Spillovers from Asynchronous Monetary Policy in Advanced Countries: The case of South Africa

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[Preliminary and incomplete. Please do not quote.]

Abstract

The potential impact of asynchronous monetary policy normalisation by large advanced economies on emerging market economies is currently a topic that is widely debated in monetary policy circles. It is generally accepted that over the next few years the global economy is likely to witness asynchronous monetary policy normalisation in the world's most advanced economies. The nature and extent of this normalisation could have significant ramifications for the domestic economic outlook, specifically for a small open economy like South Africa with fairly sophisticated and liquid financial markets. In this context, understanding the spillovers associated with such a path, and the interactions thereof with domestic policy, is of particular importance in understanding the implications of these developments on South Africa's economic outlook. Using a reduced form New-Keynesian macroeconomic model, together with a small open economy DSGE model calibrated for the South African economy, this paper first investigates the effects of Federal Reserve 'lift-off' on the domestic economy, before broadening the scope to consider the impact on the domestic economy of possible asynchronous monetary policy normalisation by including other advanced economy central banks such as the ECB.

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1 Introduction

Perhaps the most perplexing consequence of the last eight years of global economic turbulence has been the doubt cast on what can henceforth be considered 'normal' (in an economic sense). Policy options that were assumed to be unlikely, such as quantitative easing, became not only relevant but necessary and more recently a policy choice that was considered impossible, negative deposit rates, became a viable option. The global economy has been forced to become accustomed to expecting the unexpected whilst maintaining a semblance of stability.

Once more the global economy is in the midst of the unprecedented. The world's two largest economies are embarking on divergent policy paths for what should be a sustained period of time. Since the introduction of the Euro in 1999, episodes of divergent policy between the ECB and the Federal Reserve were either short-lived or, in hindsight, considered to be policy errors (see figure 1). The most recent example was during 2011 when the ECB misread economic conditions and began policy tightening, only to have to quickly backtrack before the end of the year. As we approach Fed 'lift-off' the possibility that the Fed is also about to embark on premature normalization cannot be ruled out, but should the expectations of FOMC members be realised, the Federal Funds target rate should increase by approximately 150 basis points by the end of 2016. Meanwhile, the ECB has committed to maintaining their rather rapid rate of asset purchases 'as long as needed' and certainly until at least September 2016. The global picture is further obscured by Japanese monetary and fiscal policy, an issue that is overlooked in this paper and left for further potential research.

What this implies for the global economy is a topic of much debate and, more importantly, great uncertainty. What is fairly certain however is that the impact of this episode of asynchronous monetary policy will not be limited to just the Euro Area and the USA, instead there are serious spillover implications for the rest of the world. The emerging market economies, some would argue, are likely to be affected the most, particularly those economies with twin deficits that depend rather significantly on capital inflows (such as South Africa). For these countries, understanding the potential domestic implications of divergent monetary policy in advanced economies becomes of the utmost importance. Unfortunately, given the structural changes in the global economy in the past eight years, it becomes extremely challenging to predict exactly how these events might play themselves out.

One tried and tested approach to this type of challenge is scenario analysis. By building and expanding upon scenarios in economic models, policy makers can glean some insight into economically consistent paths that might prevail under expected future conditions. The plurality of this is important to note, because several potential paths are possible given the number of opposing forces at work in this intricate question. In this paper one such scenario is explored, whilst remaining cognisant of the numerous shortcomings of the underlying assumptions that are, as always, necessary to achieve presentable results.

The paper proceeds in the following manner; first a discussion of the potential a priori expectations for a scenario of asynchronous monetary policy in advanced economies, secondly the models that will be used are explored, thereafter the approach to modelling the respective scenarios is set out and finally the results are reported for consideration.

2 Analysing the scenario

It is often advisable, when facing a complex question, to tear it down into smaller understandable pieces. Given the complexity of assessing the impact of divergent monetary policy on the global economy, this approach seems sensible. By considering each of the two advanced economy's policy actions in isolation and then combining them, one can build a consistent picture of the potential outcomes.

The impact of policy normalization in the USA is likely the easier to understand. The monetary policy transmission mechanism in the USA has been thoroughly researched and documented (see for example Taylor (1995)). The standard macroeconomic response to policy tightening could be expected in the US (the financial market response a little more uncertain) and, in a nutshell, would unfold as follows. As the Federal Reserve tightens lending rates, domestic consumption will gradually slow down. Unless this reduction in domestic demand is offset by an increase in external demand, production will also decrease, leading to a downward adjustment to the output gap, eventually resulting in lower price pressures.

The major spillover channels from this scenario are twofold, firstly via the real economy, specifically the impact on global demand and secondly via financial markets. The real economy channel is fairly straightforward. As USA domestic demand decreases, so too does the USA's demand for imports. This results in a decrease in exports for their trading partners, in turn leading to a decrease in total production in those nations, which should then have similar dampening effects on inflation as it would in the US. Meanwhile, international finance theory suggests that should uncovered interest parity hold in the long run, the US dollar should depreciate, ceteris paribus. However, over the short run, the search for yield should increase the demand for USD following Fed lift-off, causing appreciation of the greenback. Not only would Dollar strength imply depreciation of local currencies against the USD, but Dollar strength is commonly accompanied by lower commodity prices. Here emerging markets are likely to be hit doubly hard as passthrough from depreciation would lead to higher inflation (and possibly tighter monetary policy), whilst lower commodity prices would affect exports and thus GDP. However, another path is possible where commodity prices remain fairly stable and domestic currency depreciation leads to an improvement in the terms of trade, leading to an improvement in both the trade balance and GDP.

Whilst it is tempting to think of quantitative easing as the natural opposing force to policy lift-off, the details are likely to be slightly different. Under a quantitative easing programme bond prices would be driven up by the demand created by the ECB, with the intention of creating positive wealth affects (and lowering borrowing costs). However, since the majority of consumers may not hold sovereign debt directly, the purchasing of government bonds by the ECB is more likely to affect consumers indirectly through increased liquidity provided by banking institutions who observe easing pressure on their balance sheets. From here the forces would be somewhat polar opposites to those of lift-off, whilst the timing and magnitudes would likely be different and difficult to predict, culminating in the avoidance of deflation. The spillover channels remain the same as in the USA, with the exception that the euro doesn't have the same impact on financial markets that the USD does. Here an emerging market such as South Africa might find that the trade spillover dominates (given that the Euro Area is the largest export partner), causing an increase in production, inflation and eventually domestic policy rates, *ceteris paribus*.

