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Comparing the SARB's Quarterly Projection Model to the "Core" macro-econometric model – September 2017

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Abstract

The aim of this note is to highlight the differences between the Bank's "Core" econometric model and the Quarterly Projection Model (QPM). We illustrate some of the benefits of general equilibrium models "GEM's", and focus on the four key "gaps" of the QPM. Models similar to the QPM have been implemented for inflation forecasting in the central banks of New Zealand, Hungary, India, and others. The Core model relies on assumptions for the nominal interest rate and real exchange rate when generating the baseline forecast, while the QPM is a forward-looking model in which the interest rate and exchange rate are endogenously determined in the forecast.

Introduction

Similar to other central banks, the SARB uses several models to assist in the formulation of monetary policy. All models have their specific strengths and weaknesses, and the suite of models approach allows them to complement each other in order to generate better policy outcomes. Within the SARB's suite, there are two key models that play a prominent role in forecasting growth and inflation. The first is the Bank's "Core" econometric model that is a stylised structural error-correction model estimated on South Africa's historical economic relationships. The second is the Quarterly Projection Model (QPM), which is a structural macroeconomic model built on dynamic stochastic general equilibrium (DSGE) fundamentals.[2,3]

The key difference between the two is that when used for forecasting, the Core model relies on the assumed trend of the repo rate and real exchange rate over the full projection period.[4] In contrast, the QPM allows for both the interest rate and exchange rate to be endogenously determined in the forecast. Here, it is the actual forecasts of inflation and real GDP "output" that ultimately determines the repo rate's path. In addition, the trajectory of the repo simultaneously drives the trend of the exchange rate in the forecast. The QPM is also forward-looking, ensuring that expectations of the future contribute to the behavioural patterns of economic agents today.

The next section briefly discusses the properties of both models, before the impulse responses of the QPM and Core model are compared for a selection of shocks. Thereafter, historical decompositions are used to analise (explain) South Africa's growth and inflation outcomes since the inception of the inflation targeting policy framework in February 2000. The note then concludes with a table and brief summary of the key differences between the two models.

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[2] For technical details on the QPM, see *The Quarterly Projection Model of the SARB*, Working Paper 17/01.

[3] Over the last two decades, many central banks have adopted the use of QPM-style models as part of their forecasting and policy analysis process. A non-exhaustive list includes the Bank of Canada (1996), the Reserve Bank of New Zealand (2015), the Czech National Bank (2003), the Hungarian National Bank (2013), and more recently, the Reserve Bank of India (2016).

[4] The MPC usually makes the assumption that the real effective exchange rate will remain unchanged from its current level, while the nominal repo rate remains fixed at the prevailing rate.

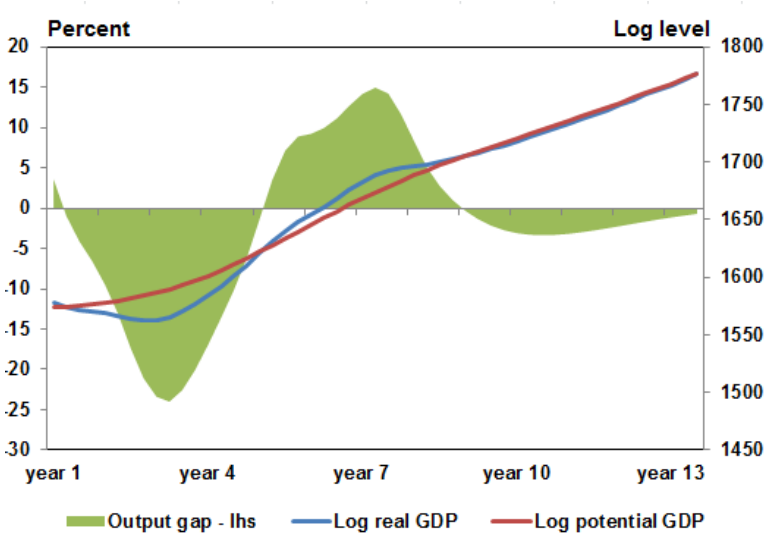
Properties of, and comparisons between the Core and QPM models

