.77	19.15	21.43	22.00	20.42
Exports	11.78	13.69	5.92	12.56	13.53	11.66
Imports	6.16	7.40	7.12	6.36	8.06	6.25
Mining exports	18.40	17.16	16.70	20.72	13.48	18.25
CPI	13.87	20.41	15.61	13.92	14.42	12.83
MPI	17.19	21.52	30.77	17.45	18.29	14.67
Wage	25.65	34.17	24.83	26.00	25.78	23.48
Risk-free rate	17.14	28.97	13.84	17.21	17.23	16.93
Spread	37.27	48.76	30.42	50.59	37.78	36.18
NEER	10.86	19.25	17.12	11.38	11.25	7.94
	1994-2009	2000-17	Trade elast.	50% NR	Exo Priors	Trade shocks
GDP	24.24	28.50	21.42	24.46	30.79	21.73
Employment	19.21	20.89	14.57	18.60	28.33	22.88
Consumption	20.23	23.26	14.57	22.18	24.27	20.52
Investment	23.04	20.13	14.52	22.14	22.10	20.24
Exports	15.65	14.11	14.73	11.12	23.12	10.52
Imports	9.15	6.21	7.00	6.21	13.39	8.62
Mining exports	18.44	21.73	14.38	18.23	27.78	19.50
CPI	14.11	13.89	15.74	14.40	21.43	14.30
MPI	17.68	15.84	14.08	17.77	24.51	17.27
Wage	25.84	28.63	19.62	26.39	32.07	25.33
Risk-free rate	17.01	17.94	21.48	18.08	25.50	18.42
Spread	31.14	40.89	38.81	39.06	43.80	39.36
NEER	10.68	9.21	7.16	11.57	21.93	11.90

Note: 2-step = domestic and foreign parameters estimated in two steps. G7 = foreign economy proxied with G7 data. Spread = JPM EMBI Global Diversified spread as proxy. Mining exp = alternative mining export proxy. Com. in C^* = commodities in foreign consumption basket. 94-2010 = estimation on a sub-sample stopping in 2009Q1. 2000-17 = estimation on a sub-sample starting in 2000Q1. Trade elast = Alternative values for trade price elasticities $\eta_c = \eta_i = \eta_f = 1.5$. 50% ROT = share of rule-of-thumb households calibrated to 50%. Exo Prior = use classical priors instead of endogenous priors. Trade shock: use two trade shocks.

its value (1) imposed in the baseline. We document an increase in the contribution of SOE shocks to GDP (from 5 to 19%) compensated by an important decrease in the contribution of domestic shocks (from 70 to 59%) and a small decline in the contribution of foreign shocks (from 24 to 22%).

Sub-period analysis We also experiment with different sample data periods. For instance, we try starting the estimation period in 2000Q1 (to exclude the pre-formal inflation-targeting monetary regime in South Africa) as well as ending the sample period in 2009Q1 (to avoid the ZLB and QE periods in the US). Our results remain qualitatively unchanged although the role of foreign shocks has been a bit amplified when the sample period of 2000-2017 is used (see Table 5).

Elasticity of substitution between domestic and foreign goods We then investigate the role of the elasticity of substitution between domestic and foreign consumption and investment goods in the domestic and foreign economies. Our estimates indicate lower values than usually described in the literature. We therefore re-estimated the model calibrating those parameters to 1.5. We find that this experiment slightly reduces the share of foreign shocks and our main results remain qualitatively unchanged (see Table 5).

Share of rule-of-thumb households We calibrate the share of rule-of-thumb households to 1/3 in the baseline based on the share of households with no access to an account at any financial institution. However, a much lower share of households do actually make use of formal savings or borrowing instruments.[54] We therefore re-estimate the model with the share of rule-of-thumb households calibrated to 50% (the shares of savers and entrepreneurs are calibrated to 25% such that their relative weight remains unchanged). In this case, we also report a small increase in the contribution of foreign shocks for some domestic variables.

Prior distributions We also evaluate the robustness of our results to the use of classical exogenous priors (instead of the endogenous prior proposed in Christiano et al., 2011). We document larger foreign shocks contributions (but at the cost of overestimated variances in simulated domestic variables).