Whilst in isolation, the potential effects of each of the above policy stances can be reasonably discussed, quantitatively it becomes very hard to discuss what the combined impact would be. Would

the positive trade impact from the Euro Area counter the negative impact from the USA? Would the appreciation of the USD result in lower commodity prices leading to a deterioration of the trade balance or would the depreciation of the Rand lead to increased competitiveness instead? It is the very nature of these questions that have been punctuating the debate on divergent policy and bring about the need for quantitative tools to at least provide a consistent framework for discussion. Naturally the choice of model to answer such a complex question is rather difficult. In the end, because the main concern is the domestic policy implication, a micro-founded general equilibrium model appears suited to the task. Of course models in this class, such as DSGEs, are not without their shortcomings, particularly with regard to their traditional large forecasting errors. But given that the interest lies in a scenario analysis to assist and inform policy, rather than a forecasting exercise, one can be forgiven for overlooking this point. Another shortcoming is that the coefficients in these models are generally calibrated and as such models developed to answer such questions are often criticized for perhaps being calibrated and/or designed to provide the desired answer. In order to partially mitigate this criticism, one can make use of pre-existing models or one can use models with estimated coefficients. Two models are utilized to answer the question at hand; firstly the so-called flexible system of global models (FSGM), developed and published by the IMF, in order to model the international scenario and thereafter a simpler small open economy DSGE with estimated coefficients (Steinbach 2013) provides the domestic spillover consequences.

3 The Models

3.1 FSGM

The FSGM was developed by the IMF and published in 2014. As the name suggests, rather than being a single model, it is a framework within which sub-models can be easily specified. The modeller specifies the number of countries/regions in the model and then selects the specific characteristics of each 'country block'. Spillovers between blocks are then governed by various macro variables, most notably each block's share of global trade. The model is not entirely micro-founded however, as the large scale of the model makes finding a solution more challenging as more blocks are added, therefore certain model sections have reduced-form representations which are similar to those observed in semi-structural models. A brief summary of the characteristics of the FSGM is set out in appendix A. The FSGM has proven to be a valuable tool for the IMF and policy makers, with the IMF using an FSGM build called the G20Mod to model the 2-in-5 objectives for the G20 under the Australian presidency in 2014. For the purposes of this paper a six region version of the FSGM is used.

3.2 DSGE

For the domestic spillover analysis a smaller, but fully structural, New Keynesian DSGE model is used. A brief discussion of this model is available in appendix B. The small open economy structure of the model allows for the introduction of scenarios that originate in the global economy with the intention of studying only the domestic spillovers. Frictions within the model include habit formation in consumption, investment adjustment costs, Calvo price and wage setting and incomplete exchange rate pass-through. There is also a full characterisation of aggregate demand

components. Ideally this model could be incorporated as a block within the FSGM for consistency, but this project is currently a work in progress and left as an area for future research.

4 Methodology

The modelling of the scenario was approached in the following manner. First the layers of the scenario contagion in the initiating country is defined and then modelled, using the FSGM. Given that the FSGM is a general equilibrium model, the spillovers into the other global regions are simultaneously assessed. Thereafter these shocks are aggregated off-model, using a weighting system based roughly on each country's share in South Africa's exports, into global variables that can be processed by the DSGE. Finally the impact of these global variables on the domestic economy is assessed using the DSGE. It is worth remembering that these scenarios aren't forecasts, they are modelled as deviations from steady state, and as such there is no possible bias from the initial conditions.

4.1 First scenario: Policy normalisation by the Federal Reserve

In the first scenario we consider the impact of 100bps of cumulative policy tightening by the Fed over the course of 2016. The extent of tightening is a fairly standard choice as 100bps should provide instantly interpretable elasticities, but it also happens to be roughly the expectation of where the Federal Funds rate will be at the end of 2016 according to the most recent FOMC projection materials (July 2015). The second layer then consists of the impact of the change in the policy rate on the other model rates – such as the 10 year bond yield. From there the contagion spreads through the US economy and spills over into the other global blocks. The results of the scenario are then aggregated and provided to the DSGE. For all scenarios considered, the following variables are taken from the FSGM to the DSGE: world GDP growth, world consumer inflation and a global policy rate proxy.

4.2 Second scenario: Quantitative easing by the European Central Bank

In the second scenario we attempt to quantify the effects of QE. The only undisputed consequence of a central bank significantly expanding its balance sheet by purchasing government bonds is that the yields on those bonds will decline. This phenomenon is the first layer of this scenario and is modelled by a one-year imposed decline in the term premium. Once more the magnitude is fairly notional, but 100bps appears a little excessive for the ECB's current QE strategy given the observed market response, so instead a decline of 80bps is used. The second layer is the consideration given to the impact that QE wold have on other bond markets. As liquidity is pushed into European bond markets, a portion thereof is likely to be absorbed by other bond markets with similar risk profiles, causing a decline in yields there. This is the second layer in this scenario. Finally the introduction of QE is expected to have a very slight impact on risk premia in the currency block, this becomes the next layer. From there the global scenario is assessed, weighted and utilized in the DSGE as mentioned above.

4.3 Combination of first and second scenario

Whilst the two scenarios outlined above are by no means comprehensive and the shocks are only present for the first year in question, it is still worthwhile for the policy maker to observe the consequence of the two shocks simultaneously. Here the timing of the shocks is such that the ECB's QE hits the global economy first, followed by the hiking actions of the Fed. It stands to reason that this ordering is significant because if the Fed had begun lift-off before the ECB had announced QE, the immediate financial markets consequences would have been quite different and could very well have impacted on the scope of the ECB's QE package.

In fact, this is a prevalent question at the moment. Should the market respond to the Federal Reserve's policy in such a manner that the impact of the ECB's QE is either partially or completely mitigated, what will the response of the ECB be? The ECB has already stated that their programme is essentially open ended and will persist until such a time that they are comfortable with the inflation trajectory. It's difficult to assume that markets have already priced in such an eventuality, therefore it stands to reason that whilst this scenario would provide some valuable insight, it does not account for the possibility of even further policy divergence.

5 Results

The two models in question are fairly detailed and as such the richness of the results therefrom is rather vast and becomes cumbersome to report efficiently. As a consequence, selected results will be reported here, whilst the full results can be made available on request. Furthermore, as this project remains a work in progress, the discussion of the results will be fairly limited, focusing on specific points of interest instead.