The Core model provides a highly detailed representation of the South African economy. The various components of aggregate demand are modelled separately to allow for focussed discussions on the individual roles of consumption, investment, government expenditure, and net exports to real GDP.[5] In terms of inflation, headline CPI is broken down into its core component, food prices, and the administered price component (including the prices of fuel and electricity). The various equations of the model are individually estimated with historical data that roughly spans the previous two decades.

The QPM is a "gap model" that provides a more aggregated view of the economy and how it can be expected to evolve over time. These so-called gaps reflect the degree to which the economy deviates from its long-run equilibrium path, and there are four key gaps that are of particular interest: (1) the output gap; (2) the exchange rate gap; (3) the inflation gap; and (4) the real interest rate gap. Within this structure, given other shocks to the economy, monetary policy closes these gaps over time and thereby generates convergence back to the long-run equilibrium path.

The drivers of the QPM's four most important gaps are discussed in greater below:

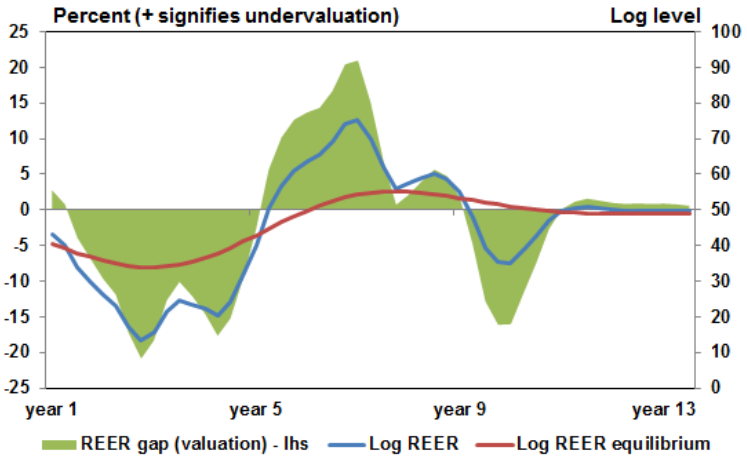
1. **The output gap:** The deviation of the level of output from its potential level. If the current level of real GDP is the same as potential, this gap would be zero and there would be no excess or insufficient demand exerting pressure on inflation. The output gap and these concepts are illustrated in the hypothetical graph below:



   The three key factors in the QPM that influence the domestic output gap are the real interest rate gap, the real exchange rate gap that captures the extent that the over/undervaluation of the currency impacts on the countries net export position, and foreign demand pressures expressed in the form of a foreign output gap.

2. **The real exchange rate gap:** The deviation of the real exchange rate from its equilibrium level. The deviation of the exchange rate shows to what extent the currency is either over/undervalued, or the pressure that the currency is exerting on growth and inflation. The real exchange rate gap and these concepts are hypothetically illustrated below:

[5] Other important channels incorporated in the Core model, include the balance sheets of households, the current account of the balance of payments and the banking sector.



The real exchange rate in the model is determined by an uncovered interest parity condition (UIP) that relates expected currency movements to the risk-adjusted differential between real interest rates at home and abroad. Similarly, the equilibrium trend of the real exchange rate is defined by an equilibrium UIP condition (i.e. where the interest rates at home and abroad are represented by their neutral levels and the equilibrium country risk premium).

3. **The inflation gap:** The deviation of the rate of headline CPI inflation from the mid-point of the three to six per cent inflation target band. Driven *inter alia* by the two gaps stated above, wage pressures and the expectations of future inflation. The QPM allows for the headline CPI to be explicitly decomposed into its non-core and core subcomponents, where non-core inflation components such as food, fuel, and electricity are separately defined.