Data proxies In the estimation, we use proxies for the corporate spread and commodity exports in South Africa. We also estimate the model using the JPM EMBI Global Diversified

[54] See the World Bank Financial Inclusion database, 2014.

Blended Spread as a proxy for the corporate spread. We also used the sum of mineral products, precious metals and iron and steel exports as an other proxy for total mining exports. Results remain quantitatively similar and are reported in Table 5.

5 Conclusion

We extend a standard SOE-DSGE model to account for various specificities of advanced and emerging economies so as to better capture the transmission of foreign shocks in a small open emerging economy. The most important extensions are the introduction of mining and financial sectors in both economies. We estimate the model with Bayesian methods using data from South Africa, the US and G7 countries. We identify a wide range of foreign and domestic (aggregate demand, aggregate supply, monetary policy, credit and commodity supply) shocks and study their relative importance in macroeconomic fluctuations in South Africa.

In contrast to standard SOE-DSGE models, we find that foreign shocks explain about 20% of macroeconomic fluctuations in South Africa. In particular, they account for 20 to 30% of the variability in real activity. These findings are in line with the predictions of the SVAR analysis in HMO. The model is also able to replicate the observed positive co-movement between real activities in advanced economies and South Africa. Typical foreign (aggregate demand, supply, credit and monetary policy) shocks reproduce this positive correlation. The endogenous response of commodity prices to these shocks and the endogenous response of domestic commodity supply to commodity prices are key in explaining these results. Exogenous foreign commodity supply shocks are also very important drivers of economic fluctuations in South Africa. They are also good candidates to explain the observed excess volatility in consumption and the wide fluctuations of investment in South Africa. However, they generate a negative co-movement between foreign and domestic business cycles. Domestic and SOE shocks also matter for macroeconomic fluctuation in South Africa. For instance, they explain about 66 and 10% of fluctuations in South African GDP, respectively. As such, any appropriate stabilization policies should take into account both these domestic and external (foreign and SOE) shocks.

Historical decomposition shows that the recent global financial crisis was mainly transmitted to South Africa via adverse foreign aggregate demand and credit supply shocks. Positive commodity supply shocks and monetary policy easing contributed to the 2011 recovery before the 2015 commodity price reversal. The recent monetary policy tightening in the US also contributed to the poor performance of the South African economy. Going further back in time, we see that commodity prices played a major role in the 1998 Rand crisis.

Our framework also allows us to explore more precisely the transmission channels of foreign shocks. By shutting down some of our extended channels one at a time, we find that the large share of commodities in South African exports plays an important role in the transmission of foreign shocks and the financial channel has contributed to amplifying the fluctuations caused by those shocks.

A number of interesting research questions emerge from the framework presented in this paper. For instance, the fact that SOE shocks also play a significant role in macroeconomic fluctuations in South Africa motivate the need to appropriately study their origins. One possibility would be to extend the model to include a block of other emerging markets to capture interconnectedness between South Africa and these economies. In any case, our framework already provides a good basis for the design of monetary and fiscal policies that could stabilize the domestic economy in the face of the various shocks identified in the paper. It would also be interesting to apply this model to other emerging economies or Sub-Saharan African countries where data availability is an issue by using South Africa as a prior and/or using a panel data approach.

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Table 6: Calibrated Parameters