5.1 First scenario

Figure 2 demonstrates the impact on four key variables (GDP, inflation, policy rate, 10yr bond yield) of the world's four largest economies (USA, Euro Area, Japan and China). As one might anticipate, the impact of Fed normalisation is negative on US output (approximately 0.5 per cent at its peak). This causes trade spillovers into the other three major economies, reducing GDP throughout but to a lesser extent. The economic slowdown causes disinflationary impacts throughout, which then illicit policy responses from the contagion receiving countries in order to stimulate their respective economies. It is interesting to note that the impact in the Euro Area is more supressed when compared to both Japan and China.

Note that in the current global economic environment neither Japan nor the Euro Area have any conventional ammunition left with regards to monetary policy, so they would need to react with unconventional measure (i.e. QE). What the converse implies is that Fed normalisation will serve to at least partially offset the benefits of QE in these countries.

5.2 Second scenario

Figure 3 reports the results of the ECB's QE. Starting in the Euro Area one notes that the fall in bond yields serves to increase GDP (through consumption) by approximately 0.4 per cent. Of increased importance to the ECB would be the roughly quarter percent improvement in CPI inflation. It is questionable whether or not that would be sufficient for the ECB to accept that the inflation trajectory was no longer a concern. The impacts elsewhere follow as one would expect. Trade spillovers allow GDP and inflationary gains to the other nations, including a roughly 10basis point boost to inflation in Japan (where deflation has been a significant issue for the past few years). Meanwhile the increased liquidity in bond markets spills over into other regions, causing lower yields globally. However, the positive GDP effects in both Japan and China are smaller in magnitude than the negative effects noted in the first scenario.

5.3 Combined scenario

It is important to note that combining the above scenarios is not equivalent to adding together the results from the two scenarios. A simple consideration of the results in figure 4 confirms that this isn't the case. Whilst in a modelling context, it can be most easily be described as placing one layer on top of another, practically the shocks from the two different scenarios are incorporated into the model simultaneously and a general equilibrium solution is found.

The interaction between these two shocks is rather interesting and can be discussed from a multitude of angles. But if we return to the discussion above regarding the impact of Fed normalisation on the ECB's QE programme: the FSGM suggests that approximately a quarter of the positive inflationary impact of QE can be negated by a simultaneous 100bps policy movement in the USA. Considering that the Fed foresees around 150bps in tightening by the end of 2016 and that the current global environment appears to be teeming with downside risks to inflation outlooks, the possibility that this divergence between the policies of the ECB and the Fed might be self-propagating to a certain extent cannot be completely discounted.

On the domestic side, even though the Euro Area is South Africa's single biggest trading partner, the effect of policy normalisation by the Fed appears to be the dominating shock. The reason for this stems from the fact that financial market spillovers are likely to dominate the real economy spillovers. Fed normalisation is anticipated to have a negative impact on the value of the rand (particularly if markets overreact and/or normalisation isn't fully priced in). Whilst this depreciation should make imports more expensive and exports more competitive (see figure 6), the pass-through to inflation will necessitate a policy response that will suppress domestic demand – and this impact is likely to be stronger than the impact on the trade balance.

6 Conclusion

Policy decisions aren't made in a vacuum. What happens in the global economy has domestic consequences and in the case of larger economies the inverse applies as well. Whilst nations have no right to dictate the policy actions of other sovereign nations, international co-operation has a role to play to try and ensure that policies don't become mutually destructive (eg currency wars). It

is in this context that international fora such as the G20 and BRICS take centre stage, particularly as they allow smaller nations such as South Africa to voice their concerns regarding potential spillovers from the actions of advanced economies. However, before that can happen, steps must be taken to further our understanding of these spillovers and what policy menu is available to us in mitigation thereof.

The results in this paper suggest that the MPC may be right to be more concerned with Fed normalization than they appear to be with QE in Europe. However the interaction between these asynchronous policies remains an important concern and if, as suggested, the ECB is forced to expand their QE programme in response to Fed normalization, the SARB (and other policy makers) need to be prepared to react in the appropriate manner.