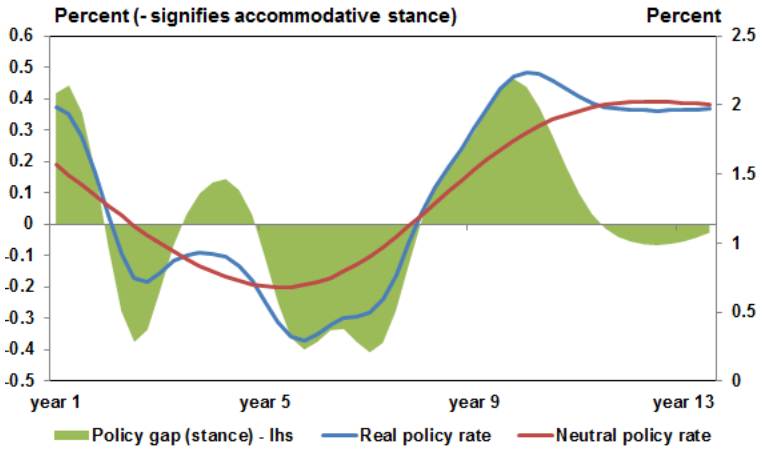
    - CPI food inflation is determined by international food prices, the exchange rate, domestic demand, and input costs related to labour and fuel.
    - Fuel prices are primarily determined by the international oil price and the exchange rate.
    - Electricity inflation is generally treated as exogenous, and is assumed to follow a prescribed path over the forecast period.

    Core CPI is split into core services and core goods, with both subcomponents largely determined by real wage pressures, the real exchange rate gap, imported inflation, the output gap and inflation expectations.[6]

4. **The real interest rate gap:** The deviation of the real (short-term) interest rate from its neutral level.[7] The real interest rate gap illustrates to what extent monetary policy is considered to be accomodative or restrictive, and is calculated as the nominal interest rate minus expected inflation. Here, the nominal short-term interest rate is determined by the central bank's policy reaction function as depicted by a "Taylor-type" rule. The nominal repo rate in this version of the Taylor rule reacts to the deviation of forecast inflation from the target midpoint, as well as the extent of the domestic output gap. The real interest rate gap and the neutral real rate are illustrated in the hypothetical example below:

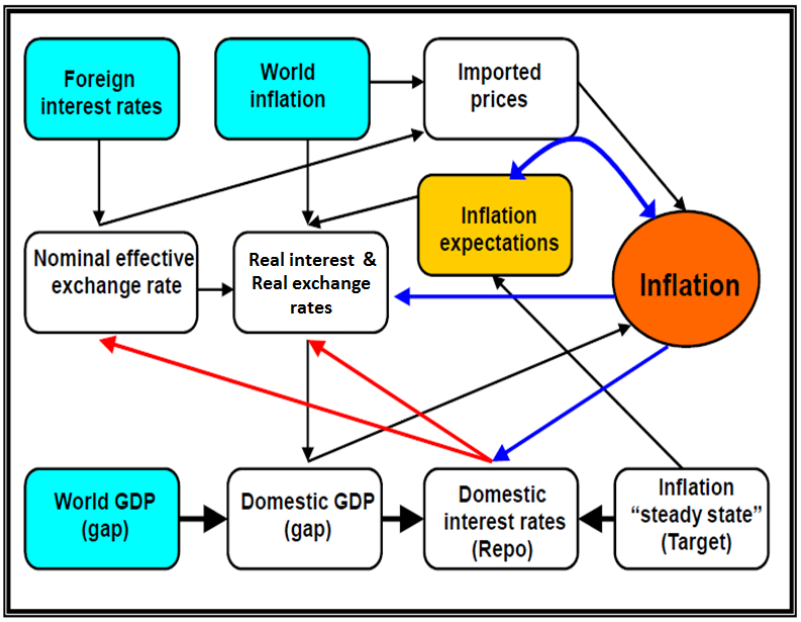
[6] All services in the CPI basket fall under core CPI.