Common para	Description	Values
h	Hours devoted to work	0.3000
μ_z	Mean GDP growth rate	1.0063
$\bar{\pi}$	Mean inflation rate	1.0113
R	Mean risk-free rate	1.0300
R^L	Mean Lending rate	1.0400
τ_k	Capital gain taxes	0.2000
τ_w	Pay-roll tax	0.0500
τ_y	Labor income taxes	0.0300
τ_c	Value added tax	0.1400
δ	Capital depreciation rate	0.0200
α	Capital income share in final good sector	0.3000
λ_d	Mark-up final good	1.2500
λ_w	Mark-up labor market	1.1000
$\frac{g}{y}$	Government consumption-to-GDP ratio	0.1950
σ_c	Consumption substitution elasticity	1.0000
σ_l	Labor suply elasticity	2.0000
σ_a	Capital variable utilization	10.000
Domestic para	Description	Values
$\frac{b_e}{y}$	Entrepreneurs loan-to-GDP ratio	1.0000
α_p	Capital income share in primary sector	0.3000
$\frac{y^p}{y}$	Share of mining sector in GDP	0.1100
ω_h	Share of mining sector in employment	0.0670
ω_c	share of imports in consumption	0.1500
ω_i	share of imports in investment	0.4500
ω_n	share of foreign inputs in final good	0.0700
ω_x	Import content of exports	0.1600
$\frac{a}{y}$	Foreign Debt to quarterly GDP ratio	-0.8000
ϕ_a	Debt-elastic foreign interest rate	0.0001
$\kappa_d = \kappa_x = \kappa_m$	Price indexation	0.1000
η_h	Labor mobility	1.0000
Foreign para	Description	Values
$\frac{f^{e*}}{y^*}$	Entrepreneurs loans-to-GDP ratio	2.0000
β^*	Commodities income share	0.0800
κ^*	Indexation final good	0.2000
ν	Share of invest. in final good trade	0.7000
σ_d^*	Labor-capital elast. of subst.	1.0000

Table 7: Estimated shocks in the joint estimation

Shocks Std		Pst mode	Pst Std	Pst 5%	Pst 95%	Pr Mean	Pr Std	Pr shape
ε_b^*	Wedge*	0.239	0.044	0.181	0.335	0.500	0.500	INV GAM.
Υ^*	Invest	0.379	0.147	0.246	0.824	0.500	0.500	INV GAM.
ε_g^*	Gov*	1.034	0.154	0.795	1.287	0.500	0.500	INV GAM.
ε_h^*	Prod.*	0.542	0.044	0.475	0.615	0.500	0.500	INV GAM.
λ_d^*	Price*	3.479	0.385	2.886	4.161	0.500	0.500	INV GAM.
λ_w^*	Wage*	8.683	1.003	7.173	10.350	0.500	0.500	INV GAM.
ε_R^*	Mon. Pol.*	0.125	0.014	0.104	0.147	0.200	0.200	INV GAM.
ε_{RL}^*	Cred. Sup.*	0.189	0.032	0.149	0.240	0.200	0.200	INV GAM.
ε_p^*	Com. Sup.*	2.126	0.316	1.729	2.762	0.500	0.500	INV GAM.
$\tilde{\phi}$	UIP	1.242	0.187	0.975	1.595	0.200	0.200	INV GAM.
$\varepsilon_{x.m}$	Trade	3.857	0.350	3.239	4.371	0.500	0.500	INV GAM.
λ_m	Import Price	8.537	1.312	6.177	9.663	0.500	0.500	INV GAM.
ε_b	Wedge	0.582	0.143	0.392	0.903	0.500	0.500	INV GAM.
Υ	Invest	12.517	2.096	9.367	15.924	0.500	0.500	INV GAM.
ε_h	Prod.	1.428	0.158	1.175	1.711	0.500	0.500	INV GAM.
λ_d	Price	1.841	0.234	1.527	2.328	0.500	0.500	INV GAM.
λ_w	Wage	3.326	0.373	2.763	4.026	0.500	0.500	INV GAM.
ε_R	Mon. Pol.	0.180	0.017	0.156	0.212	0.200	0.200	INV GAM.
ε_{RL}	Cred. Sup.	0.236	0.029	0.198	0.289	0.200	0.200	INV GAM.
$\varepsilon_{h.p}$	Com. Sup.	11.365	1.281	9.510	13.822	0.500	0.500	INV GAM.
ME		Pst mode	Pst Std	Pst 5%	Pst 95%	Pr Mean	Pr Std	Pr shape
X^{obs}	ME: exports	3.430	0.263	3.024	3.871	1.000	1.000	INV GAM.
M^{obs}	ME: imports	2.741	0.458	2.113	3.715	1.000	1.000	INV GAM.
AR(MA) coef		Pst mode	Pst Std	Pst 5%	Pst 95%	Pr Mean	Pr Std	Pr shape
ε_b^*	Wedge*	0.879	0.017	0.842	0.902	0.800	0.100	BETA
Υ^*	Invest*	0.814	0.048	0.710	0.860	0.800	0.100	BETA
ε_g^*	Mon. Pol.*	0.653	0.057	0.563	0.740	0.800	0.100	BETA
ε_h^*	Prod.*	0.953	0.014	0.926	0.971	0.800	0.100	BETA
λ_d^*	Price*	0.205	0.047	0.126	0.277	0.500	0.100	BETA
ε_R^*	Mon. Pol.*	0.210	0.055	0.127	0.299	0.330	0.100	BETA
ε_{RL}^*	Cred. Sup.*	0.800	0.036	0.722	0.845	0.800	0.100	BETA
$\tilde{\phi}$	UIP	0.760	0.036	0.700	0.815	0.800	0.100	BETA
$\varepsilon_{x.m}$	Trade: AR	0.871	0.046	0.773	0.933	0.800	0.100	BETA
$\varepsilon_{x.m}$	Trade: MA	0.466	0.098	0.316	0.619	0.500	0.100	BETA
λ_m	Import Price	0.481	0.072	0.347	0.573	0.500	0.100	BETA
ε_b	Wedge	0.848	0.033	0.776	0.889	0.800	0.100	BETA
Υ	Invest	0.516	0.073	0.399	0.627	0.800	0.100	BETA
ε_h	Prod.	0.965	0.016	0.935	0.986	0.800	0.100	BETA
λ_d	Price	0.550	0.067	0.423	0.642	0.500	0.100	BETA
ε_{RL}	Cred. Sup.	0.840	0.027	0.789	0.877	0.800	0.050	BETA
$\varepsilon_{h.p}$	Com. Sup.	0.969	0.019	0.839	0.990	0.800	0.100	BETA

