Policy Regime Switches and Evolution of Macroeconomic Outcomes*

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Abstract

In this paper, the effects of policy switches on macroeconomic variables in the South African economy are investigated using a regime-switching small open economy dynamic stochastic general equilibrium model. The model is solved and estimated by an efficient perturbation algorithm and a Bayesian inference is carried out. The novelty of this paper is found in the structural model, where the primary commodity export sector follows a regime shock process that affect the policy parameters is allowed. The results suggest that an unexpected monetary policy shock and its variances account for a smaller proportion of macroeconomic fluctuations in the South African economy compared to external shocks and its variances in the form of exports, import cost inflation, risk premia, preference and technology changes. This paper further establishes that volatility in the structural innovations outperforms constant dynamic stochastic general equilibrium model. (JEL: C32, C51, E32, E52)

Keywords: regime-switches DSGE, policy regimes, macroeconomic volatility

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1 Introduction

In the monetary policy literature, One strand seeks to understand the main sources of variability in inflation and output from its steady state. Identifying these sources remain a challenge as a result of the changing structure of the economy, changing policy framework, changing volatility and structural breaks in macroeconomic data. Despite this, monetary policy regime changes have been well documented over the last two decades. In the existing literature, thus, two views have gained prominence, that is, good luck and good policy.

According to the good luck view, vector autoregressive technique analyses of policy regimes support a stable economic environment which helps to stabilise inflation and output volatility. Thus, during a period of low inflation, the global economy experienced minimal shocks and these coincide with trade openness in the domestic economy.[1] On the contrary, the good policy view argues that institutional changes, sound monetary policy, such as an inflation targeting regime and some economic theory are responsible for low volatility in inflation and output.[2]

While these studies allow for changes in policy preferences and innovations compared to traditional econometric methods such as OLS and GMM, it does not allow for expectation formations that are likely to affect the current decision-making behaviour of private agents. As a result, Blake and Zampolli (2006), Liu and Mumtaz (2011), Davig and Doh (2014) and Foerster (2014) use Markov-switching rational expectations models to examine multiple regime shifts. The key finding of the above studies is that expectations of future policy regime shifts have significant effects on macroeconomic outcomes. In South Africa, Balcilar et al. (2016) use the Markov-switching DSGE model to forecast structural changes in the South African economy. According to them, the risk-premium shocks have a larger impact on output, inflation and interest rate, whereas policy shock affect only inflation. Similarly, the model with switching properties better fit the economy.

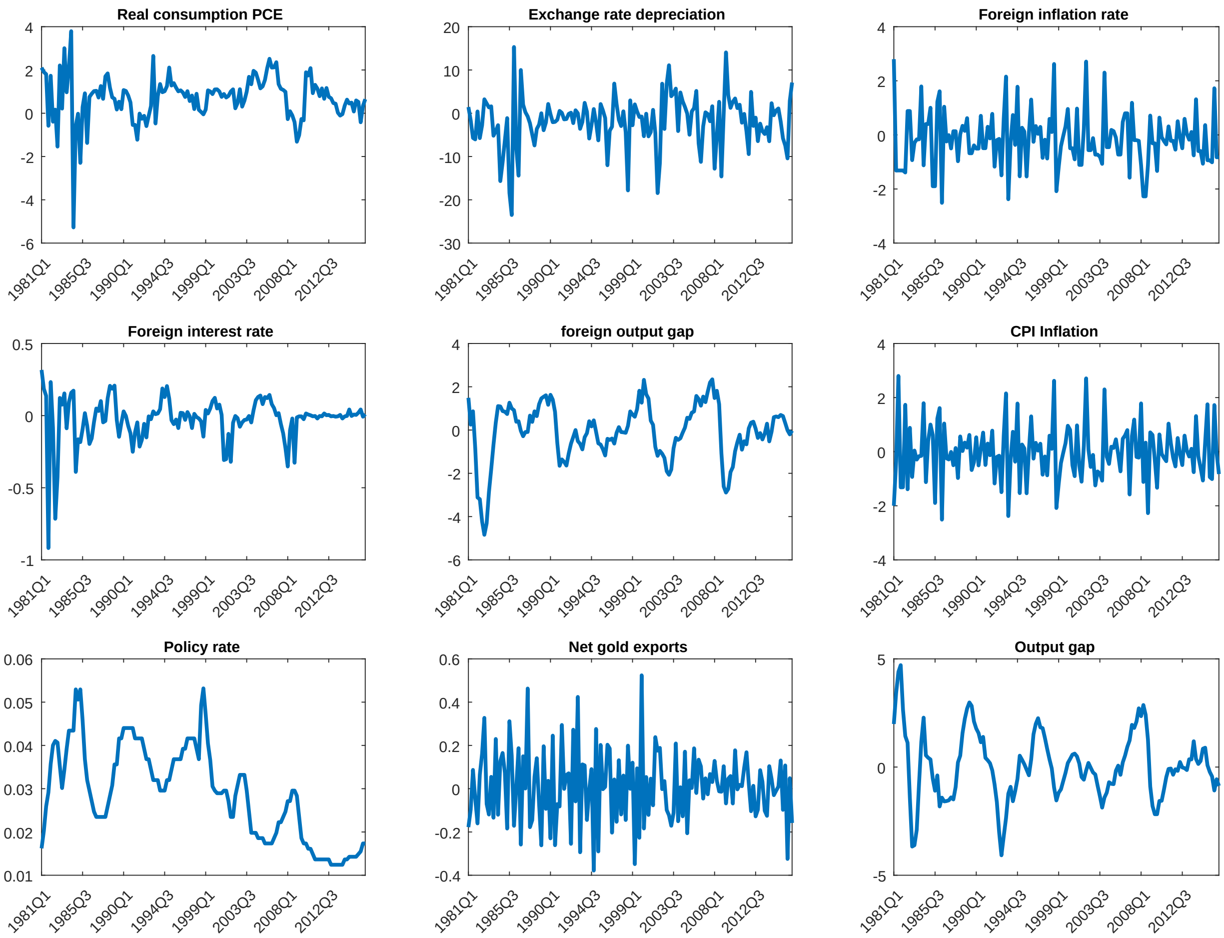
An exploratory analysis of the key macroeconomic variables in the South African

[1] See, Bernanke and Mishkin (1997), Sims and Zha (2006), Mishkin and Schmidt-Hebbel (2007) and Boivin et al. (2010).

[2] This includes, among others, Fuhrer and Olivei (2010), Canova and Ferroni (2012) and Baxa et al. (2014).

economy indicates that there are spikes in the data. Figure 1 exhibits considerable changes in the consumer price index inflation, output gap, and policy rate after the adoption of monetary aggregates regime in 1986. The other variables, such as real consumption and the exchange rate also witnessed various upswings and downswings. Gold exports followed with erratic swings that are expected to affect South Africa's macroeconomic performance. When the South African Reserve Bank officially adopted inflation targeting in 2000, the policy rate experienced remarkable reduction and then stabilised in 2005. It rose in 2008 during the global financial crisis, as shown in Figure 1. Therefore, the question that emerges is: do the changes in policy preferences explain changes in inflation and output fluctuations? If these are positive, then how do the variances in policy shocks impact on macroeconomic variables?

Figure 1: Observed variables use in this study



These questions motivate an examination as to whether the South African economy is characterised by policy regime changes using a regime-switching small open economy dynamic stochastic general equilibrium (DSGE) model. This helps to identify how policy regime changes have affected macroeconomic dynamics in South Africa. The effects of primary commodity export shocks on macroeconomic outcomes, such as inflation, output and policy rate are also addressed. Here, the role of primary commodity exports is incorporated, first, in the form of gold exports, then a merchandise exports. This, therefore, determines the changes to the dynamic responses of the variables in the system. This deepens the understanding of policy regime shifts on macroeconomic performance in small open economies that export primary commodities.

Although Blake and Zampolli (2006), Liu and Mumtaz (2011), Alstadheim et al. (2013), and Bianchi et al. (2014) allow for changes in policy shocks and transition probabilities in their analysis, this paper differs because it allows for primary export innovations in a regime dependent framework. This is relevant for this study, because one of the factors accounting for low growth in emerging economies, especially South Africa, is weak global demand and lower prices of key export commodities, such as gold, copper, iron and platinum (SARB (2016)). Most literature neglects the role of primary commodity exports within a setup of policy regime switches, either for small developed economies or in emerging economies (see Seoane (2011), Alstadheim et al. (2013), Blagov (2016) and Gonçalves et al. (2016)).

This paper follows Nimark (2009) and uses a structural small open economy model that characterises the salient features of the South African economy. However, the Taylor-type rule in Nimark (2009) model is modified to account for the exchange rate disconnect puzzle and then Markov-switches are introduced into the model. This model is solved using Maih (2015) efficient perturbation algorithm and carrying out Bayesian inference with data covering the period 1981:Q1 and 2016:Q3. In summary, the study finds that an increase in external shocks and its volatility have a larger role to play in monetary policy analyses in emerging economies compared to only using policy shocks and its volatility. The results suggest that volatilities in structural innovations are the main drivers of economic performance and better fit the economy. Moreover, the model that includes primary commodity export sector shocks in the form of gold exports outperforms the ones that do not capture commodity export shocks. Another result is that the structural parameters are not constant. Following a change in the variances of the structural innovations, the parameters of the structural model keep shifting. This result is related to the views of Fernández-Villaverde et al. (2007), who suggest that there is evidence of parameter drifting in the structural model over their sample period.

The rest of the paper is structured as follows. In sections two and three, related literature and modeling strategy are provided. Outlined in section four is a regime-switching DSGE environment that includes a generic framework, stability solution and estimation methods, as well as data, priors and number of Markov switches in this model. In section five, the empirical results are provided. This is followed by the conclusion of the discussion in section six.

2 Literature Review

This paper is related to parameter instability literature of dynamic stochastic general equilibrium models. This strand of the literature includes early research by Laforte (2005), Rubio-Ramirez and Fernéndez-Villaverde (2007) and Justiniano and Preston (2010), who use DSGE models with stochastic volatility in the structural innovations. They find considerable evidence that the parameters are nonconstant. Castelnuovo et al. (2014) examine policy regime swtiches and time-varying inflation trends with volatility shocks in a unifying model. According to them, a time-varying policy switching model is more tractable as compared to a constant policy regime model. Related findings are documented in Ferman (2011), Bianchi et al. (2014) and Debortoli and Nunes (2014).

Alstadheim et al. (2013) recently considered a Markov-switching DGSE model that endogenises the nominal exchange rate. They solve the model using a perturbation method and carry out estimations through Bayesian inference. According to them, the magnitude of policy shocks and structural parameters in relation to Canada, Norway, Sweden and the U.K. vary over their sample period. Similarly, Chen and MacDonald (2012) used U.K. dataset over the past 35 years to examine changes in the economy using a Bayesian technique. In their paper, they find that policy rule parameters, price indexes, and exogenous shocks experience major variations.

These studies have convinced the writer that policy regime switches are an important characteristics of macroeconomic data. However, the studies by Alstadheim et al. (2013) and Chen and MacDonald (2012) use Lubik and Schorfheide (2007) model, whose features are restrictive in nature to characterise emerging economies. The model assumes the existence of a complete financial market and with minimal shocks. Therefore, a structural small open economy model that characterises the features of emerging economies to quantify the effect of policy regime switches is required. This paper's contribution to this literature is the introduction of shocks unique to the South African economy that depends on primary commodity exports with incomplete financial market. This could also apply to other emerging economies.

In emerging economies Seoane (2011) uses a Markov-switching DSGE model to examine the effectiveness of fiscal and monetary policy, and Blagov (2016) investigates the sensitivity of a currency board and policy credibility of the Estonia policy authority. Seoane (2011) finds that an active monetary policy in the 1980s and 1990s lasted in short periods of a two-year interval in instances when there was an economic crisis. Consequently, a policy shift from active fiscal policy to active monetary policy resulted in high output losses. Blagov (2016) finds that a stable currency board helps mitigate the adverse effect of risk premia in the long run. It is important to note that these studies do not consider policy regime switches with a primary commodity export sector that is essential in emerging economies. This paper fills the gap in this part of the literature.

This study is related to studies that look at the literature that examines central bank responses to inflation, output and exchange rate in South Africa. This includes Steinbach et al. (2009), Alpanda et al. (2010) and Peters (2016). According to them, the SARB does not attach significant weight to the exchange rate, instead it attaches greater weight to inflation variability relative to output. Although these results are encouraging, they are based on a constant parameter assumption that may show bias in their results. Nevertheless, during certain regimes policy innovations may change, which may influence the dynamics of macroeconomic outcomes. For these reason this paper revisits these studies to establish whether in a regime-dependent state the SARB policy conduct is different from their findings.

The method used in this paper is an algorithm that is related to the solution methods of Davig and Leeper (2007), Foerster et al. (2014), Farmer et al. (2015), Maih (2015) and Bianchi and Melosi (2016). Bianchi and Melosi (2016) derive a solution method for rational expectation models that agent beliefs are subject to varying states, such as good, bad and uncertain states that impact on macroeconomic performance. According to them, the algorithm is superior because it can account for slow and sudden changes in agent beliefs and uncertainty. In this paper the efficient perturbation algorithm of Maih (2015) is followed because it is superior in solving log-linearised rational expectations models. More importantly, this solution method identifies sufficient conditions for determinacy in a mean square stability of rational expectations models. This is different from Davig and Leeper (2007) and Farmer et al. (2015) solution methods that generate multiple equilibria. This algorithm captures forward, current and lagged variables in the model.

3 Modeling Strategy

3.1 Model Characteristics

The model setup used here is adopted from Nimark (2009), a structural small open economy model applied to the Australian economy. This model is, however, presented somewhat differently in this work, for the monetary policy rule is allowed to account for the exchange rate that is a major characteristics of the South African economy. This model has three properties that satisfy the requirements needed to address the questions set out in this paper. First, the South African economy is described as a structural small open economy. Secondly, the model theoretical framework is simple to follow and provides for adequate dynamics to empirically test important monetary policy theses. Thirdly, a number of frictions are introduced in domestic and imported goods inflation and consumer utility function, as well as exogenous export demand shocks to characterise the South African economy and risk premia shocks to induce a smooth steady state.

Further, this model accounts for primary commodity exports sector and foreign shocks to the domestic economy. These features describe the South African economy as a price taker in its primary commodity exports in the international market. In South

Africa, merchandise trade is driven by primary commodities that constitute more than half of exports while half of imported goods are manufactured goods.[3]

There are four economic agents in this model, namely the policy authority, aggregation sectors, representative consumers and the rest of the world. The policy authority sets the policy rate to follow a Taylor-type rule. The nominal exchange rate depreciation is introduced in the representative consumers' budget constraint through the international securities market. In addition, the exchange rate affects commodity exporters via the world relative prices of primary commodity exports channel and profits of firms that import goods.

The aggregators consist of domestic producers, importers and primary commodity exporters. The domestic producers produce differentiated goods in a monopolistically competitive market. The goods can be exported or sold in the domestic market. In this case, firms charge a mark-up over marginal cost as a result of consumer preferences for different bundles of goods and some market power over the price of goods firms sell. In this model, the commodity export demand sector is characterised by exogenous export shocks and export income shock steming from a variablility in world commodity prices.

Representative consumer preferences are governed by domestic and imported production goods as well as labour supply. The rest of the foreign economy is large and is considered exogenous to the domestic economy.