[7] The real interest rate is calculated as the nominal interest rate minus expected inflation, i.e. where the nominal short-term interest rate is determined by the central bank's policy reaction function.



The results of the model show how long it takes for the variable to return back to its equilibrium level, and what it will take (in the form of a change to the interest rate and/or exchange rate) for the prevailing imbalance to work itself out and equalise the system. The Taylor-type rule according to which the repo rate is set in the model can be calibrated to represent the current, or past, behaviour of monetary policy in generating the optimal path to get inflation back to target. In addition, it is the neutral level of the interest rate that is of importance, since it reflects that specific level of the real interest rate that does not affect either inflation or the real economy in equilibrium. Figure 1 provides a description of the monetary policy transmission mechanism in a typical QPM, with many of the key channels and features the same as in the SARB's current QPM.

Figure 1: The Monetary Policy Transmission Mechanism in the QPM



Source: De Jager (2007)

QPM impulse responses and comparisons to the Core model

The following graphs illustrate the main properties of the QPM by means of a selection of once-off exogenous shocks to the model. All shocks are performed in reference to the model's equilibrium or steady state, so that the starting values of all variables and gaps are set at zero when the shock takes place – i.e. their steady states. The set of temporary shocks imposed on the QPM are all unexpected unitary one per cent

shocks to the very first period, so that the economic interpretation of the shock therefore depends on which part of the monetary transmission mechanism the impulse enters and then how this gradually feeds through to the rest of the models variables. The shocks are compared to the equivalent core model responses.