Table 8: Estimated Parameters in the joint estimation

Domestic Para		Pst mode	Pst Std	Pst 5%	Pst 95%	Pr Mean	Pr Std	Pr shape
ξ_d	Calvo final good	0.671	0.031	0.627	0.728	0.650	0.050	BETA
ξ_m	Calvo impots	0.577	0.038	0.519	0.647	0.650	0.050	BETA
ξ_x	Calvo exports	0.773	0.022	0.734	0.810	0.650	0.050	BETA
ξ_w	Calvo wages	0.764	0.025	0.730	0.809	0.650	0.050	BETA
ξ_e	Labor-hoarding	0.564	0.033	0.507	0.617	0.500	0.250	BETA
κ_w	Indexation wages	0.694	0.037	0.629	0.755	0.650	0.050	BETA
ϕ_i	Inv. adj. cost	6.355	0.551	5.477	7.237	3.500	1.000	NORMAL
b	External habits	0.793	0.022	0.760	0.830	0.700	0.050	BETA
η_f	Exports price elast.	1.047	0.161	0.759	1.250	1.500	1.000	INV GAM.
η_c	Imports price elast.	0.359	0.035	0.306	0.417	1.500	1.000	INV GAM.
ρ_r	Int. rate smooth.	0.885	0.009	0.868	0.898	0.800	0.050	BETA
τ_π	CB inflation resp.	1.849	0.082	1.697	1.984	1.750	0.100	NORMAL
$\tau_{\Delta s}$	CB NEER resp.	0.110	0.021	0.077	0.144	0.125	0.025	NORMAL
$\tau_{\Delta y}$	CB GDP growth resp.	0.425	0.093	0.273	0.587	0.250	0.100	NORMAL
ϕ_{nw}	Fin. accelerator	0.016	0.002	0.014	0.020	0.050	0.025	INV GAM.
σ_d	Factors subst. (final good)	0.381	0.030	0.332	0.434	0.500	0.100	BETA
σ_n	Dom.-Foreign input subst.	0.240	0.064	0.151	0.356	0.500	0.100	BETA
σ_p	Factors subst. (mining)	0.433	0.047	0.344	0.497	0.500	0.100	BETA
ω_k	Corr. Cred. Sup. shocks	0.201	0.138	0.025	0.371	0.140	0.100	BETA
ω_b	Share of foreign banks	0.324	0.062	0.236	0.425	0.220	0.050	BETA
Foreign Para		Pst mode	Pst Std	Pst 5%	Pst 95%	Pr Mean	Pr Std	Pr shape
σ_p^*	Commodity subst.	0.193	0.024	0.166	0.245	0.130	0.100	BETA
ξ^*	Calvo final good	0.787	0.021	0.756	0.823	0.650	0.050	BETA
κ_w^*	Indexation wages	0.352	0.038	0.288	0.413	0.500	0.050	BETA
ξ_w^*	Calvo wages	0.755	0.025	0.717	0.797	0.700	0.050	BETA
b^*	External habits	0.790	0.024	0.759	0.834	0.700	0.050	BETA
ρ_{r*}	Int. rate smooth.	0.905	0.008	0.890	0.918	0.850	0.100	BETA
τ_π^*	CB inflation resp.	1.918	0.091	1.767	2.065	1.750	0.100	GAMMA
$\tau_{\Delta y}^*$	CB GDP growth resp.	0.444	0.160	0.236	0.755	0.250	0.100	GAMMA
ϕ_{nw}^*	Fin. accelerator	0.026	0.005	0.019	0.039	0.050	0.025	INV GAM.
ϕ_i^*	Inv. adj. cost	2.742	0.475	2.129	3.779	3.500	1.000	GAMMA
δ_p^*	Persistence in com. supply	0.069	0.010	0.055	0.090	0.050	0.025	BETA