Figures

Figure 1: History of Fed and ECB Policy

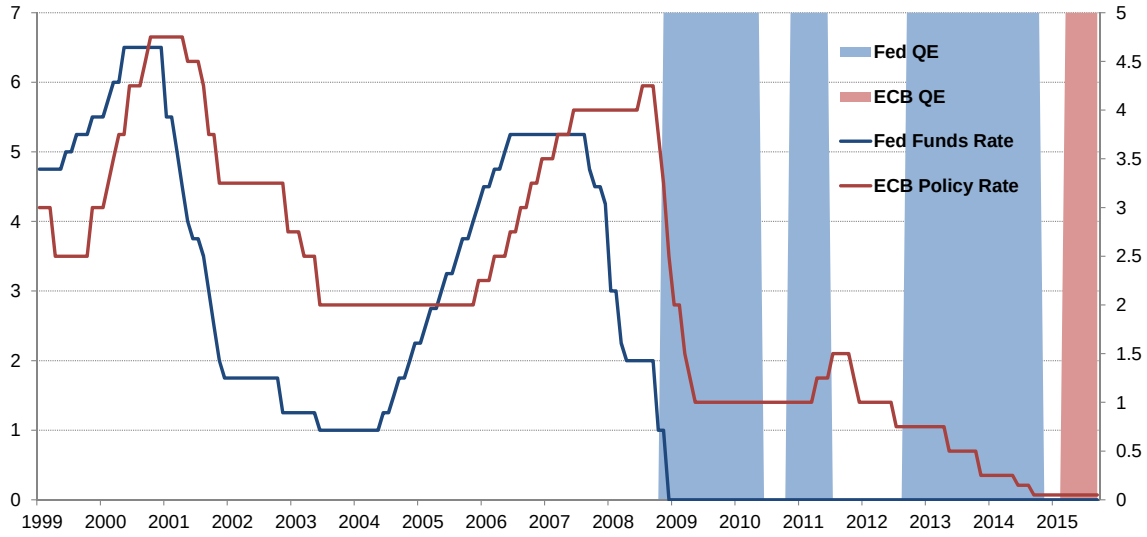


Figure 2: FSGM Results - Fed Scenario

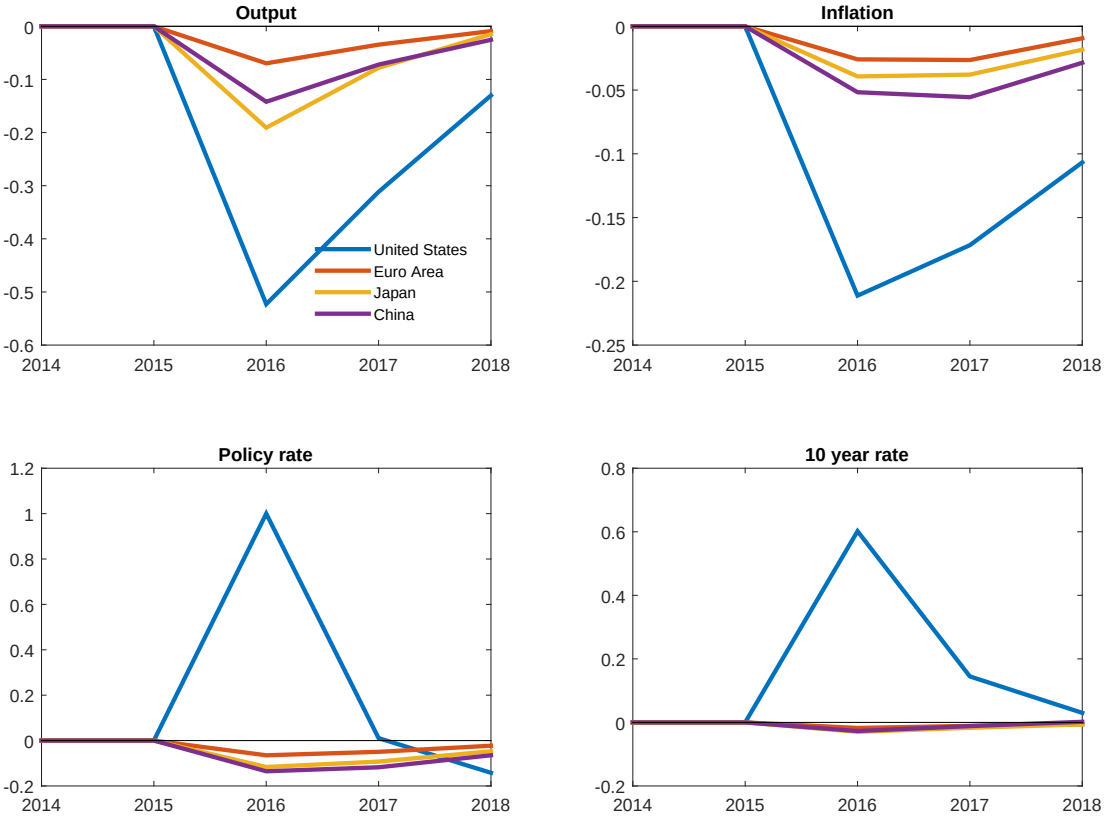


Figure 3: FSGM Results - QE Scenario

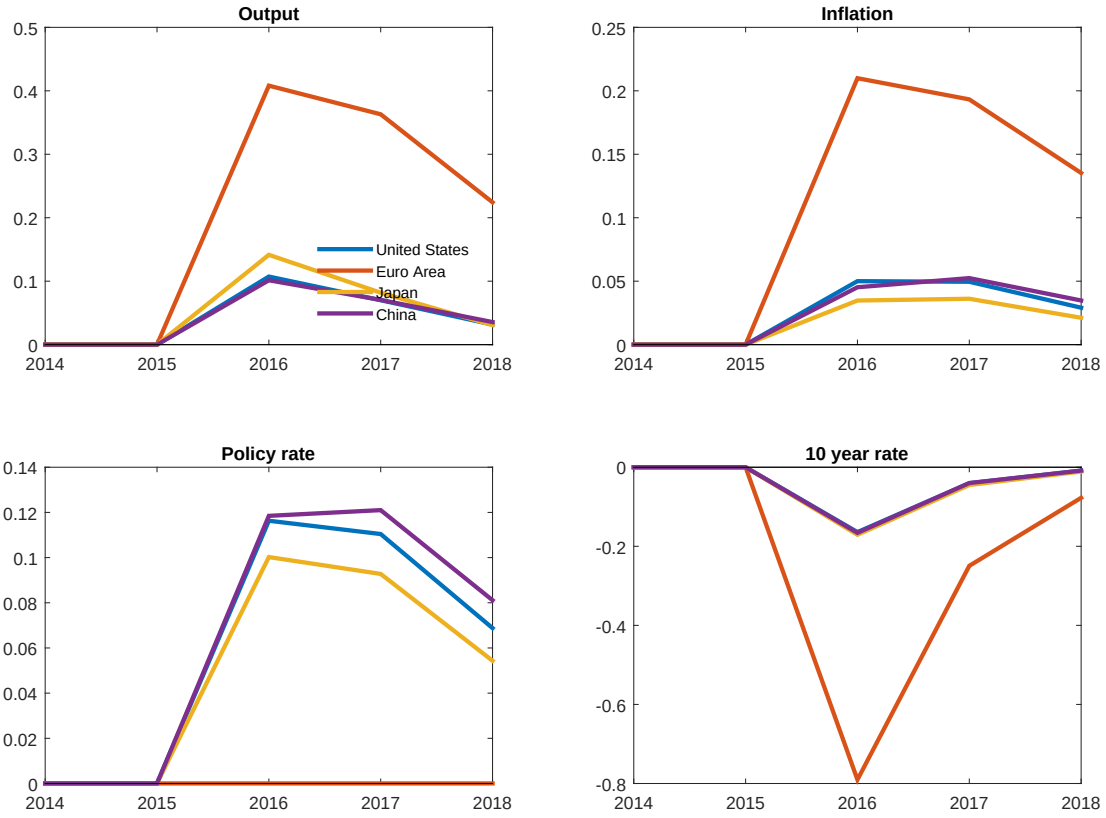