Figure 2: Repo rate shock

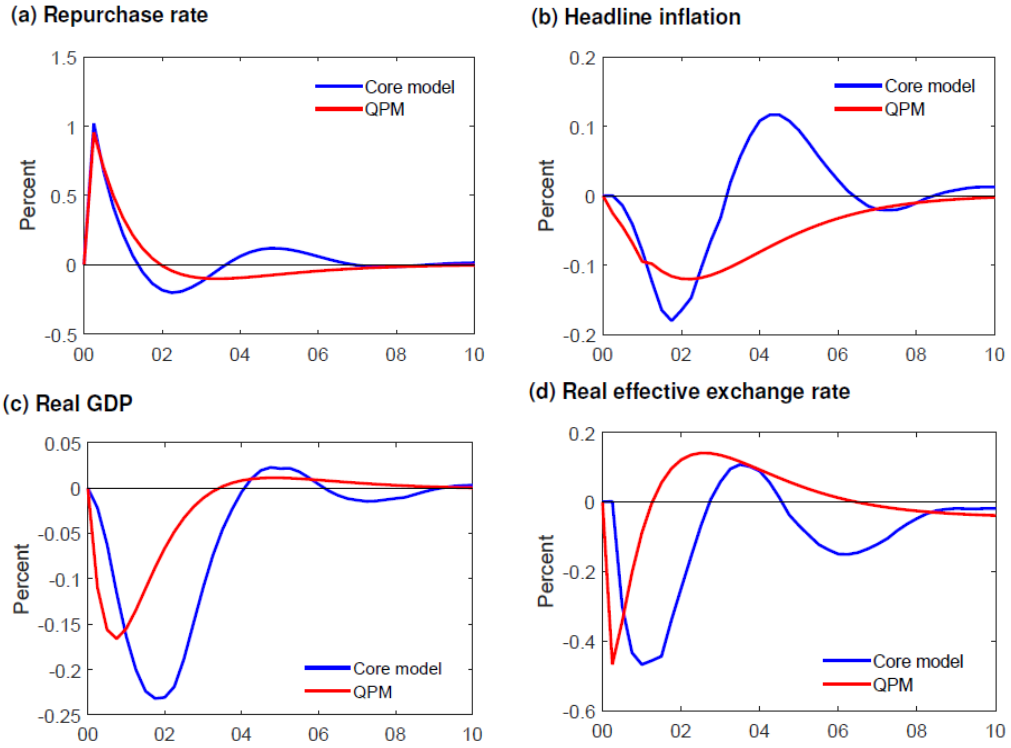
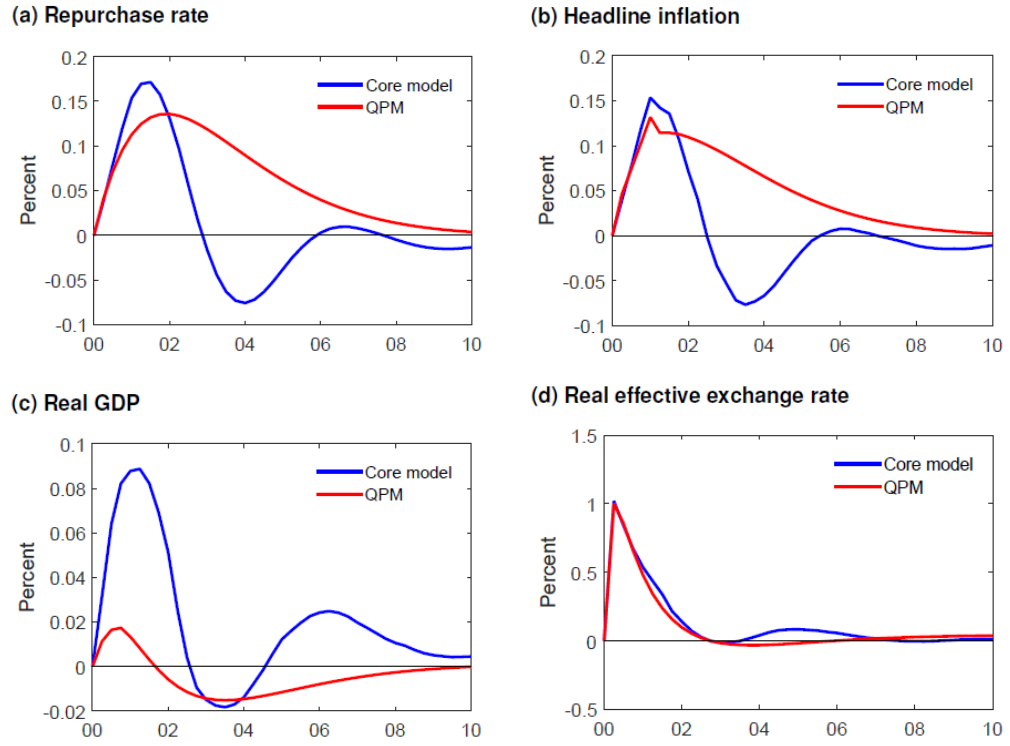