Table 9: Moments: Data vs DSGE at its mode: selected domestic variables

	Std(z)		Corr(z.GDP)		Corr(z.CPI)		Corr(z.R)		Corr(z.Spr)		Corr(z.Mining)	
	Data	DSGE	Data	DSGE	Data	DSGE	Data	DSGE	Data	DSGE	Data	DSGE
GDP	1.75	2.26	1.00	1.00	-0.05	-0.05	0.05	-0.05	-0.52	-0.20	0.53	0.58
Employment	2.08	2.93	0.72	0.46	-0.03	0.06	-0.10	-0.09	-0.46	-0.09	0.40	0.16
Consumption	2.43	2.79	0.83	0.79	-0.25	-0.23	0.01	-0.20	-0.56	-0.23	0.53	0.27
Investment	6.38	7.36	0.62	0.60	0.17	0.00	0.17	0.01	-0.33	-0.17	0.16	0.28
Exports	6.61	7.74	0.64	0.24	-0.08	0.06	0.13	0.02	-0.33	0.00	0.64	0.50
Imports	8.62	8.82	0.70	0.20	-0.10	-0.03	0.02	-0.06	-0.58	-0.06	0.47	0.26
Mining exports	9.46	8.21	0.53	0.58	-0.19	0.07	-0.14	0.05	-0.31	-0.01	1.00	1.00
CPI	2.38	3.11	-0.05	-0.05	1.00	1.00	0.51	0.69	0.41	-0.14	-0.19	0.07
MPI	8.67	8.95	0.30	0.00	0.51	0.56	0.34	0.38	0.41	-0.06	0.22	-0.09
Labor comp.	2.40	3.05	0.45	0.68	-0.69	-0.24	-0.27	-0.16	-0.57	-0.20	0.36	0.29
Risk-free rate	4.12	2.94	0.05	-0.05	0.51	0.69	1.00	1.00	0.42	-0.24	-0.14	0.05
Spread	1.68	1.65	-0.52	-0.20	0.41	-0.14	0.42	-0.24	1.00	1.00	-0.31	-0.01
NEER	5.66	5.75	0.04	0.01	0.07	0.03	0.09	0.08	0.21	-0.02	0.08	-0.01
US GDP	1.71	1.73	0.41	0.30	-0.22	-0.03	0.36	-0.07	-0.26	-0.07	0.31	0.20
US Consumption	1.55	1.59	0.27	0.27	-0.25	-0.04	0.43	-0.08	-0.13	-0.05	0.23	0.17
US Investment	5.16	5.34	0.32	0.26	-0.21	-0.03	0.26	-0.06	-0.19	-0.05	0.29	0.17
US Hours	2.49	2.75	0.42	0.32	-0.13	-0.02	0.07	-0.06	-0.35	-0.06	0.42	0.23
US CPI	1.69	2.03	0.64	0.16	0.08	0.27	0.10	0.21	-0.33	-0.12	0.49	0.09
US Wage	1.61	1.71	0.26	0.08	-0.24	0.19	0.36	0.19	0.04	-0.14	0.17	0.06
US Risk-free rate	2.82	1.63	0.38	-0.02	0.24	0.23	0.77	0.29	0.09	-0.10	0.14	0.02
US Spread	1.15	0.99	-0.28	-0.14	0.36	-0.05	-0.04	-0.05	0.55	0.41	-0.25	-0.08
Commodity Price	19.77	18.38	0.51	0.42	-0.13	-0.03	-0.06	-0.07	-0.51	-0.01	0.62	0.39