Figure 4: FSGM Results - Combined Scenario

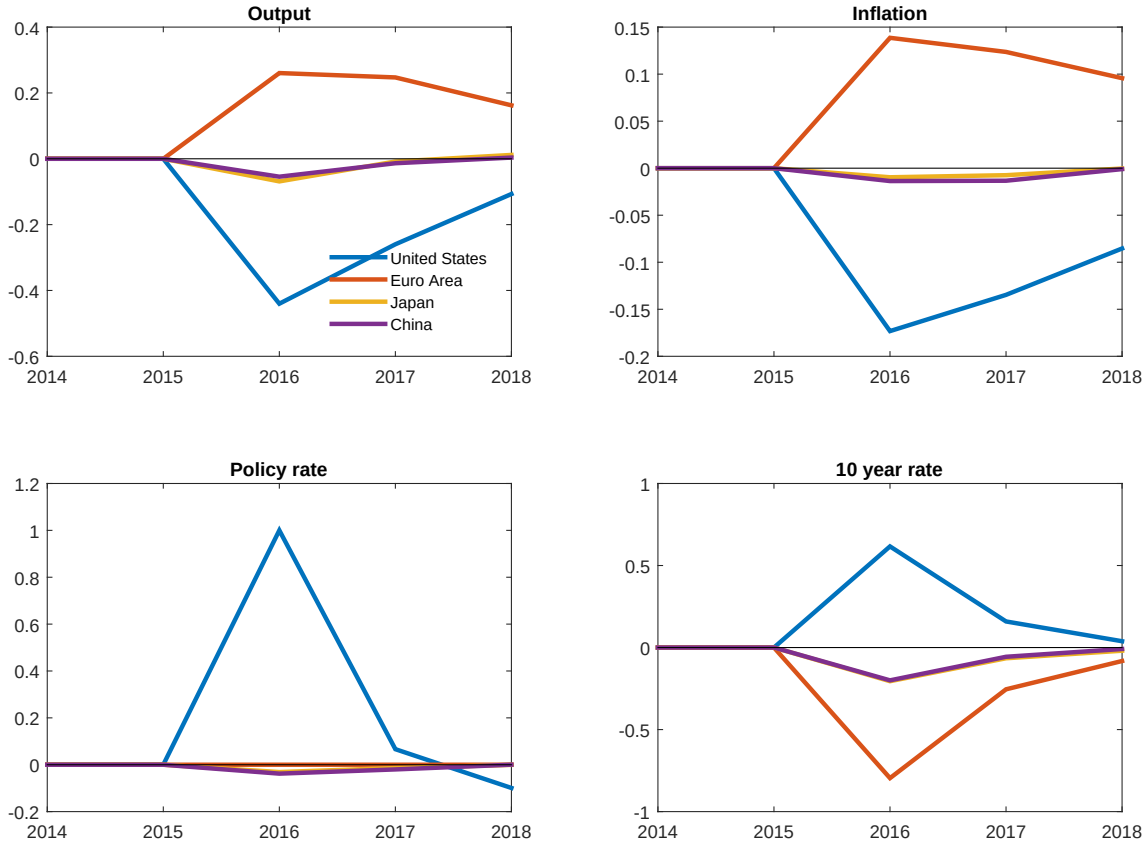


Figure 5: DSGE Results - Fed Scenario & QE Scenario

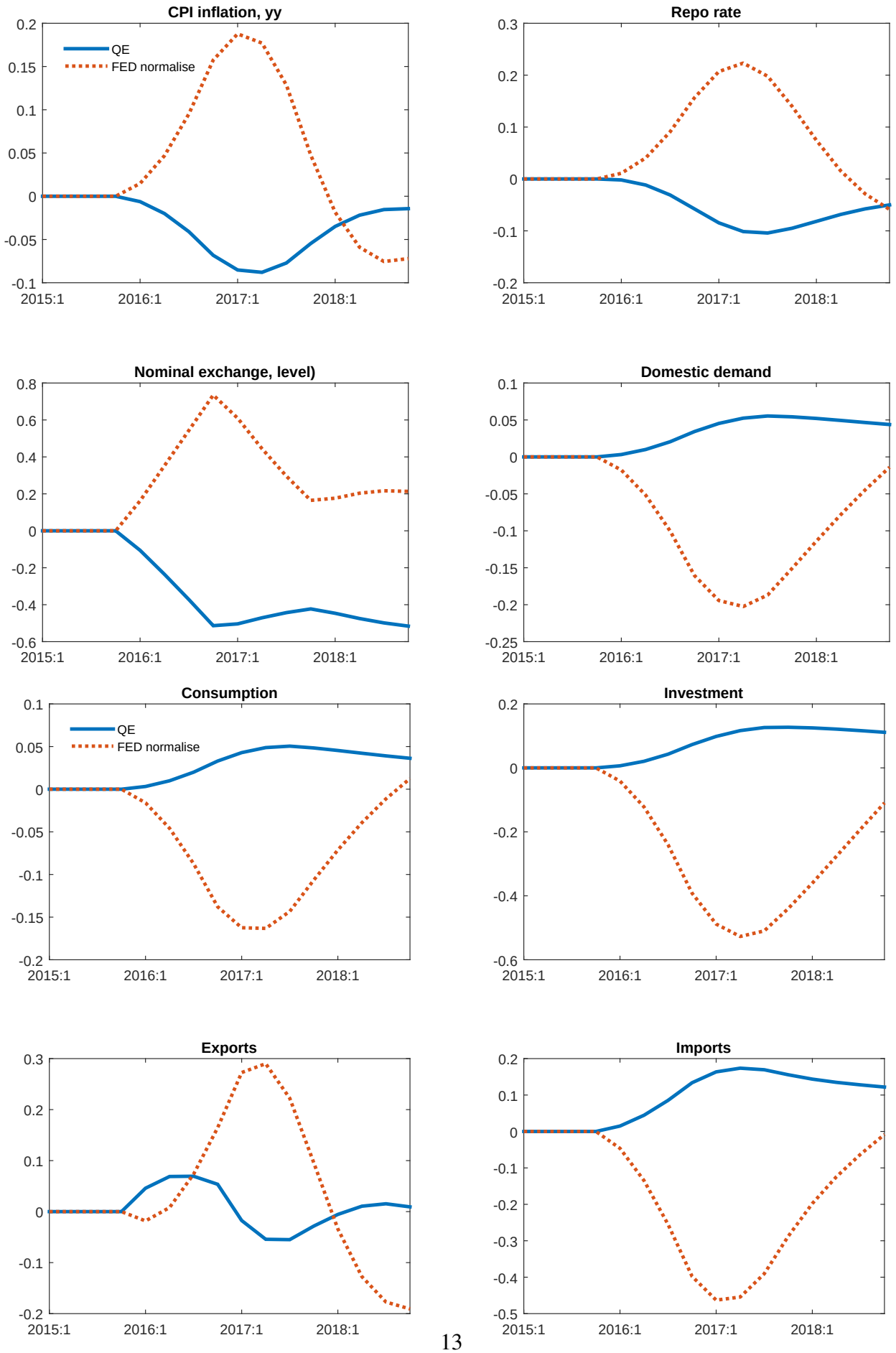
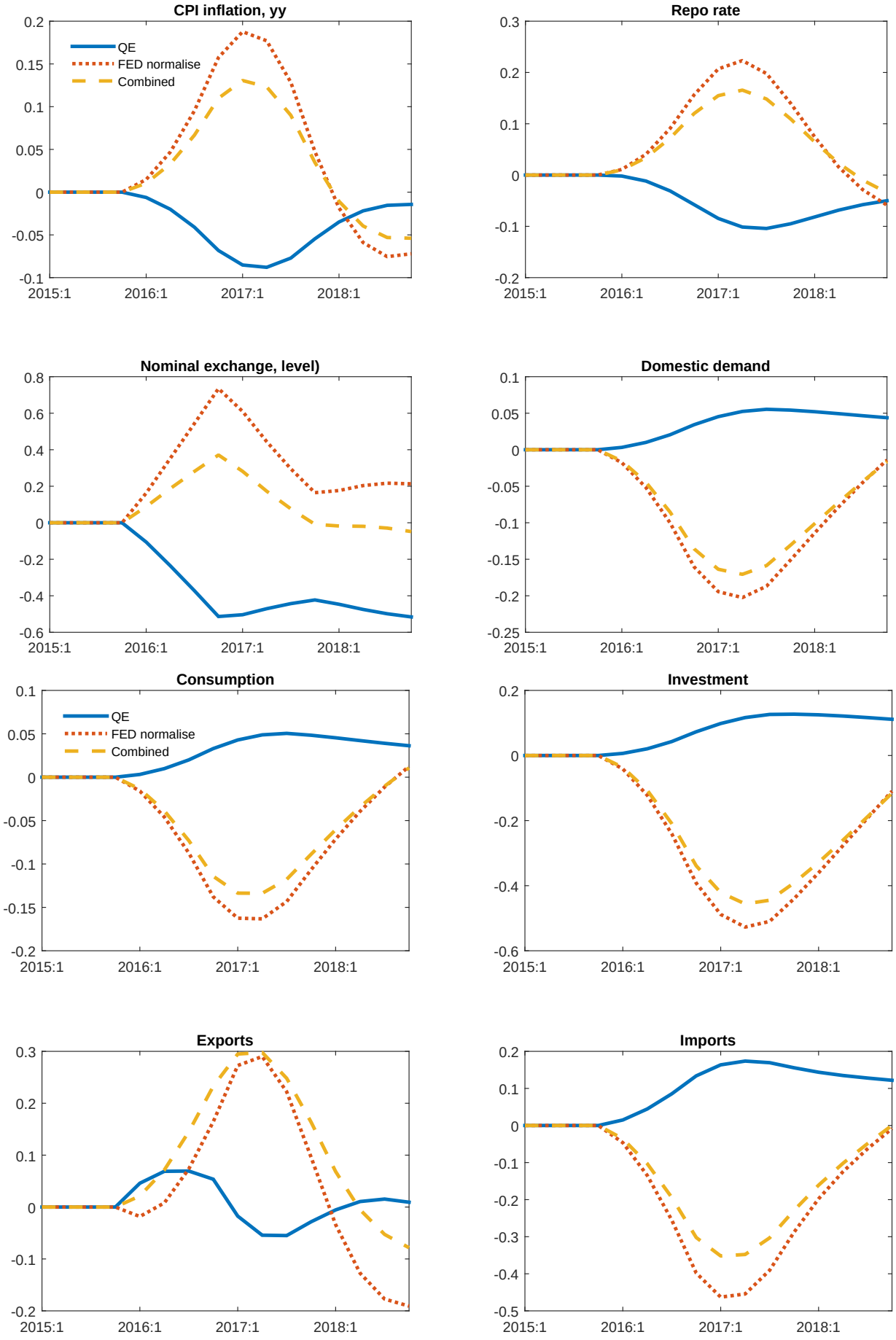