Figure 3: Real exchange rate shock

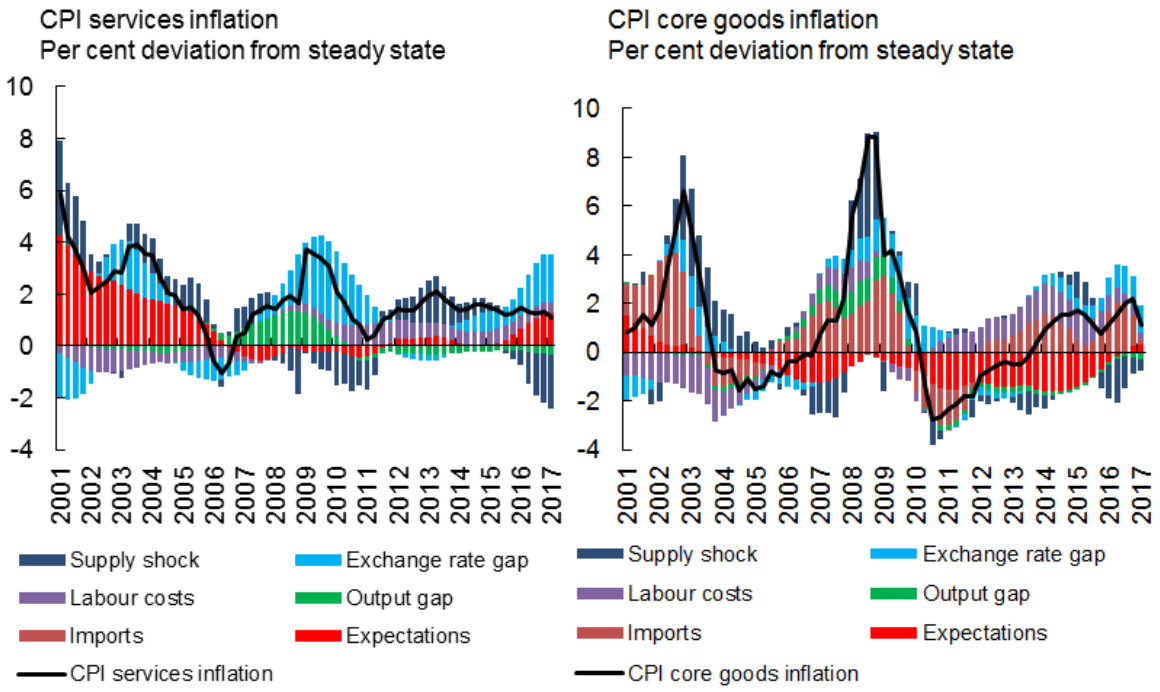


Figures 2 and 3 show that the models react fairly similarly when it comes to the imposition of temporary or transitory shocks over the initial three year policy horizon. The inherent difference in the structures of the models (i.e. where the core model is largely backward looking, while the QPM more forward looking), generally explains the different reactions to the impulse shocks over the longer term. More importantly, the results of the shocks suggest that both models converge back to zero over the longer term which confirms model stability.

Historical decompositions from the QPM

This section looks at how the model properties and data are used to decompose each key variable based on its determinants (from the equation) and shocks. The decomposition narrates the shocks from the model that have contributed to the actual variable deviating from its steady state (i.e. the origin of the pressures causing the deviation). Figure 4 shows the quarterly decompositions of services inflation (left) and core goods inflation (right), as percentage deviations from their equilibrium over the 2001 to 2017 period. The main drivers of the inflation outcomes are the real exchange rate, inflation expectations, demand, real labour costs, and the nominal exchange rate via direct imports. The currency can be seen to contribute significantly to inflation during periods of exchange rate undervaluation (i.e. 2001/02, 2008/09, and 2014 onwards). The QPM highlights the greater relative importance of the exchange rate (through intermediate inputs) and demand in the production process for services, i.e. when compared with the core goods. In addition, the direct impact of the exchange rate can be seen to be more significant, due to the higher weight of imported goods in core goods inflation (labelled imports). The QPM also shows how real labour costs rose after the financial crisis as nominal wages grew while inflation started to decline. The graphs furthermore suggest that insufficient demand has put downward pressure on inflation outcomes since 2010.