Note: Risk-free rate and spread in levels; NEER in Q/Q growth rate; all other variables in Y/Y growth rates.

Table 10: Moments: Data vs DSGE at its mode: selected foreign variables

	Corr(z.GDP*)		Corr(z.CPI*)		Corr(z.R*)		Corr(z.Spr*)		Corr(z.CP*)	
	Data	DSGE	Data	DSGE	Data	DSGE	Data	DSGE	Data	DSGE
GDP	0.41	0.30	0.64	0.16	0.38	-0.02	-0.28	-0.14	0.51	0.42
Employment	0.23	0.24	0.42	0.13	0.22	-0.04	-0.18	-0.06	0.33	0.37
Consumption	0.43	0.18	0.48	0.03	0.41	-0.06	-0.42	-0.11	0.52	0.32
Investment	0.16	0.12	0.34	0.06	0.30	-0.01	-0.04	-0.08	0.23	0.20
Exports	0.54	0.20	0.43	0.10	0.33	0.00	-0.38	-0.06	0.35	0.21
Imports	0.47	0.09	0.44	0.01	0.22	-0.01	-0.35	-0.04	0.53	0.14
Mining exports	0.31	0.20	0.49	0.09	0.14	0.02	-0.25	-0.08	0.62	0.39
CPI	-0.22	-0.03	0.08	0.27	0.24	0.23	0.36	-0.05	-0.13	-0.03
MPI	-0.01	-0.06	0.23	0.26	0.34	0.15	0.27	0.02	-0.04	-0.08
Labor comp.	0.29	0.24	0.30	0.08	0.04	-0.03	-0.29	-0.12	0.44	0.40
Risk-free rate	0.36	-0.07	0.10	0.21	0.77	0.29	-0.04	-0.05	-0.06	-0.07
Spread	-0.26	-0.07	-0.33	-0.12	0.09	-0.10	0.55	0.41	-0.51	-0.01
NEER	0.00	-0.02	-0.02	0.01	0.11	0.04	0.16	0.04	-0.10	-0.10
US GDP	1.00	1.00	0.31	-0.08	0.43	-0.31	-0.71	-0.23	0.27	0.45
US Consumption	0.89	0.88	0.12	-0.14	0.50	-0.37	-0.66	-0.18	0.15	0.41
US Investment	0.91	0.82	0.30	-0.02	0.28	-0.21	-0.64	-0.27	0.19	0.35
US Hours	0.78	0.90	0.31	-0.03	0.23	-0.29	-0.66	-0.21	0.28	0.53
US CPI	0.31	-0.08	1.00	1.00	0.33	0.55	-0.17	-0.08	0.68	0.09
US Wage	0.44	-0.02	0.21	0.65	0.52	0.36	-0.30	-0.10	0.15	0.03
US Risk-free rate	0.43	-0.31	0.33	0.55	1.00	1.00	-0.23	-0.07	0.17	-0.11
US Spread	-0.71	-0.23	-0.17	-0.08	-0.23	-0.07	1.00	1.00	-0.28	-0.10
Commodity Price	0.27	0.45	0.68	0.09	0.17	-0.11	-0.28	-0.10	1.00	1.00

Note: Risk-free rate and spread in levels; NEER in Q/Q growth rate; all other variables in Y/Y growth rates.