3.2 Extract of the Model

In what follows, the important parts of the log-linearised model that are relevant to this study are provided.[4] In this model, the primary commodity export demand sector is given in eq. (1) as

$$xe_t = y_t^{fy} - \delta_e pw_t + ze_t, \tag{1}$$

where $[xe_t,\ y_t^{fy},\ ze_t]$ are total primary commodity exports, foreign output and commodity exports shock process, respectively. δ_e is price elasticity of commodity export demand and pw_t is relative prices of world primary commodity exports which takes the

[3] http://tradestats.thedti.gov.za/ReportFolders/reportFolders.aspx

[4] See, detailed derivations are provided in Nimark (2009).

form

$$pw_t = \pi_t - \pi_t^{fi} - \Delta s_t + pw_{t-1}, \tag{2}$$

where $[\pi_t, s_t, \pi_t^{fi}]$ are consumer price index inflation, terms of trade and foreign inflation rate. The shock to commodity export income equation in Nimark (2009) is shut due to computational complexity.

Regarding monetary policy, the policy authority sets a Taylor-type rule that takes into account exchange rate deviations to address the exchange rate disconnect puzzle.[5] In this way, this paper departs from Nimark (2009) setup of the policy rule that does not account for the nominal exchange rate depreciation.

$$r_t = \rho_r r_{t-1} + (1-\rho_r)[\gamma_1 \pi_t + \gamma_2 y_t + \gamma_3 \Delta e_t] + \sigma^{er}, \tag{3}$$

where $[r_t, e_t, \sigma^{er}]$ are policy rate, nominal effective exchange rate depreciation and policy rate shocks. The parameters $[\rho_r, \gamma_1, \gamma_2, \gamma_3]$ control the degree to which policy rate adjusts to interest rate smoothing, deviations in consumer price index inflation, the output gap, and the nominal exchange rate. These show that the interest rate smoothing term in the policy rule ranges $[0 < \rho_r < 1]$ and the policy rule parameters ranges $[\gamma_1, \gamma_2, \gamma_3 \geq 0]$.

In eq. (3), y_t is domestic output that links both the direct effect from the terms of trade and an indirect effect that operate through the market clearing condition given in eq. (4) as

$$y_t = (1-\alpha)c_t + \alpha[\omega(s_t + q_t) + y_t^{fy}], \tag{4}$$

eq. (4) is made up of domestic consumption (c_t), terms of trade (s_t), real exchange rate (q_t) and foreign output, while ω is the elasticity of substitution between home and foreign goods and α is the share of foreign goods in consumption.

In this model, the uncovered interest rate parity condition is similar to Schmitt-Grohé and Uribe (2003) and Justiniano and Preston (2010). They motivate an imperfect international securities market between foreign and domestic bonds, thus the uncovered interest rate parity condition is as follows in eq. (5)

$$q_t = q_{t+1|t} - (r_t - \pi_{t+1|t}) + (r_t^{fr} - \pi_{t+1|t}^{fi}) + \kappa b_t + zq_t, \tag{5}$$

[5]The exchange rate disconnect puzzle refers to the missing link between the predictability of the exchange rate and some key economic fundamentals, such as output growth, interest rates, relative prices, forward rates and money.

where $[r_t^{fr}, b_t, \kappa, zq_t]$ are foreign interest rate, net foreign debt position, debt elasticity with respect to interest rate risk premia and risk premia shock process.

The Euler equation is given in eq. (6) as

$$c_t = \frac{\lambda}{1+\lambda}c_{t-1} - \frac{1}{1+\lambda}c_{t+1|t} - \frac{1-\lambda}{\tau(1+\lambda)}(r_t - \pi_{t+1|t} + zd_t), \tag{6}$$

where $[c_t, zd_t]$ are real household consumption and preference shock processes. $[\lambda, \tau]$ are the degree of habit formation and inverse elasticity of intertemporal substitution.

The Philips curve for domestic inflation is of the form;

$$\pi_t^h = \frac{\delta_h}{1+\beta\delta_h}\pi_{t-1}^h + \frac{\beta}{1+\beta\delta_h}\pi_{t+1|t}^h + \frac{(1-\phi_h)(1-\phi_h\beta)}{\phi_h(1+\beta\delta_h)}[\psi * y_t - (1+\psi) * zp_t + \alpha * s_t$$
$$+ (\frac{\tau}{(1+\beta * \delta_h) * (1-\lambda)})(c_t - \lambda * c_{t-1})], \tag{7}$$

where π_t^h is domestic inflation and zp_t is the technology shock process. The structural parameters are δ_h—price index for home-produced goods, and ϕ_h—price adjustment cost for home-produced goods. β is the representative consumers' subjective discount factor and ψ is the inverse elasticity of labour supply.

The Phillips curve for imported inflation takes the form;

$$\pi_t^f = \frac{\delta_f}{1+\beta\delta_f}\pi_{t-1}^f + \frac{\beta}{1+\beta\delta_f}\pi_{t+1|t}^f + \frac{(1-\phi_f)(1-\phi_f\beta)}{\phi_f(1+\beta\delta_f)}[q_t - (1-\alpha)s_t] + zs_t, \tag{8}$$

where π_t^f represents imported inflation and zs_t is the import-cost inflation shock process. δ_f is a fraction of importing firms that reset prices according to Calvo (1983) pricing. When a fraction of firms do not adjust prices, δ_f tends to 0, then deviations from the law of one price becomes smaller. ϕ_f is a fraction of importers that do change prices while the other fraction $(1-\phi_f)$ uses the rule of thumb price setting. Therefore, the consumer price inflation is given in eq. (9) as

$$\pi_t = \alpha\pi_t^h + (1-\alpha)\pi_t^f. \tag{9}$$

The rest of the foreign economy variables $[y_t^{fy}, r_t^{fr}, \pi_t^{fi}]$ follow autoregressive processes of order one [AR(1)]. In this model, the innovations of interest are nine and evolve as AR(1) processes. These include monetary policy shock, preference shock, technology shock, imported cost inflation, export shock, risk premia shock, foreign interest rate shock, foreign inflation shock and foreign output shock. The rest of the model equations are presented in Table 5 of Appendix A A.

Regime switches are introduced into eqs. (1) to (9), the remaining equations in Table 5 and all the innovations are regime-dependent.

4 A Regime-Switching DSGE Environment

This section provides a generic framework, solution method and estimation strategy of a regime-switching DSGE model. The estimations in this study are carried out through RISE, a MATLAB package that has been designed to solve and estimate regime-switching DSGE models.[6] This environment characterises a rational expectation model in which changes in policy parameters are allowed to influence the formation of expectations by private agents. When policy regime changes over time, the regime-switching rational expectations model allows private agents to take those changes into account. A simple conjecture is that if a cental bank reacts more aggressively to inflation, private agents may take into account these expectations about future inflation changes. This information may be able to stabilise inflation and output, even before the actual policy takes effect, because of either wage setting under diferent price expectations or price setting under different marginal cost facing the firm.

4.1 Generic Framework and Solution Method

It is assumed that the variances of all the variables and shock processes follow a regime-dependent state Markov chain parameters (s_t). In this vein, the transition matrix is governed by a benchmark P probability matrix characterised as

$$P = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix}, \tag{10}$$

where $P_{1,2} = prob(s_{t+1} = 2 | s_t = 1)$ is transition probability from state 1 to state 2. This follows that the small open economy dynamic general equilibrium model with regime-switching has a state space representation of the form

$$\upsilon \equiv [b_{t+1}(y_{t+1}), f_{t+1}(y_{t+1}), s_t(y_t), p_t(y_t), b_t(y_t), f_t(y_t), p_{t-1}, b_{t-1}, \varepsilon_t, \theta_{y_{t+1}}]^{`}, \tag{11}$$

[6]RISE refers to the Rationality in Switching Environment software developed by Maih (2015). This package can be obtained from https://github.com/jmaih/RISEtoolbox.

where b_t is an $m_b \times 1$ vector of forward and exogenous variables, f_t is $m_f \times 1$ forward looking variables, p_t is $m_p \times 1$ vector of exogenous variables, s_t is $m_s \times 1$ vector of current variables , ε_t is $m_\varepsilon \times 1$ vector of innovations and $\theta_{y_{t+1}}$ is $m_\theta \times 1$ a vector of the matrices with switching parameters in the model.

Following the seminal contribution of Davig and Leeper (2007), Markov-switching rational expectations research has become a popular field in macroeconometrics.[7] For example, Foerster et al. (2014), Farmer et al. (2015), Maih (2015) and Cho (2016) have found new solution methods to this class of models. Thus, the popular Klein (2000) and Sims (2002) algorithms are no longer suitable to solve this class of models.

This paper, therefore, uses the solution method developed by Maih (2015).[8] The algorithm is an efficient perturbation method for solving regime-switching rational expectations models that allow one to determine a single equilibrium condition relevant for economic analysis. This is an improvement over the minimal state variable algorithm proposed by Farmer et al. (2015).[9] The efficient perturbation method algorithm is applied on eqs. (1)- (9) leading to eq. (11) to group the parameters into lagged, current as well as forward-looking endogenous and exogenous variables. The next step is to estimate the first-order perturbation solution to yield regime-dependent solution of the form

$$\Upsilon^{y_t} \equiv \Upsilon^{y_t}(\overline{z}_{y_t}) + \Upsilon^{y_t}(z_t - \overline{z}_t), \tag{12}$$

where Υ^{y_t} is the approximation rule and $z_t = [p_{t-1}, b_{t-1}, \theta, \varepsilon_t]$ is $m_z \times 1$ vector of state variables. $\overline{z}_t$ is steady state values of the state variables and θ is a vector of the perturbation parameters.

[7]They find that determinancy condition for regime switching equilibria depend on curent regime and shocks

[8] This model accounts for lagged endogenuous variables and regime switches that depend on current and future regimes. Further, the model is suitable for log-linearised rational expectations models, where private agent parameters are allowed to switch across regimes.

[9] Davig and Leeper (2007) and Farmer et al. (2015) solution algorithms generate multiple equilibria in that when one regime produces more volatility relative to the other regime, this results in indeterminacy.

4.2 Estimation

The next step in the investigation is the estimation of the observed variables. The estimation strategy is carried out by Bayesian inference through a Markov-Chain Monte Carlo (MCMC). In particular, the random walk Metropolis-Hastings algorithm is used, because in estimating DSGE models some of the conditional distributions are not obtainable in closed form (see Herbst and Schorfheide (2015)). The parameters of the prior distribution are set and a new set of parameters is drawn from the random walk candidate density. Thereafter, the likelihood and the prior distribution at the draw value of the parameters are evaluated with the aim of generating the posterior distribution and estimating the marginal density from the data.

Here the Kalman filter algorithm is not appropriate, so the Kim filter algorithm is adopted. The Kim filter is suitable in a large set of Markov-switching DSGE models to compute the posteriors and marginal densities. The Kim filter is a combination of the Kalman and Hamilton filters, where the possible paths are collapsed through averaging at each step of the likelihood (Kim and Nelson (1999)). This keeps the computation of the likelihood tractable.

In all, 20 equations with 51 variables made up of lags, forward looking and current endogenous and exogenous variables were estimated.

4.3 Data

In this paper, nine observed variables at quarterly frequency from 1981:Q1 to 2016:Q3 are used. The sample period was chosen to cover the period prior to the adoption of a monetary aggregates regime in 1986. The domestic observed variables are six, and consist of real GDP seasonally adjusted, real household consumption expenditure seasonally adjusted, gold exports seasonally adjusted as a proxy for primary commodity exports, policy rate(repo rate), consumer price index inflation, and a nominal effective exchange rate. The foreign observed variables relate to the U.S. and are foreign interest rate, foreign output and foreign inflation. The remaining variables in the model are unobserved. CPI inflation, policy rate, foreign inflation, foreign interest rate and foreign output are sourced from IMF International Financial Statistics (IFS) database. The rest of the observed variables are obtained from the South African Reserve Bank database.

Inflation is consumer price index inflation measured on a quarterly basis. The nominal effective exchange rate is quarterly percentage changes in the South African rand measured as a trade-weighted average of twenty major trading partners of South Africa. Regarding foreign interest rate, inflation and output, we use the U.S.-three month Treasury bill, consumer price index inflation and the real GDP seasonally adjusted.

All the series were transformed into their growth rates by taking the natural log difference of the series and multiplying them by 100 to standardise the variables except policy rate and foreign interest rate. The policy rate and foreign interest rate are measured as per cent per annum. These are converted into quarterly averages as $log(1+\frac{policyrate}{400})$. With respect to domestic and foreign output, the output gaps are extracted using the HP filter.

4.4 Priors and Markov Switches

This section presents the number of Markov switches introdued into the model and priors of the structural and policy regime switches. In the Markov switches, a constant regime is allowed for, as is volatility in the structural shocks only, policy shocks only, simultaneous volatility in structural and policy shocks, and independent volatility in structural and policy shocks.

Following this, statistical estimates are used to attach values to the model structural parameters. The discount factor (β) was fixed at 0.97, which translates into a long run annual average real interest rate of 3.09 per cent. The intertemporal elasticity of substitution of labour supply (ψ) is set at 1.30 to ensure that workers are willing to increase the number of hours worked in respond to temporary changes in wages. Debt elasticity with respect to interest rate risk premia (κ) is fixed at 1.45 per cent, which gives a default spread of 145 basis points as estimated by Allan Haung country risk premiums.[10] The share of foreign goods in consumption (α) and price elasticity of primary commodity exports (δ_e) are set to 0.24 and 0.14 respectively, based on a five-year average concentration and diversification indices from UNCTAD.[11]

The elasticty of substitution between home and foreign goods (ω) is set to 1.5, in that the markup for South Africa is comparable to the U.S. and euro area estimates, as

[10] This can be assessed from www.sjsu.edu/faculty/watkins/econ202/risk.htm.

[11] unctad.org/en/pages/statistics.aspx

established by Burger and Du Plessis (2013). Justiniano and Preston (2010) results are followed, and the underlisted parameters are fixed at 0.5. These are price indexation for home and foreign produced goods (δ_h, δ_f), price adjustment-cost for home and foreign produced goods (ϕ_h, ϕ_f) and degree of habit formation in consumption (λ) and inverse elasticity of intertemporal substitution (τ).

It is assumed that the prior distributions of policy parameters switches, the priors for regime 1 and regime 2 are different as a result of money target and inflation targeting regimes. In particular, it is assumed that in regime 1, the prior responses are low for inflation and output, while in regime 2 the responses are high. The responses to exchange rate depreciation and the macroeconomic condition index are high in regime 1 and low in regime 2. The prior choice for the regimes are in line with Ortiz and Sturzenegger (2007) and Peters (2016). According to them, the SARB targets the exchange rate prior to an inflation targeting regime while in post inflation targeting regime it does not target the exchange rate. Priors for the policy smoothing parameter (ρ_r) is set at 0.60 and policy innovations (σ^{er}) is set at 0.15. The priors for the transition matrice are set to 0.95 in each regime, based on Bianchi (2012), who states that regimes are persistent.

Further, it is assumed that the economy faces primary commodity export switches in innovations. In regime 1, the economy faces relatively low volatility in primary commodity innovations (σ^{ee}), with prior distributions of 0.37. While in regime 2, the economy faces high volatility with prior distribution of 0.87 in line with Nimark (2009). In addition, the prior distributions of the structural shocks processes follow beta distribution with values of 0.60. The priors for the variances in structural innovations follow a Weibull distribution with values of 0.18.

Following Liu et al. (2011) and Bjørnland et al. (2016), there is a departure from the normal practice of the direct usage of prior means and standard deviations, and this study uses quantiles distribution of the statistical estimates of the prior means to recover the hyperparameters with 90 percent probability interval of the distributions.[12]

[12] See, Gelman et al. (2014) for a detailed discussion and treatment of this approach. Similarly, see Gelman et al. (2014) pp.11 for the exposition on the credible intervals of the posterior densities, model checking and improvements.

5 Empirical Results

In this section, estimates of the Markov-switching DSGE model are reported. First, the model comparison results are presented to help select the best fit specification and also ensure that only the model that best fit the data is discussed. Following this, a detailed account of the parameter estimates and the smoothed transition probabilities is given. Thereafter, the robustness of the baseline model used is evaluated relative to alternative specifications. Finally, some light is shed on the generalised dynamic responses, variance and historical decompostions to determine various contributions of the shocks to the economy.