Figure 6: DSGE Results - Combined Scenario



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A Overview of the FSGM structure

What follows is a brief summary of the FSGM, for a detailed breakdown of the methodology please see Andrle et al. (2015). The FSGM is a semi-structural, single good model with a minimum of two-regions. Certain model segments are fully structural (micro-founded), these include consumption and investment. Segments such as trade, labour supply and inflation and reduced form representations. The model has full stock-flow consistency with rational expectations and is closed with simple rules for endogenous determination of monetary and fiscal policy.

Consumption is given as the aggregation of two household types, the first is liquidity constrained and consumes all their wealth in each period whereas, the second is modelled with a discrete-time representation of the Blanchard-Weil-Yaari overlapping generations (OLG) model and consumption depends on their marginal propensity to consume wealth.

$$
\begin{aligned}
p_t^c \check{c}_t &= p_t^c \check{c}_t^{OLG} + p_t^c \check{c}_t^{LIQ} && (1)\\
\check{c}_t^{OLG} &= \Theta_t^{-1} \left(p_t^c \check{w} f_t + \check{w} o_t + \check{w} h_t \right) && (2)\\
p_t^c \check{c}_t^{LIQ} &= (1+\tau_t^c)^{-1} \left[\lambda_t^c \left(\Upsilon_t - tax_t^{ls} \right) + \Upsilon_t^{LIQ} + \lambda_t^c \left(1 - \tau_t^L \right) \check{w}_t \check{l}_t \right] && (3)
\end{aligned}
$$

Private investment is driven by a Tobin's Q model with quadratic real adjustment costs. This classical theory essentially bases investment decisions on the value of Q which is the market value of the firm for each unit of capital held. This implies that if Q is above the market price of capital then the firm increases investment and vice versa.

$$
q_t = p_t^i + c_1^q \left(\frac{\check{I}_t}{\check{I}_{t-1}} - 1 \right) \left(\frac{\check{I}_t}{\check{I}_{t-1}} \right) - E_t \frac{\theta g_{t+1} n}{(\check{r}^{corp})^{c_q^2}} p_{t+1}^i \left(\frac{\check{I}_{t+1}}{\check{I}_t} - 1 \right) \left(\frac{\check{I}_{t+1}}{\check{I}_t} \right)^2 + \epsilon_t^q \tag{4}
$$

Whilst aggregate demand is determined by the national accounts expenditure identity, aggregate supply is determined by a Cobb Douglas production function in capital and labour, scaled by total factor productivity.

$$
\check{y}_t^{FE} = TFP_t^{FE} COM_t^{FE} \left(\frac{\check{k}_{t-1}}{g_t n} \right)^{\alpha^{FE}} \left(\left(1 - \frac{U_t^{FE}}{100} \right) \check{lf}_t^{FE} \right)^{1-\alpha^{FE}} \tag{5}
$$