Table 11: Shocks Correlation

	ε_b^*	Υ^*	ε_g^*	ε_h^*	λ_d^*	λ_w^*	ε_R^*	$\varepsilon_{R_L}^*$	ε_p^*	ε_{xm}	$\tilde{\phi}$	λ_m	ε_b	Υ	ε_g	ε_h	λ_d	λ_w	ε_R	ε_{R_L}
ε_b^*	1.00																			
Υ^*	-0.09	1.00																		
ε_g^*	-0.16	0.34	1.00																	
ε_h^*	0.13	0.26	0.35	1.00																
λ_d^*	0.15	-0.39	-0.39	-0.28	1.00															
λ_w^*	-0.08	-0.07	0.26	-0.07	-0.09	1.00														
ε_R^*	-0.25	0.44	0.19	0.32	-0.68	-0.02	1.00													
$\varepsilon_{R_L}^*$	0.17	0.19	0.30	0.29	-0.50	-0.13	0.30	1.00												
ε_p^*	0.30	-0.40	-0.20	-0.16	0.57	-0.03	-0.57	-0.35	1.00											
ε_{xm}	0.19	0.32	0.07	-0.08	-0.04	-0.01	0.03	0.01	-0.15	1.00										
$\tilde{\phi}$	-0.14	-0.15	-0.06	-0.17	0.15	0.25	0.10	-0.40	0.18	0.18	1.00									
λ_m	0.23	-0.15	-0.04	0.08	-0.16	-0.12	-0.03	0.22	0.18	-0.37	-0.29	1.00								
ε_b	0.30	-0.13	-0.15	-0.23	0.39	0.01	-0.47	-0.25	0.34	0.07	0.15	-0.19	1.00							
Υ	-0.04	0.07	-0.12	0.00	0.34	-0.11	-0.13	-0.30	0.17	0.11	0.25	-0.19	0.05	1.00						
ε_g	-0.28	-0.03	0.09	-0.06	-0.03	0.01	-0.03	-0.08	0.13	-0.42	-0.15	0.21	-0.06	-0.15	1.00					
ε_h	0.15	0.17	0.10	0.06	-0.14	0.03	0.21	0.17	-0.11	0.21	-0.02	-0.26	0.09	0.07	-0.13	1.00				
λ_d	0.08	-0.17	-0.06	-0.20	0.27	0.06	-0.11	-0.16	0.21	0.25	0.18	-0.34	-0.10	-0.03	-0.20	0.15	1.00			
λ_w	-0.12	0.07	-0.03	-0.19	0.04	0.19	0.03	-0.15	-0.07	0.19	0.09	-0.09	0.15	-0.12	0.09	-0.07	0.12	1.00		
ε_R	-0.50	-0.01	0.14	-0.09	-0.15	0.11	0.22	-0.14	-0.20	-0.18	0.23	-0.27	-0.29	-0.06	0.16	0.03	0.14	0.11	1.00	
ε_{R_L}	0.03	0.06	0.01	0.30	-0.20	0.00	0.10	0.16	-0.20	0.03	-0.38	0.07	-0.15	-0.15	0.06	0.13	0.02	-0.16	-0.05	1.00
ε_{hp}	0.11	0.07	0.04	0.10	-0.07	-0.04	0.03	0.19	-0.04	0.32	-0.16	0.08	-0.11	-0.09	-0.32	-0.13	0.15	0.16	-0.16	0.10

Foreign shocks: $\varepsilon_b^* =$ wedge, $\Upsilon^* =$ Investment-specific, $\varepsilon_g^* =$ Government demand, $\varepsilon_h^* =$ Productivity, $\lambda_d^* =$ Mark-up, $\lambda_w^* =$ Wage-push, $\varepsilon_R^* =$ Monetary policy, $\varepsilon_{R_L}^* =$ Credit supply and $\varepsilon_p^* =$ Commodity supply.

SOE shocks: $\varepsilon_{xm} =$ Trade volumes, $\tilde{\phi} =$ Country risk premium (UIP), $\lambda_m =$ Import mark-up.

Domestic shocks: $\varepsilon_b =$ wedge, $\Upsilon =$ Investment-specific, $\varepsilon_g =$ Government demand, $\varepsilon_h =$ Productivity, $\lambda_d =$ Mark-up, $\lambda_w =$ Wage-push, $\varepsilon_R =$ Monetary policy, $\varepsilon_{R_L} =$ Credit supply and $\varepsilon_{hp} =$ Commodity supply.

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