5.1 Model Comparison

In this subsection whether the data fit a particular model based on alternative specifications is investigated. This is done using the Akaike information criterion (AIC_c), Bayesian information criterion (BIC) and the log marginal data densities. Based on the log posterior densities reported in Table 1, the data is adjusted to obtain the AIC_c and BIC.

Table 1: Statistics for model comparison

	Constant	VolPolSame	VolPolInd.	VolOnly	PolOnly
BIC	4025.18	39545.52	507480.22	3694.32	3921.72
AIC_c	3948.09	39459.89	507480.22	3584.26	3837.74
Log-posterior	-1930.75	-19656.20	-253618.59	-1738.04	-1866.62
Log-lik	-1801.89	-19618.26	-253617.24	-1679.07	-1792.15
Log-prior	-128.86	-37.94	-1.3533	-58.97	-74.47
Log-MDD(Laplace)	-2176.10	-19930	-253920.87	-1926.40	-2083.49

Note: Constant=structural shocks and policy parameters are time-invariant; VolPolSame=structural shocks and policy parameters switch simultanteous; VolPolInd=structural shocks and policy parameters switch independent; VolOnly=only volatility in the structural shocks are regime switching; PolOnly=policy parameters only are regime switching.

The model with volatility in structural shocks only has the lowest AIC_c and BIC

scores indicating that this model is parsimonious for the South African economy. There is strong evidence in favour of the model with switches in volatility in the structural innovations only relative to policy only and a constant model, as shown in Table 1.

Next, the marginal likelihood, that is, the log-marginal data densities (log-MDD) is used to characterise the estimated DSGE model that best fits the data—the model with the largest marginal likelihood is considered as the best fit model, as reported in Table 1. The model with volatility in structural shocks only continues to outperform policy shocks volatility and the constant DSGE model. This result is similar to the finding of Liu et al. (2011) for the U.S. economy. To validate the results, a number of robustness tests were run to determine the appropriateness of the best fit model. In Table 4, it is seen that the model with volatility in structural shocks only continues to outperform all the alternative robustness check specifications.

This suggests that the regime-switching DSGE model with volatility in structural innovations only is preferred to either policy only switches or constant DSGE models. This, further, means that policy authorities should pay attention to variances emanating from structural shocks compared to shocks hitting the economy from policy innovations only. Following this, the results in relation to policy shocks only, combined and independent volatility in structural and policy shocks switches only are not discussed. The results are, however, provided for interested readers to make their own judgement in Appendix B.

5.2 Parameter Estimates

Estimates of the simulations are reported in Tables 2 and 3. First, the constant DSGE model is examined. This is followed by an examination of what is here considered as best fit model that is the volatility in structural innovations only DSGE model.

Table 2 shows the posterior mode of the structural and innovation process parameters. The estimates of the constant DSGE model are reported in column 5 of Table 2. It is revealed that the structural parameters are very similar to Alpanda et al. (2010), who use a similar model to examine the responses of the SARB to exchange rate and other marcoeconomic variables. Although there are slight variations in the estimations as shown here, this may reflect the wider coverage of the data sample that includes the

Table 2: Posterior mode of structural and shock process parameters

		Prior		Posterior			
Par.	Distr.	5%	95%	Constant	Volatility	5%	95%
λ	G	0.54	1.50	0.014	0.12	0.06	4.59
τ	G	0.54	1.50	1.93	1.17	0.06	4.59
α	G	0.54	1.50	0.12	0.09	0.06	4.59
ω	G	0.54	1.5	1.54	1.23	0.06	4.59
β	B	0.10	2.00	0.06	0.22	0.18	3.94
ϕ_h	G	0.58	1.00	0.008	0.10	0.25	1.58
ϕ_f	G	0.58	1.00	1.41	1.22	0.25	1.58
δ_h	G	0.54	1.50	1.92	0.21	0.06	4.59
δ_f	G	0.54	1.50	0.05	0.01	0.06	4.59
δ_e	G	0.54	1.50	0.003	0.012	0.06	4.59
ψ	G	0.54	1.50	1.65	1.18	0.06	4.59
κ	G	0.05	1.50	0.001	0.002	0.001	1.58
ρ_d	B	0.05	0.90	0.81	0.86	0.28	8.97
ρ_s	B	0.05	0.90	0.89	0.83	0.28	8.97
ρ_z	B	0.05	0.90	0.96	0.85	0.28	8.97
ρ_q	B	0.05	0.90	0.96	0.93	0.28	8.97
ρ_e	B	0.05	0.90	0.98	0.99	0.28	8.97
ρ_{fi}	B	0.05	0.90	0.19	0.21	0.28	8.97
ρ_{fy}	B	0.05	0.90	0.86	0.80	0.28	8.97
ρ_{fr}	B	0.05	0.90	0.45	0.61	0.28	8.97

Note: B=Beta distribution, G=Gamma distribution. See Gelman et al. (2014) pp.11 for exposition on why some of the posterior densities may be outside the Bayesian credible intervals.

1980s and the financial crisis in 2008 and beyond. The posterior mode for the inverse elasticity of labour supply (ψ) is 1.65, which is much higher than 1.45 for Alpanda et al. (2010) and 1.59 for Justiniano and Primiceri (2008). This may be due to the inclusion of the primary export sector explicitly in the model, coupled with a long period sample coverage. The estimated posterior mode for habit formation in consumption (λ) is 0.014, which is much lower than the 0.83 that was reported in Alpanda et al. (2010)

for South Africa and the 0.81 that was reported in Justiniano and Primiceri (2008) for the US. Similarly, the lower impact of habit formation in consumption is slightly far from a median value of 0.14 that was reported by Liu and Mumtaz (2011) who use Markov-switching model for the U.K. economy.

Another feature of constant DSGE model estimates is that the shocks processes exhibit quite a high degree of persistence, except for foreign interest rate (ρ_{fr}) and foreign inflation (ρ_{fi}) shock processes, with an estimated posterior mode of 0.45 and 0.19, respectively. The estimated posterior mode for the share of foreign goods in domestic consumption (α) is 0.12. This suggests that trade policy pursued in the South African economy is less outward oriented. The estimated posterior mode for price adjustment cost for home (ϕ_h) and foreign produced goods ϕ_f are about 0.01 and 1.41, respectively. This may imply that home-produced goods adjust faster relative to price adjustment cost for foreign-produced goods. Contrary, the estimated posterior mode of price indexation for home-produced goods (δ_h) exhibit more stickness than foreign produced goods (δ_f). It can thus be concluded that the price adjustment cost for home-produced goods and the price indexation for foreign-produced goods have a long run pass-through effect as compared to price indexation for home-produced goods and price adjustment for foreign-produced goods.

Next, the estimated posterior modes of the policy parameters and the structural innovations for the Constant DSGE model are reported in column 5 of Table 3. The estimated policy parameters reveal that policy authorities respond significantly to inflation (γ_1) relative to output (γ_2) and exchange rate depreciation (γ_3). Another revealing feature is that inflation and output parameters of 1.26 and 0.63 are similar to Steinbach et al. (2009) values of 1.39 and 0.63 for inflation and output, respectively, although they did not take into account the exchange rate depreciation in their policy rule. The weights on inflation vis-a-vis output and exchange rate depreciation reflect the fact that the SARB is more responsive towards consumer price inflation variability relative to output volatility and exchange rate depreciation. It can also be concluded that policy authorities have a lower preference for exchange rate depreciation. The computed exchange rate posterior mode weight of 0.31 is slightly higher than the median value of 0.25 computed by Alpanda et al. (2010).

Table 3: Posterior mode of policy parameters and structural innovations

	Prior			Posterior			
Par.	Distr.	5%	95%	Constant	Volatility	5%	95%
ρ_r	B	0.60	0.90	0.89	0.98	0.48	3.97
γ_1	G	2.19	5.00	1.26	1.45	0.92	2.44
γ_2	G	0.30	3.00	0.63	0.71	0.69	1.01
γ_3	G	0.30	3.00	0.34	0.31	0.69	1.01
$vol_{tp,1}2$	B	0.95	0.99	-	0.42	0.43	0.96
$vol_{tp,2}1$	B	0.95	0.99	-	0.94	0.43	0.96
$\sigma_r(vol,1)$	W	0.18	1.00	0.36	0.04	0.13	1.54
$\sigma_r(vol,2)$	W	0.23	1.00	-	0.05	0.13	1.54
$\sigma_d(vol,1)$	W	0.18	1.00	0.76	0.95	0.13	1.54
$\sigma_d(vol,2)$	W	0.27	1.00	-	1.03	0.13	1.54
$\sigma_s(vol,1)$	W	0.37	1.00	2.77	1.29	0.13	1.54
$\sigma_s(vol,2)$	W	0.87	1.00	-	1.96	0.13	1.54
$\sigma_z(vol,1)$	W	0.18	1.00	0.35	1.81	0.13	1.54
$\sigma_z(vol,2)$	W	0.23	1.00	-	0.87	0.13	1.54
$\sigma_q(vol,1)$	W	0.37	1.00	0.33	0.68	0.13	1.54
$\sigma_q(vol,2)$	W	0.87	1.00	-	0.67	0.13	1.54
$\sigma_e(vol,1)$	W	0.37	1.00	0.54	1.36	0.13	1.54
$\sigma_e(vol,2)$	W	0.87	1.00	-	1.62	0.13	1.54
$\sigma_{fi}(vol,1)$	W	0.18	1.00	0.78	1.21	0.13	1.54
$\sigma_{fi}(vol,2)$	W	0.23	1.00	-	1.43	0.13	1.54
$\sigma_{fy}(vol,1)$	W	0.18	1.00	0.57	0.68	0.13	1.54
$\sigma_{fy}(vol,2)$	W	0.23	1.00	-	0.18	0.13	1.54
$\sigma_{fr}(vol,1)$	W	0.18	1.00	0.17	0.20	0.13	1.54
$\sigma_{fr}(vol,2)$	W	0.23	1.00	-	0.18	0.13	1.54

Note: B=beta distribution, G=Gamma distribution and W=Weibull distributin. See Gelman et al. (2014) pp.11 for exposition on why some of the posterior densities may be outside the Bayesian credible intervals.

The estimated posterior mode for policy smoothing parameter (ρ_r) and its shock variances are 0.89 and 0.36 respectively. These are related to the estimates of Alpanda et al. (2010) of 0.92 and 0.24 for policy smoothing and its shock variances. The implication is that policy authorities prefer to stabilise policy rate smoothing to keep the inflation targeting regime credible. The variances of imported-cost inflation (σ_s), preference (σ_d) and foreign inflation (σ_{fi}) shocks are quite high, compared to technology (σ_z) and export (σ_e) shock variances as reported in Table 3. This may reflect the fact that the shocks hitting the South African economy are driven by import-cost inflation, preference and foreign inflation shock variances.

The volatility in structural innovations only DSGE model, herein the preferred model, is considered below. The results are displayed in column 6 of Tables 2 and 3. These results are very similar to the ones obtained in the constant DSGE model reported in column 5 of Tables 2 and 3. However, there are some important distinctions that need mention. Most of the estimated posterior modes of the structural and shock process parameters decline marginally in magnitude, with the exception of export shock, foreign inflation, foreign interest rate and preference shock processes. This may show how critical these variables have become in the design of monetary policy.

With respect to the estimated posterior mode of inverse elasticity of labour supply (ψ) is 1.18 compared to 1.65 in the constant model in Table 2. This implies that workers have to use about 0.85 more hours of their time to work when volatility increase in the economy is compared to 0.61 in the constant model. Thus, an increase in volatility of the structural innovations have negative effects on the welfare of workers in this context.

The posterior mode of the price elasticity of exports demand (δ_e) value of 0.012 suggests that at present South Africa's gold export demand is price inelastic. However, when volatility in the structural innovations are accounted for, the value increases from 0.003 to 0.012, respresenting about a 300 per cent increase. This suggests that changes in world prices of primary commodity exports contribute to major shifts in macroeconomic outcomes in emerging economies that depend on primary commodity exports. Clearly, the movements in the commodity exports price presents a challenge to the economy because of its larger effect on fiscal policy and the balance of payments.

Similarly, the commodity export shock process ρ_e of 0.99 is quite high. Since the shock process parameter is a long-lived one, it is most likely that the cost of policy stabilisation may exceed gains from policy smoothing ρ_r of 0.98. In the light of this, there is likely to be a little scope for successful implementation of policy stabilisation.

In regime 2 export shock variance ($\sigma_e(vol, 2)$) is 1.62, this is much higher relative to regime 1 export shock variance of 1.36, as shown in Table 3. This evidence suggests that the primary commodity export sector may have an important role to play in the design of monetary policy in emerging economies. This study reveals that one of the main drivers of shocks variances hitting the economy is the primary commoditiy export shock. What is more, is that it can be deduced that the constant DSGE model may pick up some of the shock variances emanating from primary commodity export shocks leading to bias conclusions.

Regarding the policy parameters of inflation, output, and exchange rate depreciation, the values are slightly higher compared to the constant DSGE model estimates, except the exchange rate. The weights are 1.45, 0.71 and 0.31 for inflation (γ_1), output (γ_2) and exchange rate (γ_3), respectively. It is proposed here that when volatility increases in the structural innovations, policy authority pays more attention to inflation and output relative to the exchange rate. This is to ensure that policy authority does not deviate from its policy objectives of stable inflation and output growth.

The estimated posterior mode of the interest rate smoothing (ρ_r) is 0.98, slightly higher than what has been observed in the South African economy. This suggests that when the economy experiences high volatility in structural shocks, policy authorities either engage in smoothing the interest rate to keep the financial markets sound instead of either explicitly targeting the exchange rate or intervening in the activity of the foreign exchange market. It is thus suggested that when volatility increases, policy authorities are willing to combine price stability with financial stability (see also Clarida et al. (1999) and Woodford (2003) for the reasons why a central bank may smoothing the interest rates). However, the variances of the policy shock $\sigma_r(vol, 1)$ reduced from 0.36 in the constant DSGE to 0.04 in regime 1 and 0.05 in regime 2. This implies that an increase in volatility makes monetary policy less effective. The conclusion here is that the effects of policy shocks is clearly weaker when the economy experiences a rise in volatility of the structural shocks. The evidence given as shown above, there is little support for this view in the literature discussed earlier that monetary policy is important in influencing the level of aggregate variables in the economy.

Finally, the estimated posterior mode variances for the transition probabilities of regime 2 is quite high. In regime 2 ($vol_{tp,2}$), that is, the high volatility state has estimated posterior mode of 0.95 is substantially larger compared to regime 1 ($vol_{tp,1}$) variance of 0.42. This shows that the responses of policy authorities to inflation and output are high in regime 2 compared to regime 1, which also suggests that policy authority prefers to remain longer in the inflation targeting regime compared to the monetary aggregates regime.

5.3 Smoothed Transition Probabilities

The top panel of Figure 2 in Appendix B shows the smoothed transition probabilities for high volatility state in regime 2. Thus two major high volatility states in the South African economy are identified for the periods 1981 to 1985 and 2008 to 2010. From 1981 to 1985, the South African economy experienced the longest period ever of high macroeconomic volatility. The high volatility regime coincided with gold price shock, poor sovereign risk rating, trade and financial sanctions that adversely affected the economy over the period 1981 and 1985. Similarly, the high volatility regime is consistent with the SARB estimates of downswing business cycle phases that lasted about 40 months between 1981 and 1986. The second major shift was in 2008, when the global economy experienced the financial crisis. This suggests that the South African economy is financially integrated into the global economy, therefore, major global events are likely to affect the domestic economy.

A critical observation of the top panel of Figure 2 shows that there are many short periods of high macroeconomic volatility. These short period volatilities coincided with domestic events in the economy, such as large capital outflows towards the run up to the 1994 election and over the period 2001 to 2002, when the economy witnessed an exchange rate depreciation of over 30 per cent.