Trade appears in the form of a reduced form relationship and bilateral trade isn't modelled, only total trade. This is purely due to computational limitations. Exports are driven by foreign demand and relative prices, whereas imports are driven by domestic demand, import prices as well as a business cycle indicator (output gap).

$$
\begin{aligned}
\Delta \log (\check{x}_t^m) &= c_4^x \Delta \log \left(A\check{C}T_t^F \right) + c_1^x \Delta RCI_t \\
&+ c_2^x \left(c_3^x RCI_{t-1} + \log \left(\frac{A\check{C}T_{t-1}^F}{g_t} \right) + c_5^x - \log \left(\frac{\check{x}_{t-1}}{g_t} \right) \right) + \epsilon_t^{x^m} && (6)\\
\Delta \log (\check{m}_t^m) &= c_5^m \Delta \log \left(A\check{C}T_t \right) + c_1^m \Delta \log (p_t^m) + c_2^m \Delta \log (\check{y}t^{gap}) \\
&+ c_3^m \left(c_4^m \log (p_{t-1}^m) + \log \left(\frac{A\check{C}T_{t-1}}{g_t} \right) + c_6^m - \log \left(\frac{\check{m}_{t-1}}{g_t} \right) \right) + \epsilon_t^{m^m} && (7)
\end{aligned}
$$

Inflation within the model is determined by a reduced form, standard new Keynsian Phillips curve.

Exchange rates in the model are governed by uncovered interest parity (UIP). The model also has a complete risk premium structure and government bonds are the only internationally traded asset.

$$\begin{aligned}\pi_t^{cpix} &= c_1^{cpix} E_t \pi_{t+1}^{cpix} + \left(1 - c_1^{cpix}\right)\left[c_2^{cpix}\pi_{t-1}^{cpix} + \left(1 - c_2^{cpix}\right)\pi_{TAR}^{cpix}\right] \\ &+ c_3^{cpix}\log(\breve{y}_t^{gap}) \\ &+ c_4^{cpix}\Delta\log\left(REER_t\right) \\ &+ c_5^{cpix}\left[c_6^{cpix}\Delta\log\left(p_t^{oil}\right) + \left(1 - c_6^{cpix}\right)\Delta\log\left(p_{t-1}^{oil}\right)\right] \\ &+ c_9^{cpix}\Delta\log\left(p_t^{food}\right) + \epsilon_t^{\pi^{cpix}} \end{aligned} \tag{8}$$

Finally, monetary policy is represented by a Taylor-type rule which targets an inflation forecast and the fiscal authority follows a simple rule ensuring a stable debt-to-GDP ratio in the long run.

$$\begin{aligned}\log(INT_t^{MP}) &= \delta_i \log\left(IMT_{t-1}^{MP}\right) \\ &+ (1 - \delta_i)\Big\{\log\left(r_t^{neut}\right) + \log\left(E_t\pi_{t+1}^{cpix}\right) \\ &+ \delta_\pi\left[(1 - \delta_w)\log\left(\pi_{t+1}^{cpix}\right) + \delta_w\log\left(\pi_t^{cpix}\right) - \log\left(\overline{\pi}_t^{cpix}\right)\right] \\ &+ \delta_Y\log\left(\breve{y}_t^{gap}\right) + \delta_e\log\left(\frac{\epsilon_t}{\overline{\epsilon}_t}\right) + \epsilon_t^{INT^{MP}}\Big\} \end{aligned} \tag{9}$$

$$\overline{gdef}_t^{rat} = -\frac{\overline{\pi}_t^{cpix} gn - 1}{\overline{\pi}_t^{cpix} gn}\overline{b}_t^{rat} \tag{10}$$

B Overview of the DSGE structure

We use a modified version of the medium-scale dynamic stochastic general equilibrium (DSGE) model of Du Plessis, Smit, and Steinbach (2014) to simulate the South African economy's response to the global scenario delivered by the FSGM (2015). Being a structural open-economy model, global developments play an active role in domestic macroeconomic dynamics. This feature makes the DSGE model of Du Plessis, Smit, and Steinbach (2014) an ideal tool to analyse the potential impacts of divergent monetary policy abroad. Moreover, the exchange rate's UIP condition includes a risk premium, which serves as an additional key channel through which global policy development may spill over into the South African economy. Below are some highlights of the DSGE model's structure.

Households

Households maximise utility in consumption and (dis)utility in labour as follows:

$$E_0^j \sum_{t=0}^{\infty}\beta^t\left[\xi_t^c \ln\left(C_{j,t} - bC_{j,t-1}\right) - \xi_t^h A_L\frac{(h_{j,t})^{1+\sigma_L}}{1+\sigma_L}\right] \tag{11}$$

subject to a budget constraint

$$\begin{aligned}\frac{B_{j,t}}{R_t} + \frac{S_t B^*_{j,t}}{R^*_t \Phi\left(\frac{A_t}{z_t}, S_t, \tilde{\phi}_t\right)} + P^c_t C_{j,t} + P^i_t I_{j,t} + P^d_t \left[a(u_{j,t})K_{j,t} + P^{k'}_t \Delta_t\right] \\ = B_{j,t-1} + S_t B^*_{j,t-1} + W_{j,t} h_{j,t} + R^k_t u_{j,t} K_{j,t-1} + \Pi_t - T_t\end{aligned} \tag{12}$$

Optimisation (and linearizing) leads to following key relationships:

UIP condition

$$\hat{R}_t - \hat{R}^*_t = (1 - \tilde{\phi}_s) E_t \Delta \hat{S}_{t+1} - \tilde{\phi}_s \Delta \hat{S}_t - \tilde{\phi}_a \hat{a}_t + \hat{\tilde{\phi}}_t, \tag{13}$$

where ϕ represents the exogenous risk premium.