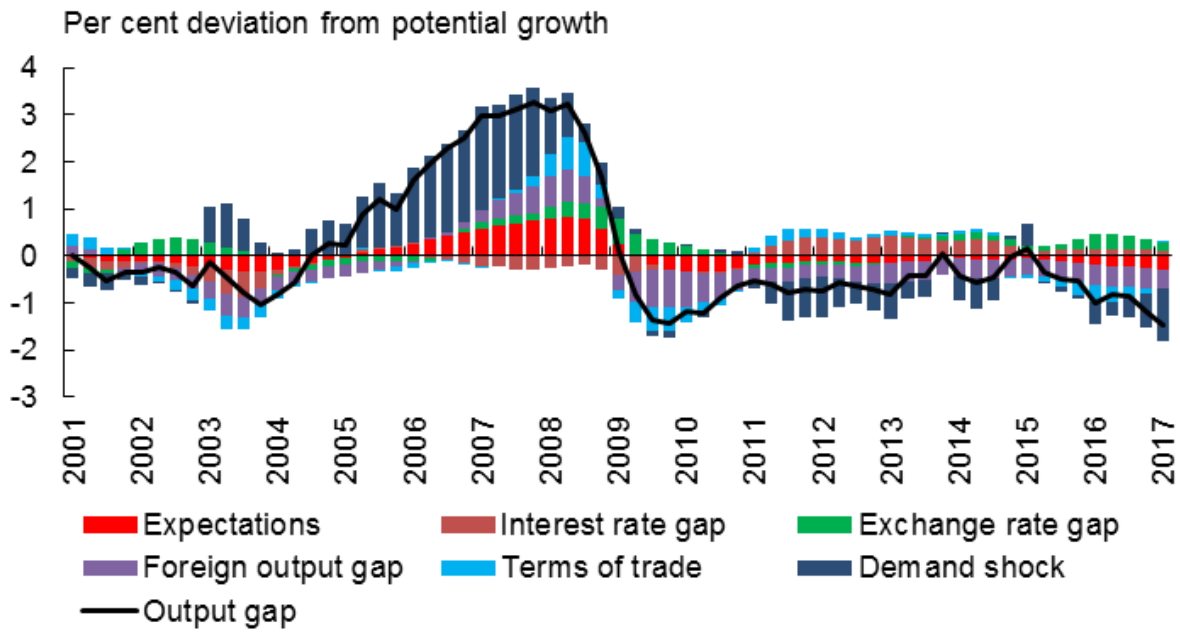
Figure 4: Decomposition of Core goods and Services inflation



The decomposition of the output gap in Figure 5 shows that developments in the exchange rate gap, foreign demand gap, commodity price gap (labelled terms of trade), the policy stance (the gap of the real interest rate from its natural rate), and demand shocks drive the extent of the gap. Prolonged periods of rand weakness (rand undervaluation), has helped to narrow the output gap during and following the financial crisis, and more recently since 2014. The world economy was growing strongly and initially supported the more positive output gap during the mid-2000s, but since the great recession this has subsided to contribute

negatively to the output gap. Monetary policy is expansionary since 2011, which together with the exchange rate over the last four years helped to close the output gap. By contrast, monetary policy support has lessened since 2014 as interest rates have generally increased in response to the acceleration in inflationary pressures.

Figure 5: Decomposition of the Output Gap



Long-run behaviour of the QPM

The QPM has well defined steady-states, i.e. the long-run values that the variables in the model tend to over time – some of which are shown in the equations and table that follow.

Specifically, these steady-states show the implications of choosing a particular target for inflation over the medium- to long-term. The implications follow from the model being consistent with certain exchange rate relationships put forward in economic theory. Namely, the uncovered interest rate parity (UIP) relationship, the Fisher equation, and the purchasing power parity (PPP) relationship, listed as equations 1 – 3.

$$\text{UIP relation:} \quad \underset{(2.5)}{rr} = \underset{(0.5)}{foreign\,rr} + \underset{(2.0)}{prem} + \underset{(0.0)}{E_t\Delta(reer_{t+1})} \tag{1}$$

$$\text{Fisher equation:} \quad \underset{(7.0)}{rn} = \underset{(2.5)}{rr} + \underset{(4.5)}{inflation} \tag{2}$$

$$\text{PPP relation:} \quad \underset{(2.5)}{\Delta(neer)} = \underset{(0.0)}{\Delta(reer)} + \underset{(4.5-2.0)}{(inflation - foreign\,inflation)} \tag{3}$$

The UIP condition in Equation 1 states that investors will be indifferent between investing in country A and country B if the risk-adjusted (real) rates of return, rr, are equal across the two countries.[8] The Fisher equation merely states that the difference between real and nominal rates, rn, is the inflation rate. Equation

[8] Where $prem$ is the risk premium and $E_t\Delta(reer_{t+1})$ is the expected depreciation of the real effective exchange rate in the next period.