The bottom panel of Figure 2 shows the low monetary policy response state in regime 2 on a macroeconomic condition index. Thus policy switched from a high monetary policy regime to a low monetary policy regime from 1985 until 2003. This suggests that the actual conduct of monetary aggregates regime ended in 2003, according to the plot in the bottom panel of Figure 2. Besides, this implies that the effect of monetary policy responses to macroeconomic condition index is low, beginning 2003. Following this, the policy authority switched from responding more towards a marcoeconomic condition index, such as the exchange rate in 2003, to responding more to inflation and output stability after the adoption of an inflation targetiing regime.

5.4 Robustness Check

The aim of this subsection is to evaluate the robustness of the baseline model used here in relation to two alternative specifications as reported in Figure 4, for the baseline model might not be parsimonious as described by the data. First, gold exports are replaced with merchandise exports, in that they capture heterogenous clusters of primary commodity exports. Secondly, the baseline model is restricted similar to Justiniano and Preston (2010), in case the primary commodity export shock biases these baseline results.

Table 4: Robustness check: Statistics for model comparison

	BIC	AIC_c	Log-MDD	Log-posterior	Log-like	Log-prior
MEX	6416.20	6326.37	-3398.25	-3098.98	-3023.97	-75.01
REM	3826.86	3740.65	-2010.87	-1814.23	-1721.64	-92.59
Vol	3694.32	3584.26	-1926.40	-1738.04	-1679.07	-58.97

Note: MEX=merchandise exports and assume the structural shocks are regime switching. REM=restricted model, that is, the original model of Justiniano and Preston (2010) and assume the structural shocks are regime switching, Vol=volatility only in the structural shocks are regime switching.

The two alternative specifications reveal that the model with volatility in structural shocks only fit the data better. The models' selection criterion is compared with the baseline model, as reported in Table 4. The three criteria, namely AIC_c, BIC and log-MDD, show that the chosen baseline model outperforms the other two specifications. Most of the parameter estimates of the two alternative specifications are displayed in Tables 7 and 8 in Appendix B B. These are very similar to these baseline estimates with few variations in the estimates although there are huge differences in the the transition probabilities and shock variances.

5.5 Evolution of Macroeconomic Outcomes in the South African Economy

The generalised dynamic responses, variance and historical decompositions of the volatility in structural shocks DSGE model are used in this section to evaluate the performance of the South African economy. It is only observed domestic variables relevant to this study that are examined to keep the discussion brief.

5.5.1 Generalised Dynamic Responses

To characterise the macroeconomic outcomes of the South African economy, the generalised dynamic responses are investigated in this section. A one standard deviation of a policy shock, as reported in the first block of Figure 3, generates about 0.2 per cent decline in real consumption and this leads to about 0.1 per cent decline in output growth. As output growth declines, it slows down increases in consumer price inflation by about 1.5 per cent and gradually decay within 3 quarters. This transmission is consistent with inflation targeting principles in that once policy authority adjusts the policy rate, investments decline and this leads to a decline in output growth and slows inflationary pressures. It is also found that a policy shock transmits about 2 per cent to exchange rate appreciation and this results in about 0.4 per cent fall in import cost inflation.

Regarding export shock reported in the last block of Figure 3, a one standard deviation of export shock results in about 0.007 per cent reduction in policy rate. This transmits approximately a 1.8 per cent increase in gold export, which translates to about a 0.03 per cent output growth. This means that a reduction in policy rate serves as an incentive for a lower cost of gold extraction and raises gold revenues, which in turn boost output growth.

A positive risk premium shock, as shown in the first block of Figure 4, is followed by more than a 5 per cent to exchange rate depreciation. This translates into an about 1 per cent increase in import-cost inflation. The effect on import-cost inflation gradually decays within 12 quarters, which generates an about 0.2 per cent slowdown in consumer price inflation. This improves on the terms of trade by about 2.5 per cent and also provides a marginal increase in output growth. With respect to import-cost inflation as shown in the last block of Figure 4, a one standard deviation leads to an about 0.1 per cent increase in policy rate. This further generates an about 2 per cent decline in real household consumption and leads to an about 0.2 per cent reduction in output growth. This follows a consumer price inflation increase of about 4 per cent.

It is found that a one standard deviation to a preference shock in the first block of Figure 5 generates an about 2 per cent increase in real household consumption, which stabilises within 12 quarters. This increases output growth by about 1 per cent and leads to a 2 per cent increase in consumer price inflation. The preference shock also leads to exchange rate appreciation by about 2 per cent, which generates a decline in gold exports by about 0.15 per cent. A technology shock in the last block of Figure 5 transmits a positive response to gold exports. It has, however, a depreciating effect on consumer price inflation. The responses to real consumption and nominal effective exchange rate depreciation are lower.

It is worth mentioning that import-cost inflation, risk premia and export shocks have a larger impact on macroeconomic movements compared to monetary policy shock.

5.5.2 Counterfactual Dynamic Responses

Because this work is interested in the responses of each regime, regime 1 and regime 2 are compared with respect to policy, exports, import-cost inflation and risk premia shocks to isolate the effects of the dynamics of each regime.

In the first and last blocks of Figure 6, policy responses in regime 1 and regime 2 are compared. The policy responses in regime 2 is much larger relative to the responses in regime 1 by about 0.3 per cent for inflation and output. This implies that in regime 2 policy authority is much more concerned with inflation and output stability relative to regime 1, and this is also supported by the estimates in Table 3. Similarly, the first and last blocks of Figure 7 show the responses to export shock regimes. In regime 2, export shocks have relatively larger effect on inflation and output, exchange rate and gold exports compared to policy rate, while in regime 1 export shocks have larger effects on policy rate. This suggests that in regime 2—an inflation targeting regime—minimal shocks from export shocks may have helped the conduct of monetary policy relative to regime 1, which is a monetary aggregates regime.

Figure 8 shows the import-cost inflation regimes. Regime 1 shows higher pass-through effects of import cost inflation relative to regime 2. This suggests that the exchange rate pass-through to import prices then to consumer price inflation has been well managed in an inflation targeting regime as compared to a monetary targeting regime. Important evidence is given in the risk premia regimes as reported in Figure 9. This shows that the effect of risk premia shocks and its volatility remain relatively the same in inflation targeting and monetary aggregates regimes. This suggests that the two regimes are less effective in helping to reduce risk premia shocks in the economy.

5.5.3 Variance Decompositions

To understand the relative importance of each variable to another at each forecast horizon and thus the extent of their interaction over a particular forecast horizon, the variance decompositions are evaluated and the estimates in Figure 10 through to Figure 12 are reported upon.

In the left panel of Figure 10, the variance decomposition of the policy rate shows that technology and import-cost shocks are the main contributors to policy rate volatility. In the long run, the size of import-cost inflation is larger relative to a technology shock. One striking finding is that monetary policy shock variances have barely no impact on policy rate, as reported in the left panel of Figure 10. The variance decomposition of consumer price inflation in the right panel of Figure 10 reveals that technology and import cost inflation shocks drive consumer price inflation volatility, but policy shock remains small in consumer price inflation volatility. This result is consistent with the real business cycle thesis in which technology shock is the main driver of volatility in an economy. This suggests that in an inflation targeting regime, policy authority should pay attention to technology and import-cost inflation because of their larger effects on the inflation and policy rate.

Regarding the variance decomposition of output gap in the left panel of Figure 11, preference shock is the main driver of output gap volatility. Although import-cost inflation, risk premia and technology shocks have a slight effect on output gap volatility, monetary policy shock variances do not affect output gap. A similar pattern is exhibited in the real consumption in the right panel of Figure 11. However, import-cost inflation contributes relatively larger volatility to real consumption in the long run compare to output gap growth.

Gold exports in the left panel of Figure 12, show that monetary policy, risk premia and foreign shocks do not have significant impact on gold exports volatility. Instead, export, import-cost inflation and technology shocks are the main contributors to gold exports variability. With regards to exchange rate variable in the right panel of Figure 12, the main contributor to exchange rate variability is the risk premia shock. Moreover, changes in policy shock has smaller effect on exchange rate depreciation relative to risk premia shock. This implies that on average, the short-term interest rate in South Africa is relatively higher as compared to foreign investor country and thus generates excess returns for investors.

In conclusion, the results of the variance decompositions suggest that the major drivers of macroeconomic volatility in the South African economy are import-cost inflation, technology changes, commodity exports and preference changes. These findings seem to be consistent with South Africa, an emerging economy with a volatile currency that experiences volatile portfolio flows and went through financial market liberalisation, and is thus susceptible to adverse exchange rate shocks. Moreover, the majority of its exports are primary commodities and a large component of its imports are usually manufactured goods. Further, the South African currency was one of the most important currencies of emerging economies over the period 1998 to 2013 and usually has a trade ranking between the top 10 and top 20 in the currencies distribution of global foreign exchange market turnover.[13]

5.5.4 Historical Decompositions

The historical decompositions are analysed to help identify the role played by the shocks in the movements of domestic observed variables.

[13]See Bank for International Settlement preliminary global results on the Triennal Central Bank Survey Foreign exchange turnover in April 2014. South Africa also has the most developed financial markets in sub-Saharan African and a higher financial development index that is of higher ranking relative to even some developed and emerging economies such as Italy, Poland, Brazil, Chile and Russia, among others. This can be found in the World Economic Forum Financial Development Ranking Report 2012.

The left panel of Figure 13 shows a different contribution of shocks to movements in policy rate. From 1982 to 1990, import cost inflation and export shocks subtracted from the policy rate. This meant that the economy was saddled with structural bottlenecks, such as a high desire for imported goods and weak export promotion relative to demand management policies. In 2000 and 2003, however, it became modest, for this trend was reversed during the global financial crisis until 2016, contributing positively to policy rate movements. In the mid 1990s to 2016, export and preference shocks made a positive contribution to upward movements in policy rate. Risk premia and technology shocks accounted for a positive contribution to policy rate movements in the 1980s until 1994. But this trend was reversed from the beginning of 1999 to 2016, as risk premia and technology shock made a negative contribution to the policy rate. This suggests that an increase in technology and capital inflows lead to output growth.

Regarding consumer price inflation reported in the right panel of Figure 13, the main driver of movements in consumer price inflation is import-cost inflation shock. In the mid 1980s, import-cost inflation shock showed a negative effect on consumer price inflation. However, from 1986 to 2008, it showed persistent upswings and downswings in the movements of consumer price inflation. After the global financial crisis of 2008, the swings continued but with less pass-through to consumer price inflation. This may suggest that lower import cost inflation to consumer price inflation can in part be attributed to trade integration of the South African economy. However, policy shock has a neglible effect on consumer price inflation.

Prior to 1999, import cost inflation and risk premia shocks positively contributed to output growth movements but remained modest between 1999 to 2005, as reported in the left panel of Figure 14. Afterwards this trend is reversed, where import cost inflation and risk premia shock contribute negative to output growth. Similarly, preference shocks contributed negative to output growth beginning in 1991 until 1997. From 2008 to 2016, technology and preference shocks contributed positive to output growth, whereas risk premia and import cost inflation substracted from output. These findings suggest that downward movements in import-cost inflation and risk premia and upward movements in technology and preference changes can stimulate the economy, even to holding policy rate constant. A similar trend is observed in the real household consumption, as reported in the right panel of Figure 14. However, import-cost inflation has a larger effect on real household consumption.

With respect to gold exports shown in the left panel of Figure 15, import-cost inflation and technology shocks contributed negatively to gold exports movements from 1981 to 2008. Beginning in 2008, import-cost and technology shocks had a positive effect on gold exports movements. Likewise, risk premia, exports and preference shocks contribute positively to gold export growth from 1998 to 2010, while from 2003 risk premia and export shocks made a negative contribution to gold exports movements. The right panel of Figure 15 reports the movements in exchange rate depreciation. This shows that from 2008 until 2016, import-cost inflation, export, and risk premia subtracted from exchange rate depreciation, whereas technology shock positively impacted on real exchange rate.

To sum up, it is found that import cost inflation, risk premia, technology, preference, and export shocks are the main drivers in the movements of macroeconomic variables in the South African economy. Therefore, it is proposed that the policy authority should endeavour to identify the sources that contribute to macroeconomic fluctuations. Once the sources are identified, then policy authority is advised to understand the effects of the underlying factors more broadly instead of paying attention to changes in the monetary policy rule only.

6 Conclusion

In macroeconomic modeling, the importance of establishing the sources that account for economic fluctuations has always been underscored. In this paper, therefore, empirical evidence of some of the likely sources of macroeconomic volatility is provided. The primary commodity export sector shock is thus allowed to follow a regime switching process and carry out Bayesian inference in a Markov-switching dynamic stochastic general equilibriun model. The present findings suggest that constant dynamic stochastic general equilibrium model results are very similar to the evidence in the literature with slight variations. Whereas in the volatility in structural innovations only model, some of the estimated posterior modes of the structural and shock processes fall marginally, exports, import-cost inflation, technology and preference shock persistence are high. This indicates that these shock processes have relatively long-lived effects on macroeconomic outcomes in emerging economies.

In addition, the estimated policy parameters reveal that policy authority responses to inflation is significant relative to output and exchange rate depreciation. Two major high macroeconomic volatilities are identified in the transition probabilities that coincide with the movements in the observed variables and the business cycle phases in the South African economy. Another finding shows that a monetary policy shock decreases the output gap, but has a negligible effect on consumer price inflation. In historical and variance decompositions, import-cost inflation shock, preference shock, technology shock, risk premia and export shocks are the main drivers of economic performance in the domestic economy. In short, the model with the primary commodity export sector coupled with volatility in structural shocks better explain macroeconomic dynamics in an emerging economy as compared to alternative experiements.

Of course this study is not conclusive, the transition probabilities of the switching parameters are time-invariant, that is, subject to critique. This, therefore, requires that the switching parameters are endogenised. Moreover, future research along these lines is needed to understand how these models work and interact to shape monetary policy conduct in the South African economy and similar emerging economies.