Consumption Euler equation

$$\begin{aligned}\hat{c}_t &= \frac{\mu^z b}{(\mu^z)^2 + \beta b^2} \hat{c}_{t-1} + \frac{\beta \mu^z b}{(\mu^z)^2 + \beta b^2} E_t \hat{c}_{t+1} - \frac{\mu^z b}{(\mu^z)^2 + \beta b^2} \left(\hat{\mu}^z_t - \beta E_t \hat{\mu}^z_{t+1}\right) \\ &- \frac{(\mu^z - b)(\mu^z - \beta b)}{(\mu^z)^2 + \beta b^2} \left(\hat{\psi}^z_t + \hat{\gamma}^{c,d}_t\right) + \frac{\mu^z - b}{(\mu^z)^2 + \beta b^2} \left(\mu^z \hat{\xi}^c_t - \beta b E_t \hat{\xi}^c_{t+1}\right)\end{aligned} \tag{14}$$

Investment Euler equation

$$\hat{i}_t = \frac{1}{1+\beta}\left[\beta E_t \hat{i}_{t+1} + \hat{i}_{t-1} + \beta E_t \hat{\mu}^z_{t+1} - \mu^z_t\right] + \frac{1}{(\mu^z)^2 \phi_i (1+\beta)} \left(\hat{P}^k_t - \hat{\gamma}^{i,d}_t + \hat{\xi}^i_t\right) \tag{15}$$

Wage setting condition

$$\hat{w}_t = -\frac{1}{\eta_1}\left[\begin{array}{l} \eta_0 \hat{w}_{t-1} + \eta_2 E_t \hat{w}_{t+1} + \eta_3 \left(\hat{\pi}^d_t - \hat{\tilde{\pi}}^c_t\right) + \eta_4 \left(E_t \hat{\pi}^d_{t+1} - \rho_\pi \hat{\tilde{\pi}}^c_t\right) \\ + \eta_5 \left(\hat{\pi}^c_{t-1} - \hat{\tilde{\pi}}^c_t\right) + \eta_6 \left(\hat{\pi}^c_t - \rho_\pi \hat{\tilde{\pi}}^c_t\right) + \eta_7 \hat{\psi}^z_t + \eta_8 \hat{H}_t + \eta_9 \hat{\xi}^h_t \end{array}\right] \tag{16}$$

Firms

Three types of firms exist: domestic firms, importing firms and exporting firms, and they set prices for their respective produce as follows:

Domestic firms price setting

$$\begin{aligned}\hat{\pi}_t^d - \hat{\bar{\pi}}_t^c &= \frac{\beta}{1+\beta\,\kappa_d}\left(E_t\hat{\pi}_{t+1}^d - \rho_\pi\hat{\bar{\pi}}_t^c\right) + \frac{\kappa_d}{1+\beta\,\kappa_d}\left(\hat{\pi}_{t-1}^d - \hat{\bar{\pi}}_t^c\right) - \frac{\beta\,\kappa_d\,(1-\rho_\pi)}{1+\beta\,\kappa_d}\hat{\bar{\pi}}_t^c \\ &+ \frac{(1-\theta_d)\,(1-\beta\,\theta_d)}{(1+\beta\,\kappa_d)\,\theta_d}\left(\hat{mc}_t^d + \hat{\lambda}_t^d\right) \end{aligned} \tag{17}$$

where marginal costs $\hat{mc}_t^d$ represent the rental rate of capital and the real wage after adjusting for gains in productivity.

Importing firms price setting

$$\begin{aligned}\hat{\pi}_t^{m,j} - \hat{\bar{\pi}}_t^c &= \frac{\beta}{1+\beta\kappa_{m,j}}\left(E_t\hat{\pi}_{t+1}^{m,j} - \rho_\pi\hat{\bar{\pi}}_t^c\right) + \frac{\kappa_{m,j}}{1+\beta\kappa_{m,j}}\left(\hat{\pi}_{t-1}^{m,j} - \hat{\bar{\pi}}_t^c\right) - \frac{\kappa_{m,j}\beta\,(1-\rho_\pi)}{1+\beta\kappa_{m,j}}\hat{\bar{\pi}}_t^c \\ &+ \frac{\left(1-\theta_{m,j}\right)\left(1-\beta\theta_{m,j}\right)}{\left(1+\beta\kappa_{m,j}\right)\theta_{m,j}}\left(\hat{mc}_t^{m,j} + \hat{\lambda}_t^{m,j}\right) \end{aligned} \tag{18}$$

where marginal costs $\hat{mc}^{m,j}$ of importers represent the relative price of imported goods to the domestic price level, and $j \in \{c, i\}$ captures either consumption or investment goods

Exporting firms price setting

$$\begin{aligned}\hat{\pi}_t^x - \hat{\bar{\pi}}_t^c &= \frac{\beta}{1+\beta\kappa_x}\left(E_t\hat{\pi}_{t+1}^x - \rho_\pi\hat{\bar{\pi}}_t^c\right) + \frac{\kappa_x}{1+\beta\kappa_x}\left(\hat{\pi}_{t-1}^x - \hat{\bar{\pi}}_t^c\right) - \frac{\kappa_x\beta\,(1-\rho_\pi)}{1+\beta\kappa_x}\hat{\bar{\pi}}_t^c \\ &+ \frac{(1-\theta_x)\,(1-\beta\theta_x)}{(1+\beta\kappa_x)\,\theta_x}\left(\hat{mc}_t^x + \hat{\lambda}_t^x\right) \end{aligned} \tag{19}$$

where marginal costs $\hat{mc}_t^x$ of exporters represent the relative price of the domestic good to that of the export good in domestic currency.

Monetary policy

The central bank set the policy rate according to the following Taylor-type rule:

$$\hat{R}_t = \rho_R\hat{R}_{t-1} + (1-\rho_R)\left[\hat{\bar{\pi}}_t^c + \phi_\pi\left(\hat{\pi}_{t+1}^{c,4} - \hat{\bar{\pi}}_t^c\right) + \phi_{\Delta\pi}\hat{\pi}_t^c + \phi_y\hat{y}_t + \phi_{\Delta y}\Delta\hat{y}_t\right] + \varepsilon_t^R \tag{20}$$

Market clearing

The market clearing condition ensures that everything that is produced, is consumed or invested, albeit at home or abroad:

$$\begin{aligned}\hat{y}_t &= (1-\vartheta_c)\left(\gamma^{c,d}\right)^{\eta_c}\frac{c}{y}\left(\hat{c}_t+\eta_c\hat{\gamma}_t^{c,d}\right)+(1-\vartheta_i)\left(\gamma^{i,d}\right)^{\eta_i}\frac{i}{y}\left(\hat{i}_t+\eta_i\hat{\gamma}_t^{i,d}\right)\\ &+ g_y\hat{g}_t+\frac{y^*}{y}\left(\hat{y}_t^*-\eta_f\hat{\gamma}_t^{x,*}+\hat{\tilde{z}}_t^*\right)+\frac{r^k}{\mu^z}\frac{k}{y}\left(\hat{k}_t^s-\hat{k}_t\right)\end{aligned} \tag{21}$$

The foreign economy

For the purposes of this analysis, the foreign economy is represented by the FSGM's processes for global output, global inflation, a global interest rate and a global risk premium.