3 states that if a good were priced in a currency common to two countries, then the price of that good should be equal in the two countries (over the medium- to long-term).[9]

Table 1: Steady-states of the QPM

Policy variables	**Domestic**	**Foreign**
Inflation target	4.5	2.0
Neutral real interest rate	2.5	0.5
Neutral nominal interest rate	7.0	2.5
Exchange rates		
Real exchange rate depreciation	0.0	
Nominal exchange rate depreciation	2.5	
Risk-premium	2.0	

Steady state value chosen by policy maker

Steady states calibrated to match data characteristics

Value derived to ensure steady state consistency

Using these equations, we see that an inflation target of 4.5%, taking the steady-states highlighted in yellow in Table 1 as given, implies the the neutral repo rate is 7.0%. Put differently a repo of 7% is the level of the policy interest rate that is consistent with an inflation target of 4.5%.

The key differences between the QPM and the Core model and conclusions

The QPM differs from the core model, by being forward-looking, with a "rational expectations" structure, i.e. relative to the more backward-looking "adaptive" nature of the core model's error-correction model structure. From a model consistency and policy perspective, the QPM is perhaps superior in this regard as it is modelled within a general equilibrium framework that derives the monetary policy stance and exchange rates endogenously.

To conclude, some of the key differences between the models are clarified in the comparison below.

Estimation of model parameters[10]:

QPM

- Model calibration and estimation of parameters with "Bayesian" priors to constrain the mean and variance of the estimated parameter within feasible limits

Core model

- Individually estimated behavioural equations in a cointegrated "error-correction" framework, with the calibration of some of the key homogeneous relationships
- Compiled to generate form the full model

[9] Where $\Delta neer$ is the nominal effective deprecation and $\Delta reer$ is the real effective depreciation. Technically the PPP relationship presented in Equation 3 is stated in terms of growth rates and is therefore the "relative" PPP.

[10] Bayesian econometrics allows the modeller to inform a parameter estimate with his/her prior beliefs about the value of that parameter.

Key focus areas of the model:

QPM
- Endogenous interest rate path
- Output gap and the exchange rate gap
- Inflation rate
- Decomposition of variables into the underlying structural shocks of the model

Core model
- Inflation rate
- Real GDP growth and the components of aggregate demand
- Interest rates and the real exchange rate are exogenous to the model

Disaggregation of the model

QPM
- Highly aggregated model concentrating on the four main gaps
- Disaggregation to sectoral components largely by ratio adjustment, core model scenario results or evidence from supplementary research

Core model
- More disaggregated to illustrate the various sectors of the economy
- Detailed expenditure components classification
- Current account of the balance of payments
- Credit and wealth channels
- Government revenue/expenditures
- Macro-prudential channels

Model shocks/residuals:

QPM
- Shocks provide for other off-model effects not provided for in the model structure
- All shocks are stationary and converge to zero over the projection period to ensure steady-state is achieved

Core model
- Shocks account for other off-model effects not provided for in the model structure
- All residuals are stationary, but do not necessarily converge to zero over the projection period

Model consistency:

QPM
- Model is theoretically consistent
- Interest rate is used as primary lever to converge gaps to steady state research
- Central Bank is an active agent in the economic system, that must work to control inflation
- Model has well defined steady-states (e.g. inflation of 4.5

Core model
- Model is theoretically consistent
- Homogeneity is imposed on behavioural relationships in individual equations to ensure long-run stability of the model
- Results generally converge to the historical average as the steady-state
- Central Bank is a passive agent (constant repo), inflation does not run away without its involvement

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