Appendices

A Model Equations

Table 5: Rest of model equations fitted to data

Description	Equation
Terms of trade	$s_t = s_{t-1} - \pi_t^h + \pi_t^f$
Exchange rate depreciation	$\Delta e_t = q_t - q_{t-1} + \pi_t - \pi_t^{fi}$
CPI inflation	$\pi_t = (1-\alpha)\pi_t^h + \alpha\pi_t^f$
Net foreign assets	$nfa_t = \frac{1}{\beta} nfa_{t-1} - \alpha(q_t + \alpha s_t) + y_t - c_t$
Shock processes	
Export shock	$ze_t = \rho_e ze_{t-1} + \sigma^{ee}$
Preference shock	$zd_t = \rho_d zd_{t-1} + \sigma^{ed}$
Import cost shock	$zs_t = \rho_e zs_{t-1} + \sigma^{es}$
Technology shock	$zp_t = \rho_z zp_{t-1} + \sigma^{ep}$
Risk premia shock	$zq_t = \rho_q zq_{t-1} + \sigma^{eq}$
Foreign inflation shock	$\pi_t^{fi} = \rho_{fi}\pi_{t-1}^{fi} + \sigma^{efi}$
Foreign output shock	$y_t^{fy} = \rho_{fy} y_{t-1}^{fy} + \sigma^{efy}$
Foreign interest rate shock	$r_t^{fr} = \rho_{fr} r_{t-1}^{fr} + \sigma^{efr}$

Table 6: Parameters and variables description

Parameter	Description	Variable	Description
δ_e	Price elasticity of export demand	xe_t	Export demand
α	Share of foreign goods in consumption	y_t^{fy}	Foreign output gap
ω	Elasticity of sub betw. home and foreign goods	pw	Relative price of exports
δ_h	Price index for home-produced goods	π_t	CPI inflation
δ_f	Price index for foreign-produced goods	s_t	Terms of trade
β	Subjective discount factor	c_t	Final household consumption
ϕ_h	Price adjustment cost for home-produced good	r_t	Policy rate
ϕ_f	Price adjustment cost for foreign-produced good	y_t	Output gap
ψ	Inverse elasticity of labour supply	q_t	Real exhange rate
κ	Debt elast. w.r.t. interest rate risk premia	e_t	Nominal exchange rate
τ	Inverse elasticity of intertemporal substitution	π^f	Import cost inflation
γ_1	Weight on inflation param.	π^h	Domestic inflation
γ_2	Weight on output param.	π^{fi}	Foreign inflation
γ_3	Weight on changes in exchange rate	nfa_t	Net foreign assets
ρ_r	Policy rate smoothing param.	ze_t	Export demand shock process
ρ_e	Persistence param. for export shock	zd_t	Preference shock process
ρ_d	Persistence param. for preference shock	zp_t	Technology shock process
ρ_s	Persistence param. for imported inflation shock	zs_t	Import-cost shock process
ρ_z	Persistence param. for technology shock		
ρ_q	Persistence param. for risk premia shock	zq_t	Risk premia shock process
ρ_{fi}	Persistence param. for foreign inflation shock	σ^{er}	Policy shock
ρ_{fy}	Persistence param. for foreign output shock	σ^{ed}	Preference shock
ρ_{fr}	Persistence param. for foreign interest rate shock	σ^{ep}	technology shock
σ^{ee}	Standard deviation of export shock	σ^{es}	Import cost shock
σ^{ed}	Standard deviation of preference shock	σ^{eq}	Risk premium shock
σ^{es}	Standard deviation of import-cost shock	σ^{ee}	export demand shock
σ^{ep}	Standard deviation of technology shock	σ^{efi}	foreign inflation shock
σ^{eq}	Standard deviation of risk premia shock	σ^{efy}	foreign output shock
σ^{efi}	Standard deviation of foreign inflation shock	σ^{efr}	foreign interest rate shock
σ^{efy}	Standard deviation of foreign output shock	λ	Habit formation
σ^{efr}	Standard deviation of foreign interest rate	r_t^{fr}	Foreign interest rate

B Estimation Results

Table 7: Robustness check: Posterior mode of structural and shock processes

	Prior			**Posterior Mode**						
Par.	Distr.	5%	95%	VolPolSame	VolPolInd	Polonly	MEX	REM	5%	95%
λ	G	0.54	1.50	0.31	0.49	0.04	0.32	0.62	0.06	4.59
τ	G	0.54	1.50	0.11	0.49	1.05	0.67	1.93	0.06	4.59
α	G	0.54	1.50	0.12	0.41	0.09	0.14	0.05	0.06	4.59
ω	G	0.54	1.50	1.04	0.51	1.86	0.97	1.64	0.06	4.59
β	B	0.10	2.00	0.09	0.10	0.14	0.05	0.22	0.18	3.94
ϕ_h	G	0.58	1.00	0.003	0.003	0.013	0.002	0.001	0.25	1.58
ϕ_f	G	0.58	1.00	0.84	0.48	0.83	0.61	0.98	0.25	1.58
δ_h	G	0.54	1.50	0.19	0.36	0.11	0.29	0.22	0.06	4.59
δ_f	G	0.54	1.50	0.24	0.39	0.003	0.01	0.02	0.06	4.59
δ_e	G	0.54	1.50	0.05	0.12	0.004	005	-	0.06	4.59
ψ	G	0.54	1.50	0.22	0.36	0.49	1.12	1.19	0.06	4.59
κ	G	0.05	1.50	0.11	0.43	0.002	0.13	0.001	0.001	1.58
ρ_d	B	0.05	0.90	0.81	0.78	0.89	0.84	0.88	0.28	8.97
ρ_s	B	0.05	0.90	0.71	0.83	0.85	0.87	0.47	0.28	8.97
ρ_z	B	0.05	0.90	0.73	0.74	0.87	0.93	0.90	0.28	8.97
ρ_q	B	0.05	0.90	0.99	0.89	0.91	0.97	0.93	0.28	8.97
ρ_e	B	0.05	0.90	0.99	0.97	0.99	0.34	-	0.28	8.97
ρ_{fi}	B	0.05	0.90	0.46	0.58	0.25	0.58	0.61	0.28	8.97
ρ_{fy}	B	0.05	0.90	0.47	0.59	0.89	0.99	0.62	0.28	8.97
ρ_{fr}	B	0.05	0.90	0.42	0.51	0.27	0.43	0.98	0.28	8.97

B=Beta distribution, G=Gamma distribution, See Gelman et al. (2014) pp.11 for exposition on why some of the posterior densities are outside the Bayesian credible intervals. VolPolSame=structural shocks and policy parameters are simultanteous regime switching. VolPolInd=structural shocks and policy parameters switch independent. PolOnly=policy parameters and shocks only are regime switching, MEX=merchandise exports with regime switching. REM=restricted model that is the original model of Justiniano and Preston (2010).

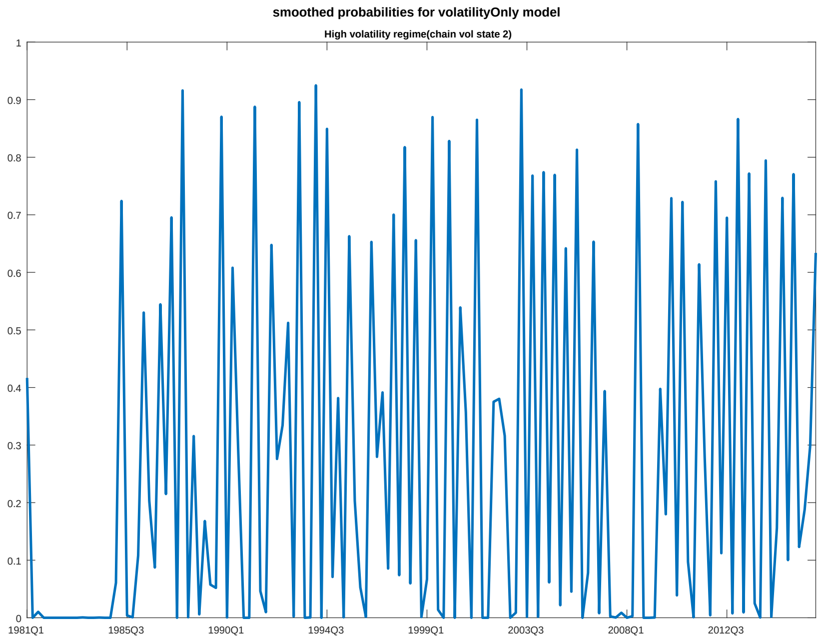
Table 8: Robustness check: Posterior mode of policy parameters and structural innovations

	Prior			**Posterior Mode**						
Par.	Distr.	5%	95%	VolPolSame	VolPolInd	PolOnly	MEX	REM	5%	95%
ρ_r	B	0.6	0.90	0.40	0.52	0.99	0.68	0.94	3.47	8.97
$\gamma_1(vol,1)$	G	2.19	5.00	1.64	1.92	2.16	3.15	5.94	0.92	2.44
$\gamma_1(vol,2)$	G	0.77	5.00	0.39	0.34	2.05	-	-	0.92	2.44
$\gamma_2(vol,1)$	G	0.30	3.00	0.14	0.27	0.16	0.31	0.70	0.69	1.01
$\gamma_2(vol,2)$	G	0.17	3.00	0.25	0.15	0.00	-	-	0.69	1.01
$\gamma_3(vol,1)$	G	0.30	3.00	0.20	0.26	0.26	0.002	0.00	0.69	1.01
$\gamma_3(vol,2)$	G	0.17	3.00	0.25	0.15	0.00	-	-	0.69	1.01
$vol_{tp,1}2$	B	0.95	0.99	0.71	0.949	-	0.95	0.15	0.43	0.96
$vol_{tp,2}1$	B	0.95	0.99	0.75	0.949	-	0.20	0.04	0.43	0.96
$coefl_{tp,1}2$	B	0.95	0.99	-	0.948	0.00	-	-	0.43	0.96
$coefl_{tp,2}1$	B	0.95	0.99	-	0.949	0.00	-		0.43	0.96
$\sigma_r(vol,1)$	W	0.18	1.00	0.12	0.14	0.03	0.77	0.37	0.13	1.54
$\sigma_r(vol,2)$	W	0.23	1.00	0.21	0.23	-	0.77	1.05	0.13	1.54
$\sigma_d(vol,1)$	W	0.18	1.00	0.14	0.17	0.70	0.30	0.001	0.13	1.54
$\sigma_d(vol,2)$	W	0.27	1.00	0.33	0.27	-	0.93	1.16	0.13	1.54
$\sigma_s(vol,1)$	W	0.37	1.00	0.21	0.31	2.71	0.001	6.32	0.13	1.54
$\sigma_s(vol,2)$	W	0.87	1.00	0.97	0.74	-	8.57	9.36	0.13	1.54
$\sigma_z(vol,1)$	W	0.18	1.00	0.14	0.18	1.52	1.81	0.14	0.13	1.54
$\sigma_z(vol,2)$	W	0.23	1.00	0.35	0.30	-	0.37	0.48	0.13	1.54
$\sigma_q(vol,1)$	W	0.37	1.00	0.22	0.32	1.18	0.003	0.003	0.13	1.54
$\sigma_q(vol,2)$	W	0.87	1.00	0.66	0.85	-	3.94	1.04	0.13	1.54
$\sigma_e(vol,1)$	W	0.37	1.00	0.22	0.28	1.90	0.006	-	0.13	1.54
$\sigma_e(vol,2)$	W	0.87	1.00	0.65	1.20	-	5.47	-	0.13	1.54
$\sigma_{fi}(vol,1)$	W	0.18	1.00	0.14	0.16	1.78	0.42	37.38	0.13	1.54
$\sigma_{fi}(vol,2)$	W	0.23	1.00	0.25	0.20	-	1.13	0.66	0.13	1.54
$\sigma_{fy}(vol,1)$	W	0.18	1.00	0.13	0.15	0.72	0.09	0.38	0.13	1.54
$\sigma_{fy}(vol,2)$	W	0.23	1.00	0.16	0.20	-	0.46	0.70	0.13	1.54
$\sigma_{fr}(vol,1)$	W	0.18	1.00	0.13	0.15	0.18	1.04	0.07	0.13	1.54
$\sigma_{fr}(vol,2)$	W	0.23	1.00	0.16	0.21	-	0.18	0.14	0.13	1.54

MEX=merchandise exports with regime switches; REM= the original model of Justiniano and Preston (2010); VolPolSame=structural shocks and policy parameters switches; VolPolInd=structural shocks and policy parameters switch independent. PolOnly=policy parameters switches only.

Figure 2: Smoothed transition probabilities

Note: Top panel is high volatility in regime 2 and bottom panel is low monetary policy response in regime 2



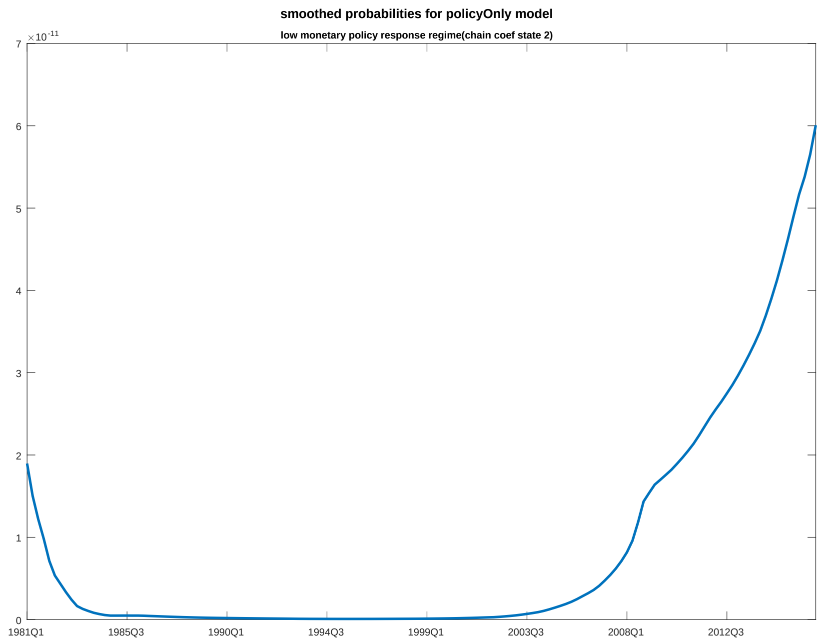
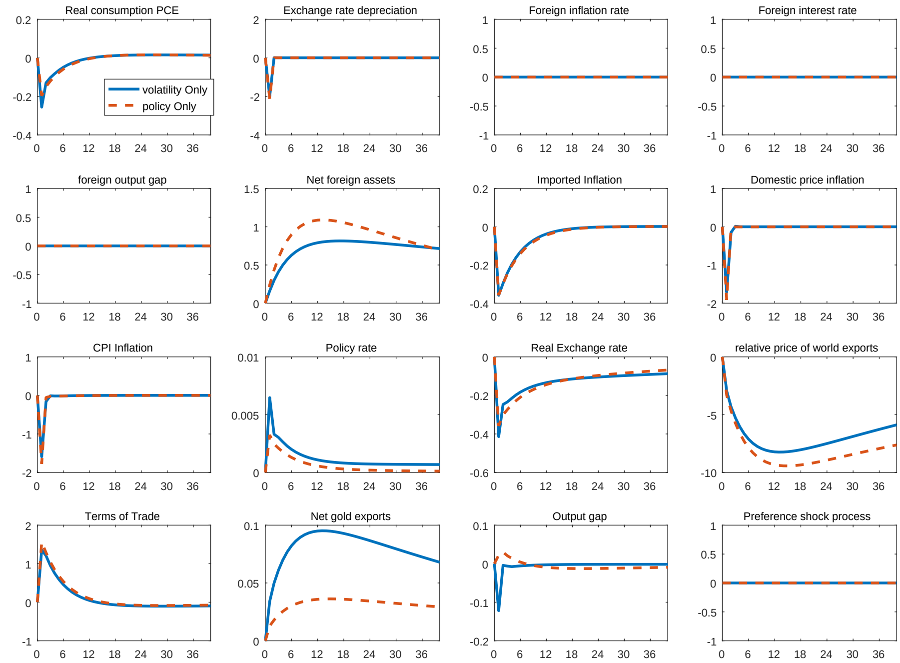


Figure 3: Dynamic responses to policy and export shocks

Note: First block is a policy shock and last block is an export shock



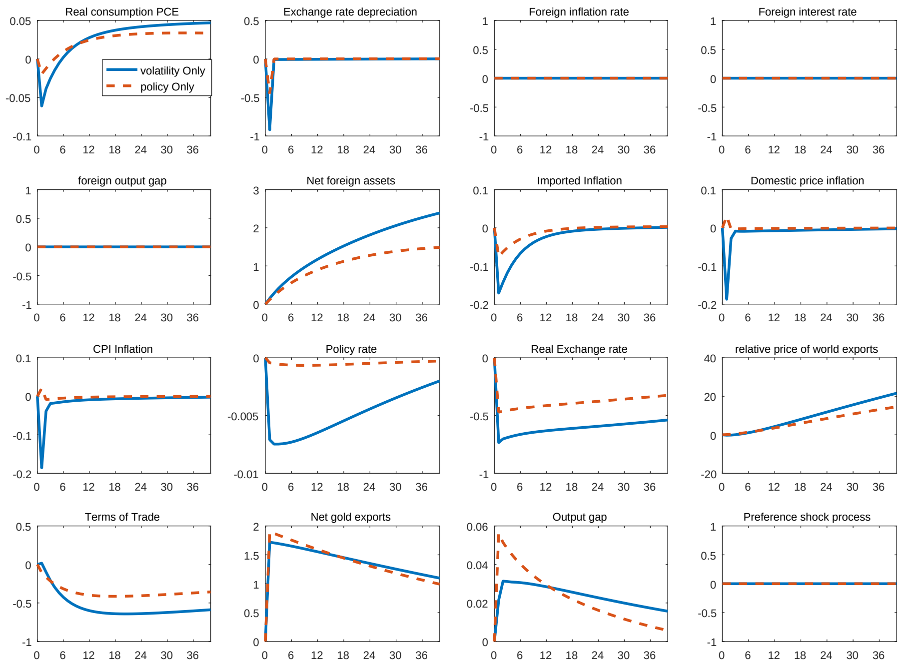


Figure 4: Dynamic responses to risk premia and import-cost inflation shocks

Note: First block is a risk premia shock and last block is an import cost inflation shock

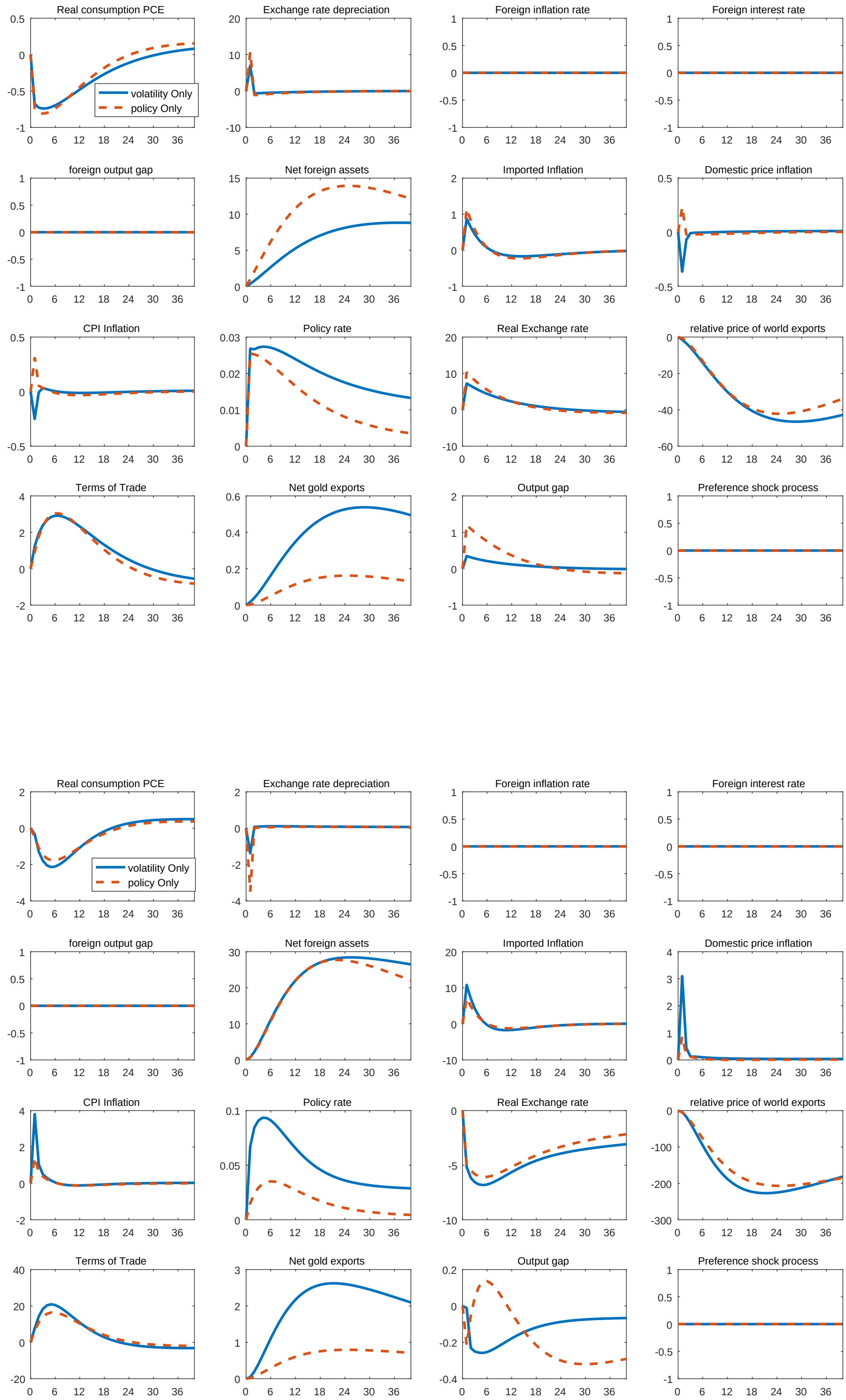


Figure 5: Dynamic responses to preference and technology shock

Note: First block is a preference shock and last block is a technology shock

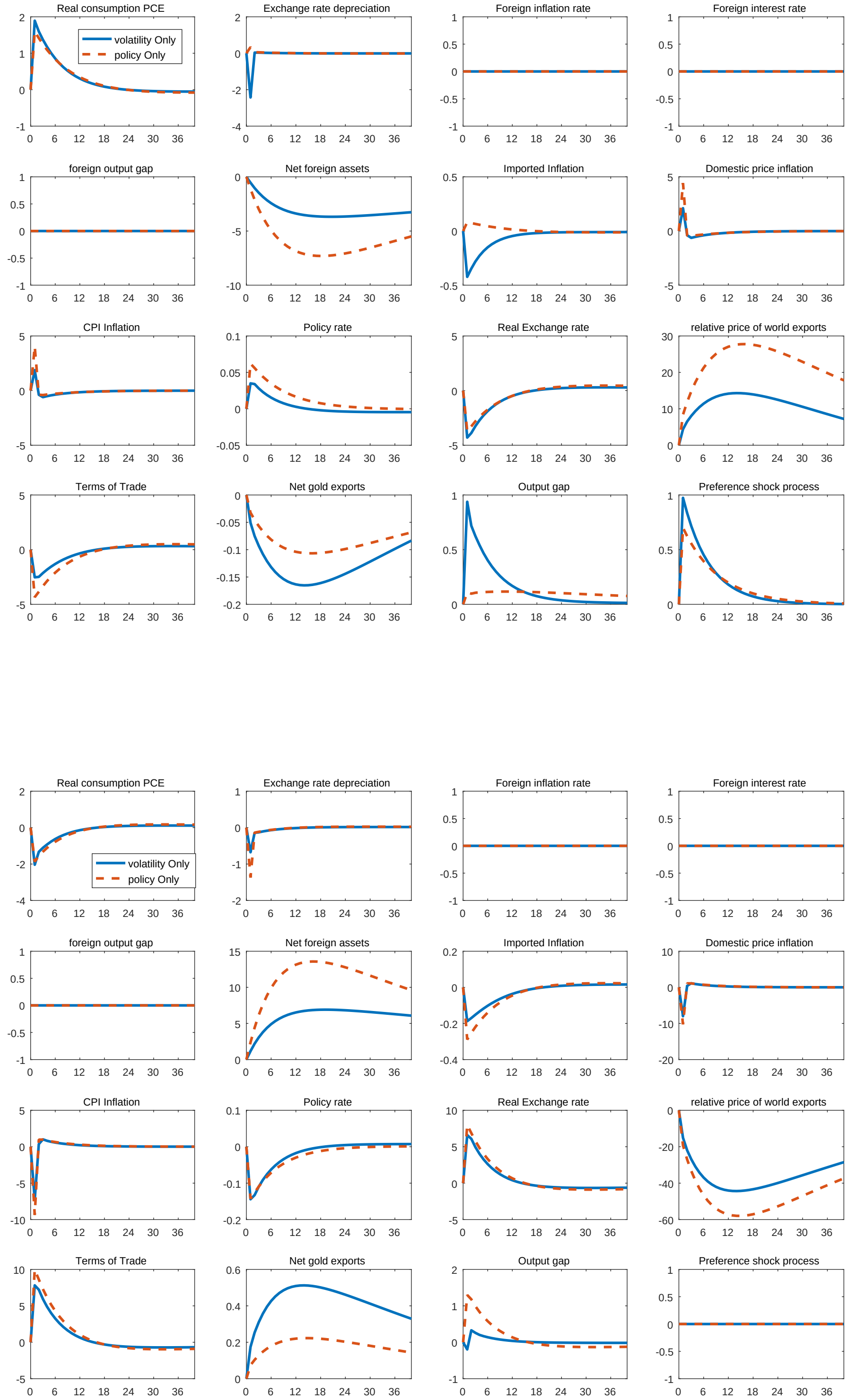


Figure 6: Dynamic responses to monetary policy regimes

Note: First block is regime 1 and last block is regime 2

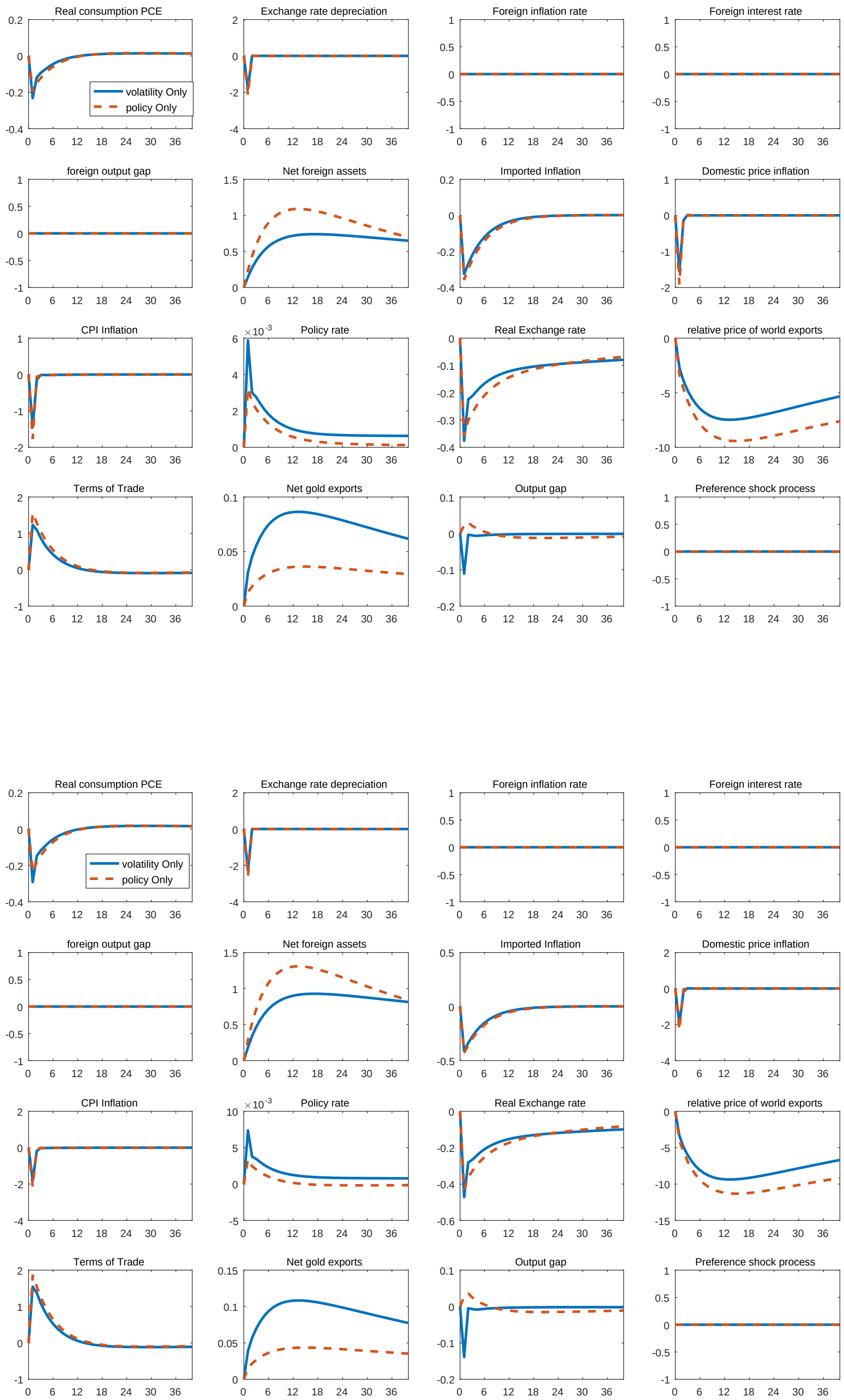


Figure 7: Dynamic responses to export shock regimes

Note: First block is regime 1 and last block is regime 2

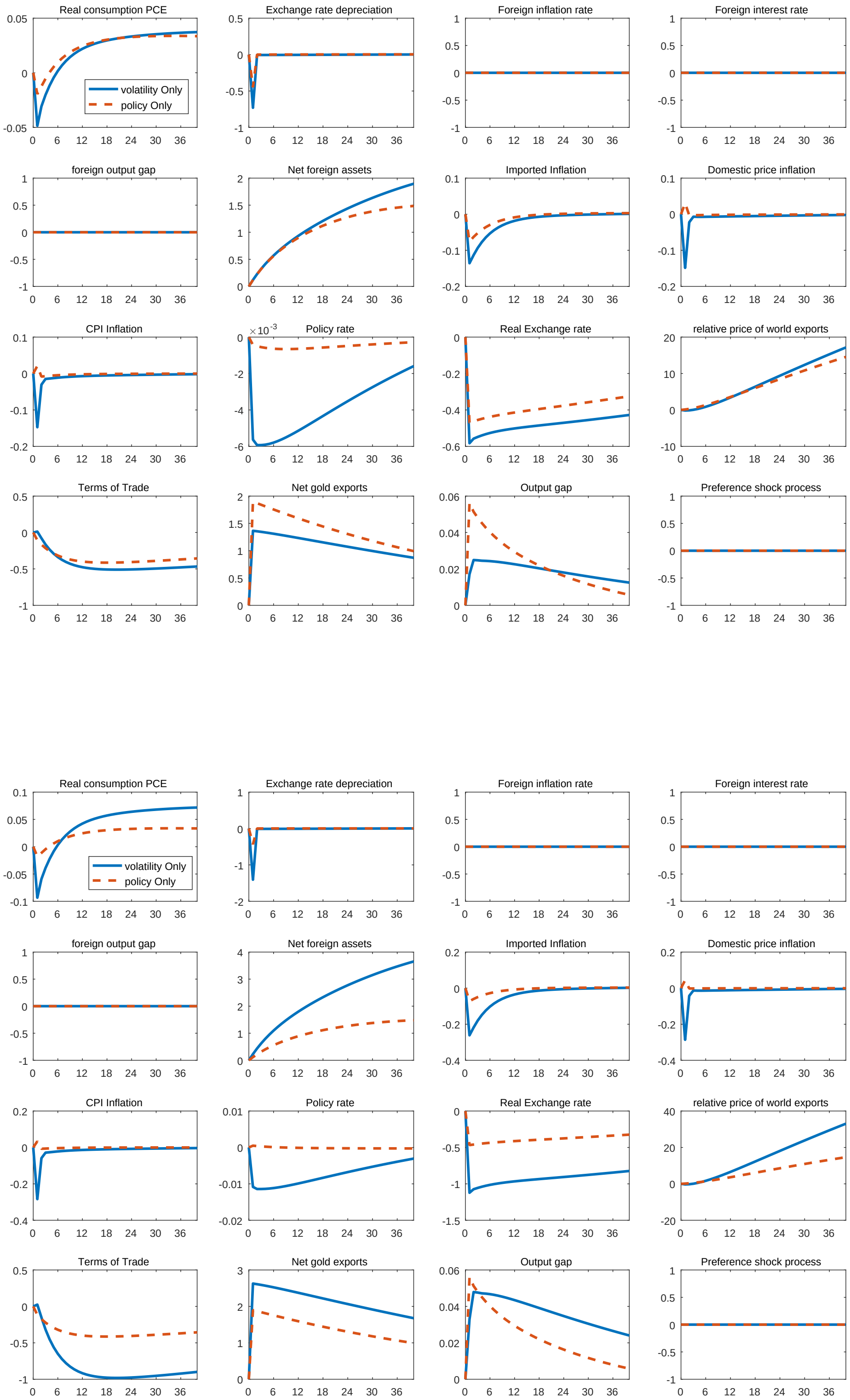


Figure 8: Dynamic responses of import-cost inflation regimes

Note: First block is regime 1 and last block is regime 2

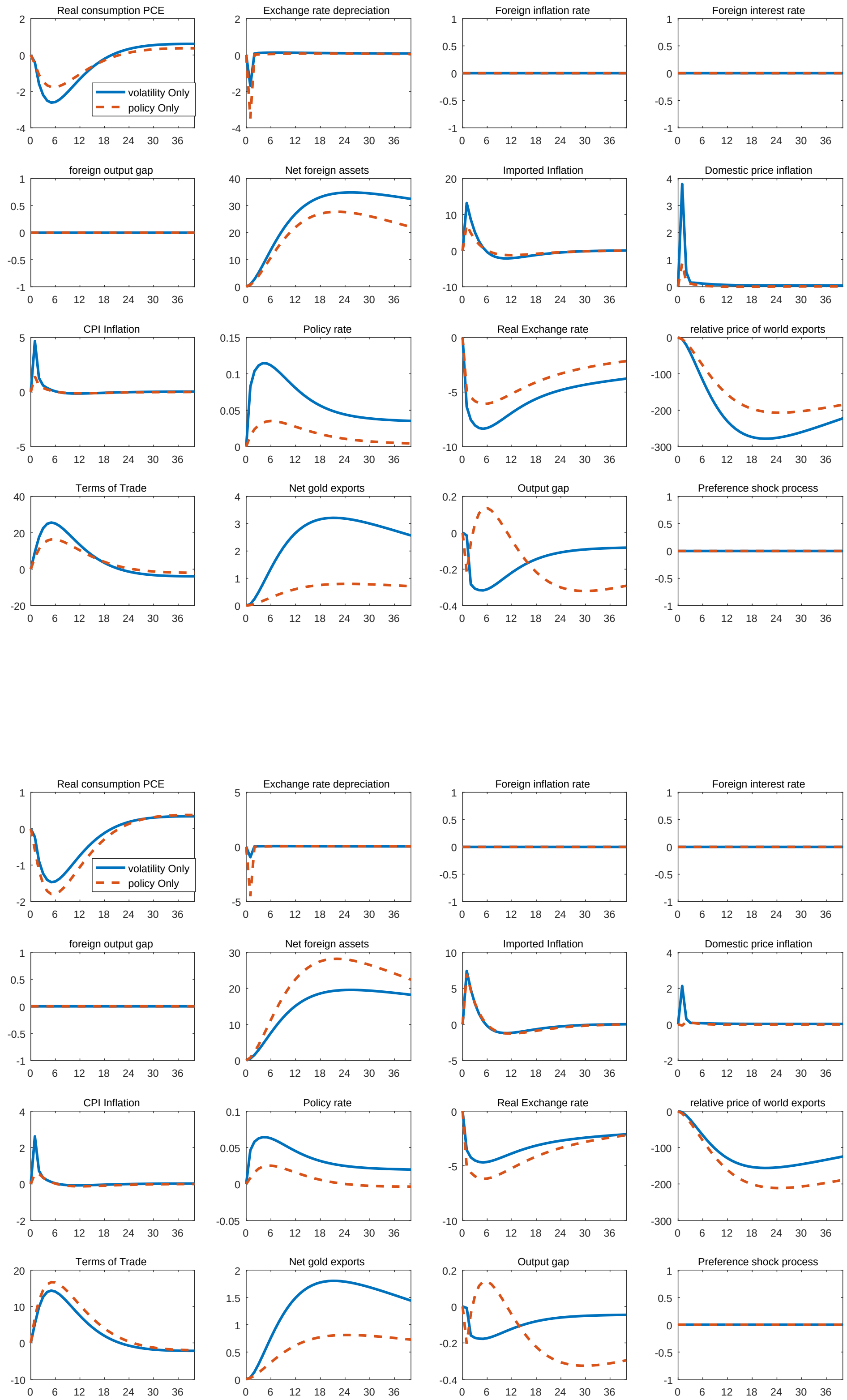


Figure 9: Dynamic responses of risk premia regimes

Note: First block is regime 1 and last block is regime 2

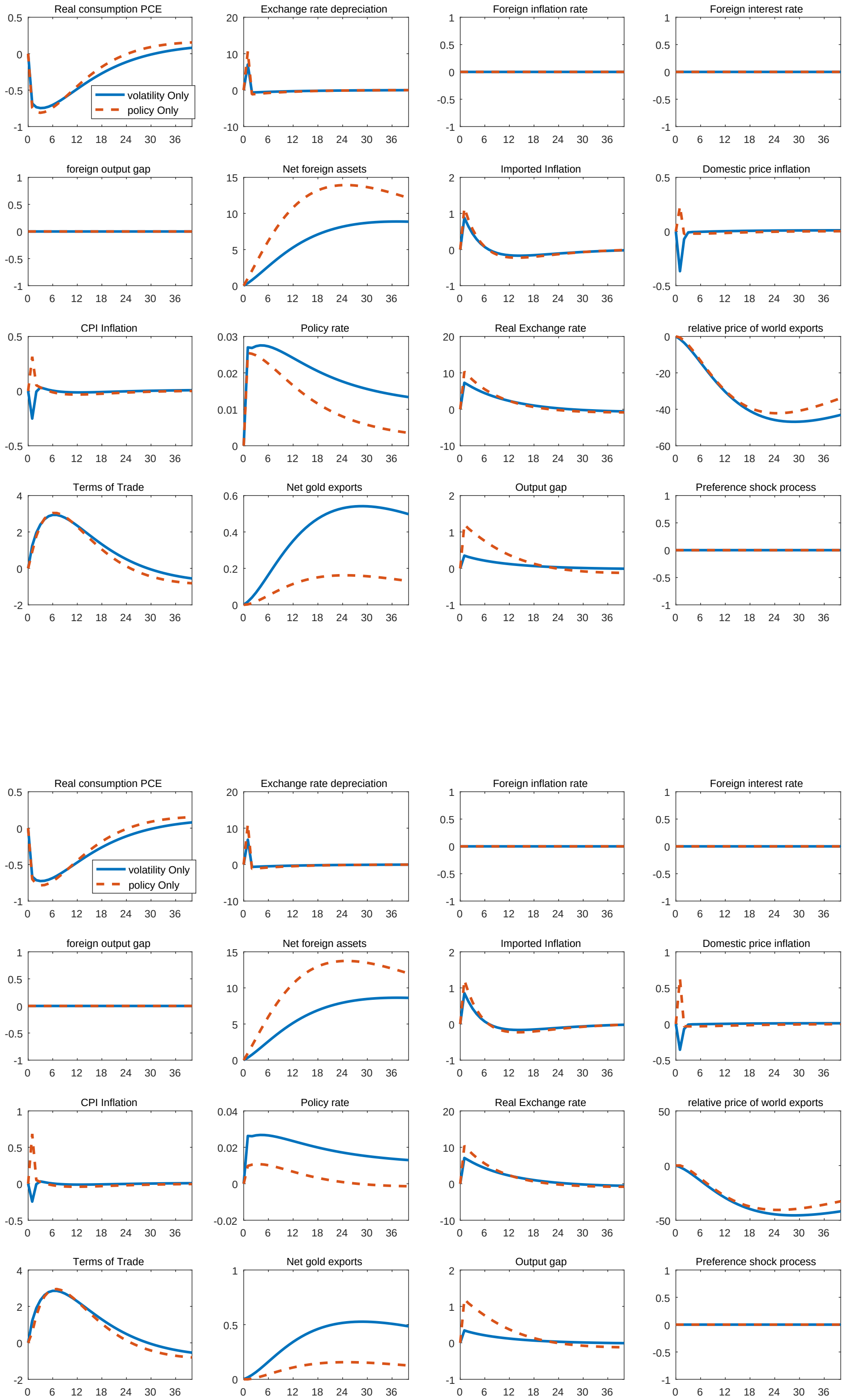


Figure 10: Variance deompositions of policy rate and CPI inflation

Note: Left panel is monetary policy rate and right panel is consumer price inflation

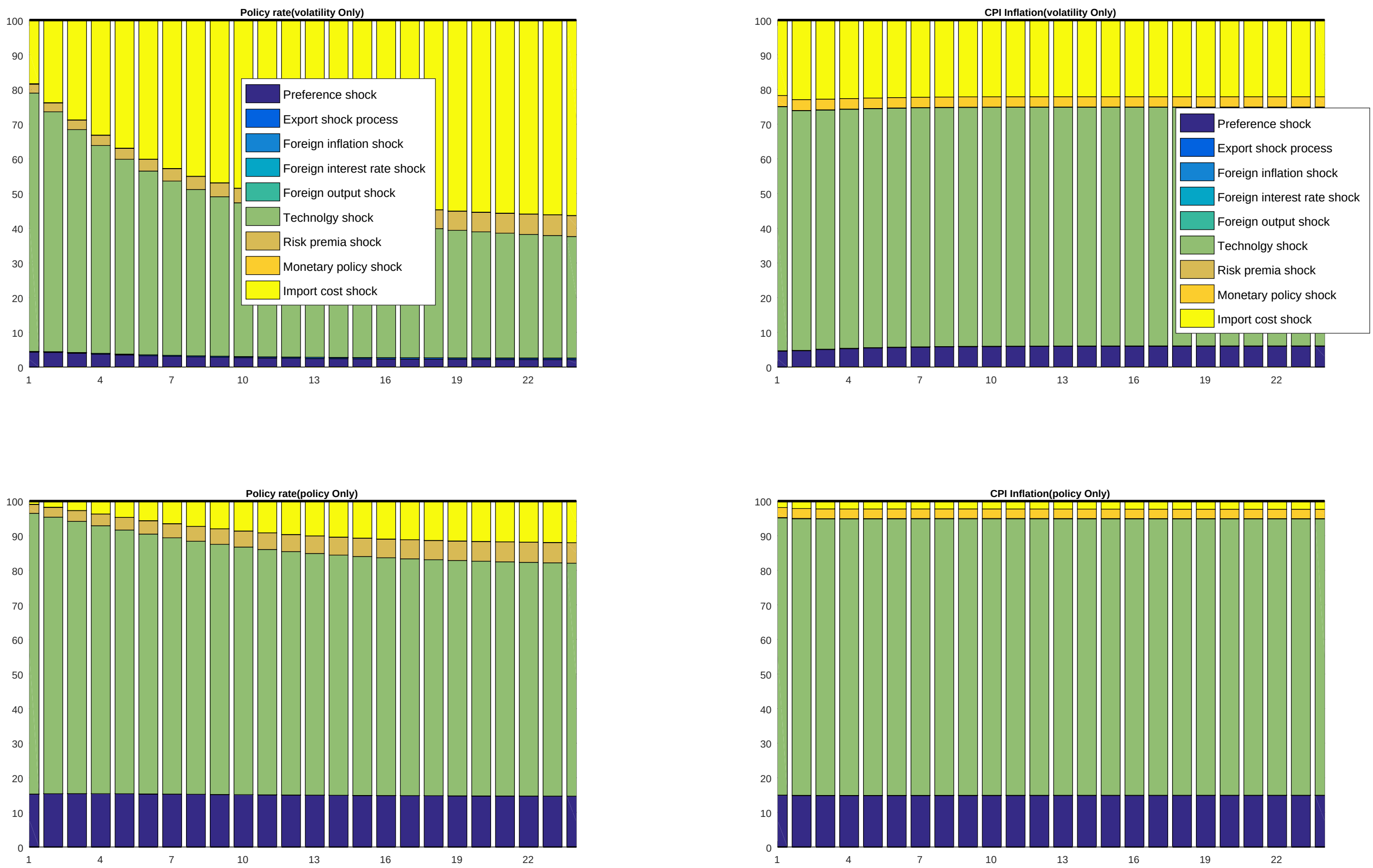


Figure 11: Variance decompositions of output gap and real consumption

Note: Left panel is output gap and right panel is real consumption

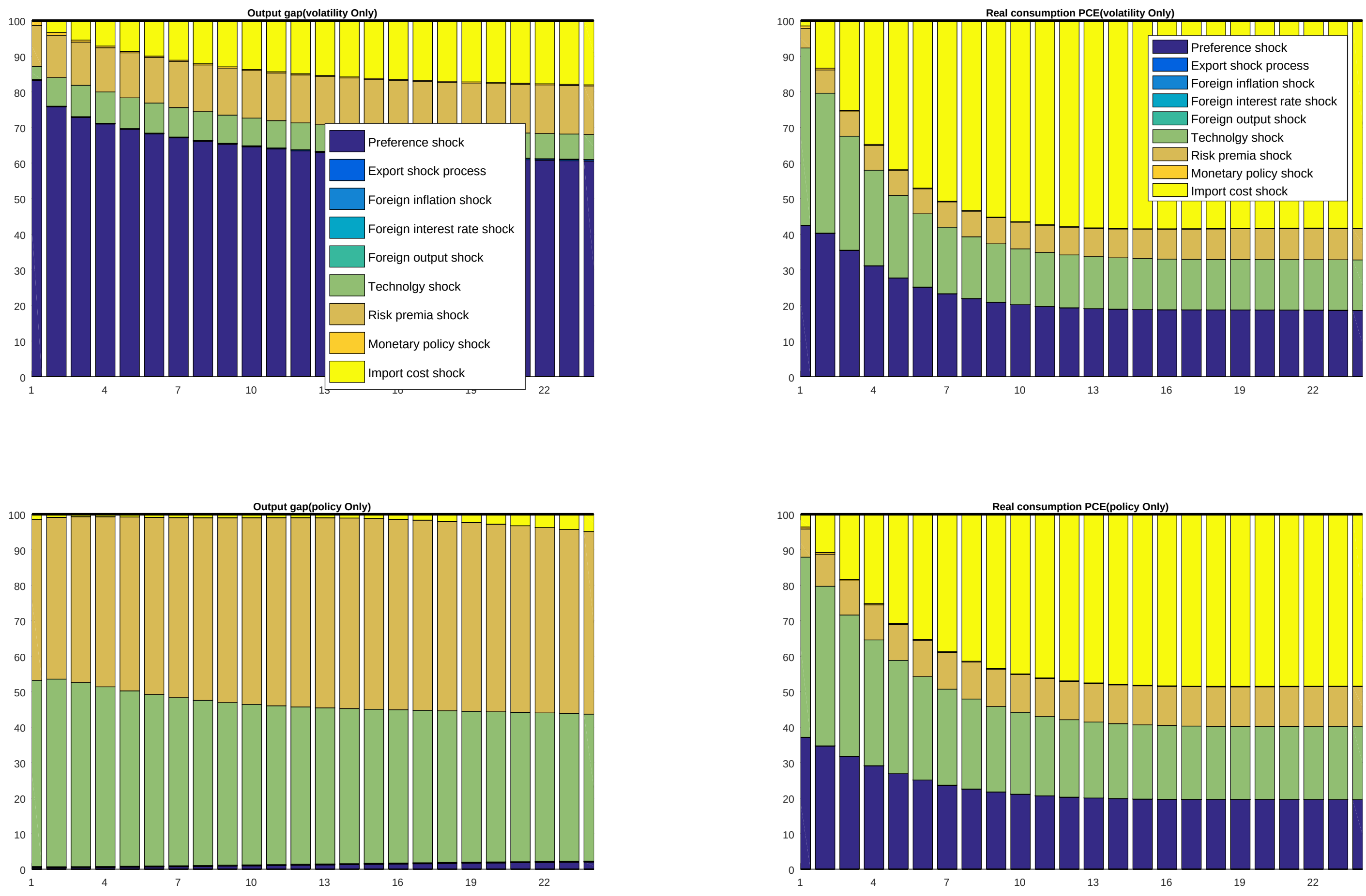


Figure 12: Variance decompositions of net gold exports and exchange rate depreciation

Note: Left panel is net gold exports and right panel is exchange rate depreciation

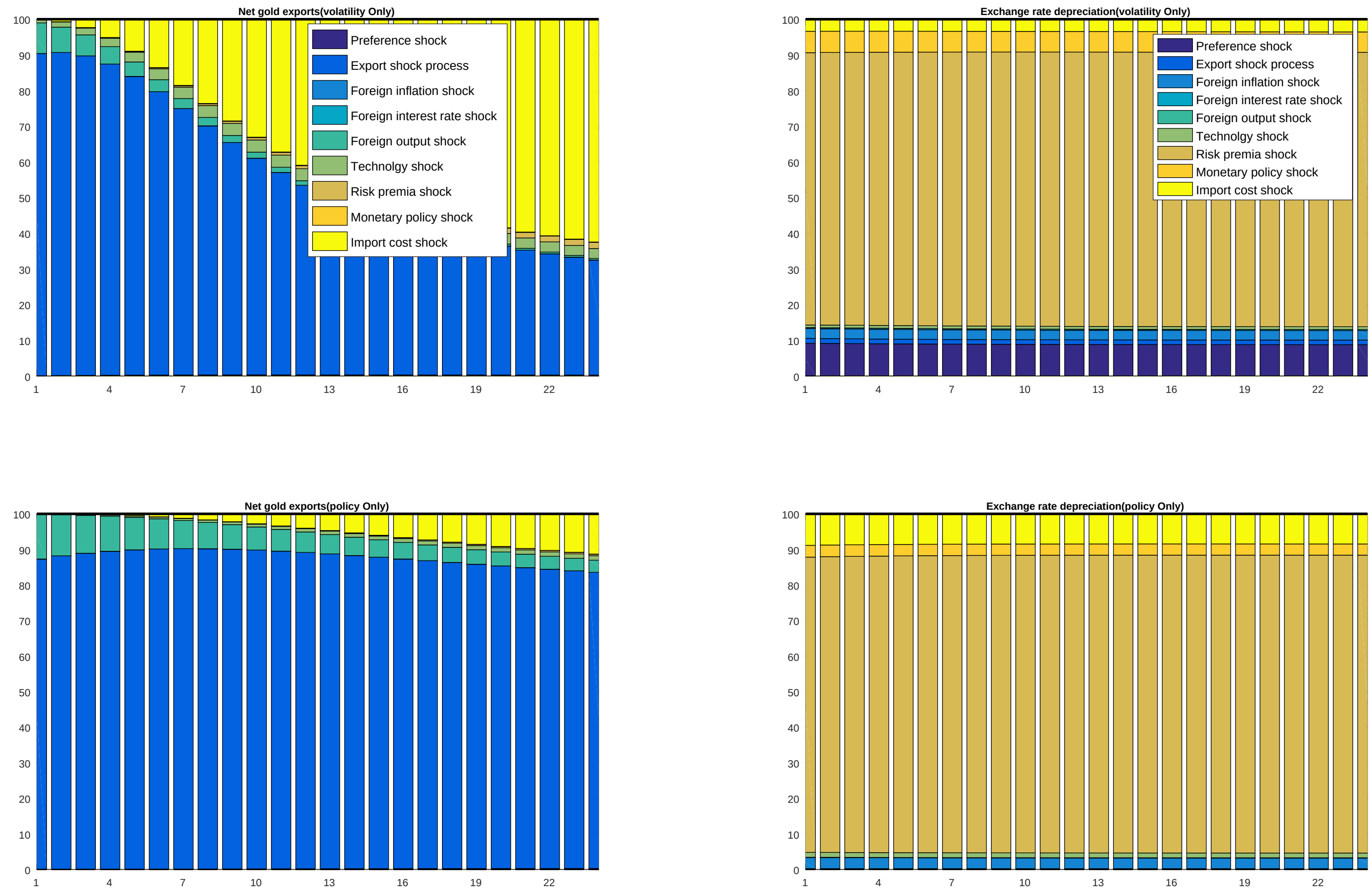


Figure 13: Historical decompositions of policy rate and consumer price inflation

Note: Left panel is monetary policy rate and right panel is consumer price inflation

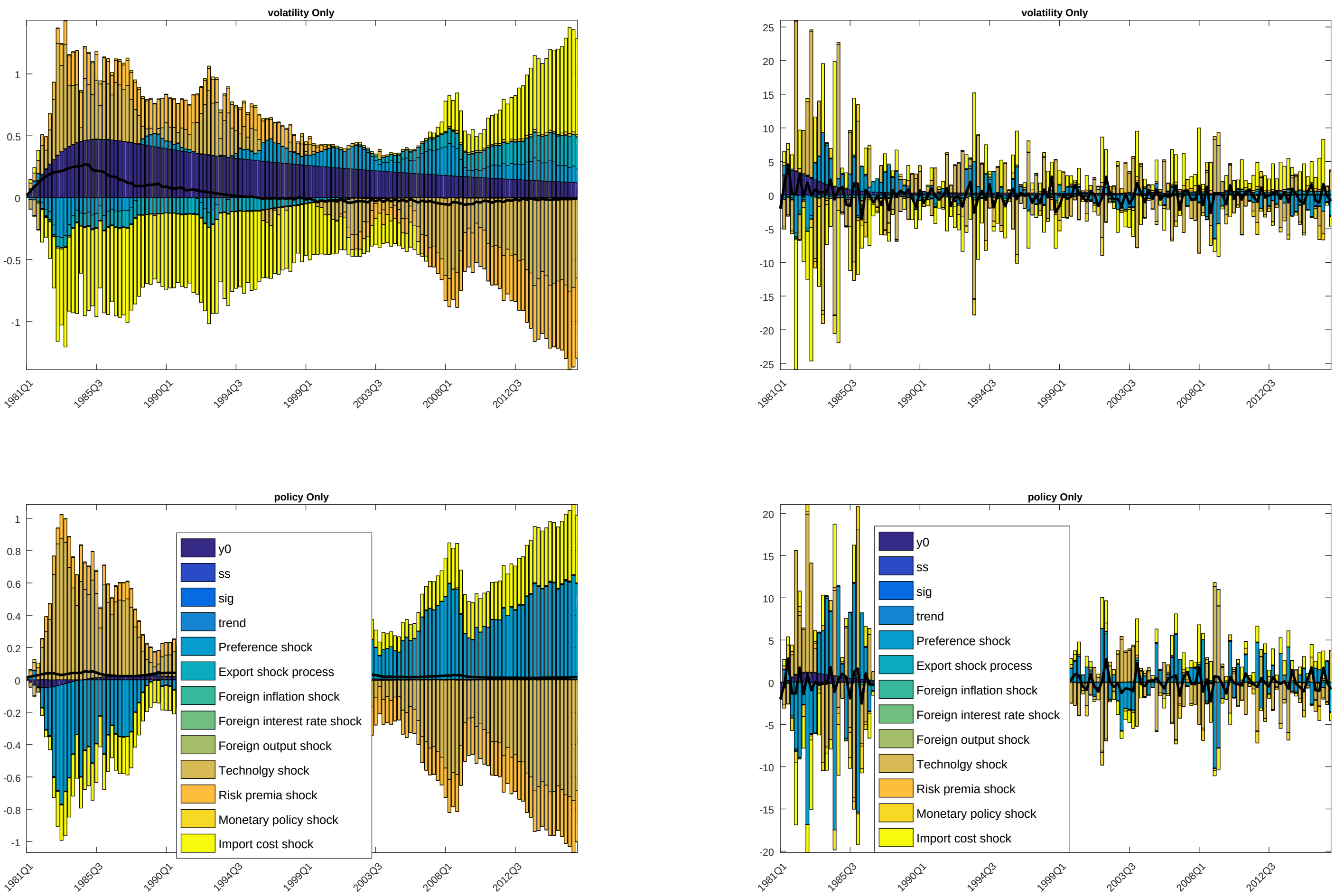


Figure 14: Historical decompositions of output gap and real consumption

Note: Left panel is output gap and right panel is real consumption

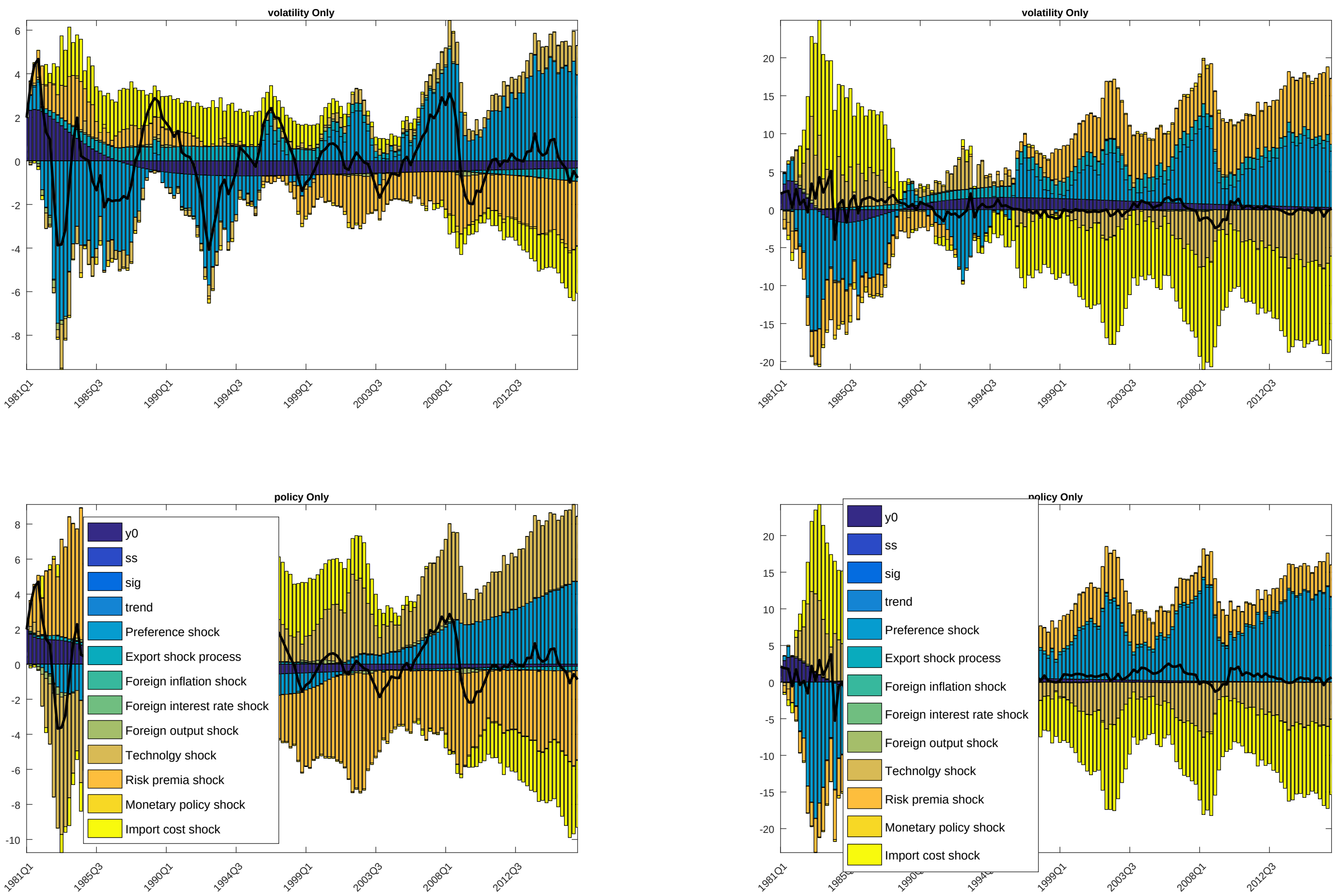
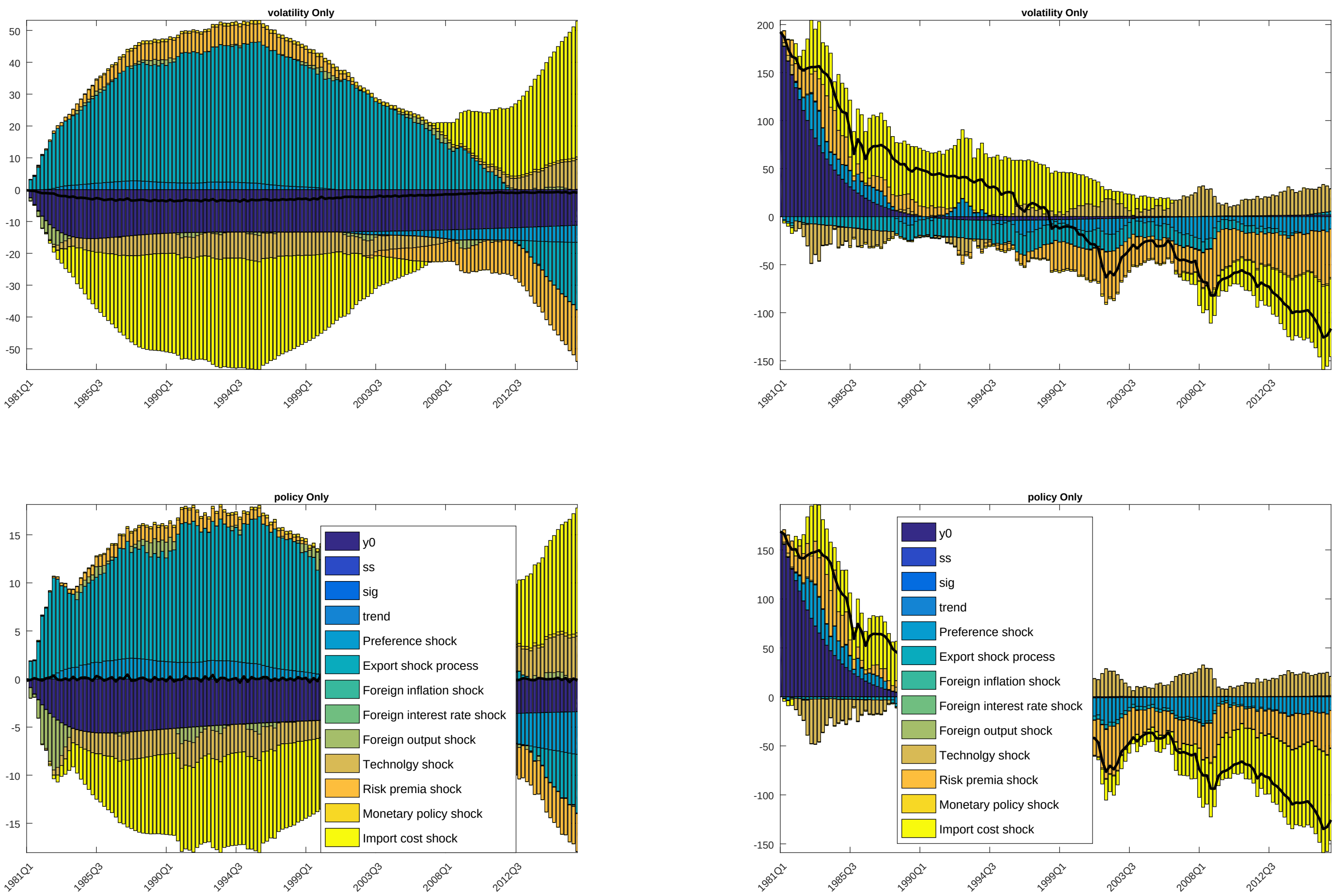


Figure 15: Historical decompositions of net gold exports and exchange rate depreciation

Note: Left panel is net gold exports and right panel is exchange rate depreciation



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