

South African Reserve Bank Working Paper

A steady state QPM model for the South African economy

S de Jager

Working Papers describe research in progress and are intended to elicit comments and contribute to debate. The views expressed are those of the author(s) and do not necessarily represent those of the South African Reserve Bank or Reserve Bank policy. While every precaution is taken to ensure the accuracy of information, the South African Reserve Bank shall not be liable to any person for inaccurate information or opinions contained herein.



South African Reserve Bank

**South African Reserve Bank Working Paper
Research**

A steady state QPM model for the South African economy

Prepared by S de Jager¹

Authorised for external distribution by Brian Kahn

November 2007

Abstract

Policy makers of central banks in an inflation targeting framework need confidence in a model to forecast and analyse the key factors influencing the future rate of inflation. A model does not necessarily need to be sophisticated to ensure forecast consistency, and a great deal of innovative development in simplified modelling methods and techniques has taken place over the last few years. This study describes a small structural Quarterly Projection Model (QPM) as an addition to the South African Reserve Bank's current suite of models for monetary policy purposes. The model differs from conventional models in that the coefficients are calibrated and the model has well defined steady state properties to generate a balanced growth path for the economy. At its core are four key equations: an aggregate demand or IS curve, a price setting or Phillips curve, an uncovered interest rate parity condition for the effective exchange rate, and a monetary policy reaction rule. The model expresses these variables in terms of their deviation (or gap) from their equilibrium levels and highlights the role of monetary policy in ensuring that the model projection returns to its long run equilibrium steady state. This essentially means that the emphasis in the QPM forecast now shifts to the reaction of monetary policy as it responds to the model's exchange rate, inflation and real output projections. The study elucidates the use of the model and the calibration of the QPM, thereafter it is put through a battery of hypothetical temporary and permanent shocks to validate its structure. The research paper then concludes with an exercise on how the model can be used for forecasting purposes. The QPM was found to be successful in not only producing a reliable forecast, but also in its ability to provide a consistent explanation or economic coherent interpretation of a shock – i.e. a model characteristic generally considered to be important in an inflation targeting environment.

JEL classification: E52, E47, C51

Key words: Monetary policy modelling, QPM, forecasting and simulating, forward-looking rational expectations, steady state equilibrium.

Corresponding author's e-mail address: Shaun.deJager@resbank.co.za

¹ Valuable assistance in the development of the model and preparation of this document was provided by Dr Jaromir Benes and Dr David Vavra originally from the Czech National Bank. Assistance in the form of helpful comments and suggestions by Mr Coen Pretorius and other staff members of the Research Department is also gratefully acknowledged.

Table of Contents

1	Introduction	1
2	The Quarterly Projection Model	2
2.1	The structure of the QPM model	5
2.1.1	The aggregate demand curve equation	6
2.1.2	The Phillips curve equation	6
2.1.3	The uncovered interest rate parity equation	6
2.1.4	The policy reaction function	7
2.1.5	The inflation expectations equation	7
2.2	The transmission mechanism in the QPM	7
3	Analysing the link between the data and theoretical structure of the QPM	9
4	Shocks to the model	14
4.1	Temporary shocks initiated to the QPM	14
4.1.1	A demand shock	15
4.1.2	A supply side shock	16
4.1.3	An exchange rate depreciation shock	18
4.1.4	An oil-price shock	19
4.1.5	An increase in interest rates (Repo rate)	21
4.2	Permanent or steady state shocks initiated to the QPM	23
4.2.1	A decline in the steady state inflation rate (target)	23
4.3	A delayed policy response to an external shock to QPM	24
5	Forecasting with the QPM	26
6	Concluding remarks	32
	References	34
	Appendix :	36

List of Figures

Figure 1	The transmission mechanism of monetary policy in the QPM	8
Figure 2	The output gap and its influence on CPIX(μ) rates of inflation	10
Figure 3	The import price and its influence on the CPIX(μ) rate of inflation	11
Figure 4	The oil price and factors influencing import prices	12
Figure 5	The real monetary conditions index and the output gap	13
Figure 6	The components of the real monetary conditions	14
Figure 7	The demand shock in the QPM	15
Figure 8	The supply shock in the QPM	17
Figure 9	The exchange rate depreciation in the QPM	18
Figure 10	The effect of the oil price on inflation in QPM	20
Figure 11	The overall effect of the oil price on key variables in the QPM	21
Figure 12	The effect of more restrictive monetary policy in the QPM	22
Figure 13	The effect of a disinflationary shock (new steady state) in QPM	24
Figure 14	The effect of the delayed response of monetary policy in QPM	25
Figure 15	Forecasting with the QPM– the real, nominal and R/\$ exchange rates	27
Figure 16	Forecasting with the QPM– Base and near term forecast (Inflation rates)	28
Figure 17	Forecasting with the QPM– Base and near term forecast (Output)	29
Figure 18	Forecasting with the QPM– Base and the near term forecast (Interest rates)	30
Figure 19	Forecasting with the QPM– Base and the near term forecast (RMCI)	31

List of Tables

Table 1	The gap model	4
---------	---------------------	---

The large majority of central banks that have adopted the inflation targeting framework feel the need to clarify and understand the key factors that influence the future rate of inflation. There has been a great deal of innovative development with regard to modelling methods and techniques to achieve this, and much of this has taken place in the past decade. However, it should be noted that although the actual forecast of the inflation rate plays a prominent role in the monetary policy decision making process, it is certainly not the overriding factor that determines the future trend in the domestic official interest rate.

There are numerous internal and external factors that can potentially alter the current state and future outlook for inflation and the economy in general. In addition, the long and variable lags associated with a monetary policy stance can at times complicate or even distort the transmission channels of monetary policy. Central banks have accordingly opted to develop models in a well defined manner, i.e. one that brings inflation gradually back to its equilibrium level (or steady state) after an exogenous shock temporarily causes it to drift away from its target. The aim of the Quarterly Projection Model (QPM) is therefore not only to produce an accurate estimate of the key economic variables, but also to be able to tell a consistent story with regard to the economic interpretation and impact of the shock. For example, if inflation suddenly increases (or falls), the model will need to distinguish between competing explanations such as a productivity shock, a demand shock, exchange rate pass-through, energy prices, cost shock, or any other special factors. This means the model needs to be based on all available evidence, and secondly needs to contain a well-articulated view on how the economy is perceived to function. Coletti (2004) states that a model (such as the QPM) can be used as a tool where staff can interpret the source of the shock, trace the key channels through which the shock impacts on the economy, assess the implications for future inflationary pressures, and also recommend an interest rate response that ensures inflation returns back to the target after a period of time.

The emphasis becomes greater in an inflation targeting environment where the central bank strives to promote transparency in its policy decision making process and communication with external parties. The structure and projection from a QPM type of model serves not only as a reference for discussions leading up to the monetary policy decision making process, but also assists policy committee members to effectively organise their thoughts on the outlook and interpretation of an important shock on the economy when communicating with an external audience.

In addition, central bankers generally prefer to focus on the macroeconomic dynamics of the economy's equilibrium rather than on a static description of its estimated features. This confirms the view that monetary policy is interested in the economic phenomena associated to the economy's long-run equilibrium trends, - and of course, any impacts that may cause either a temporary or permanent deviation from these equilibrium trends. Of special concern and relevance is the deviation of the trajectory from the economy's long-run balanced economic growth path, as this disequilibrium condition holds important consequences for inflation, exchange rates and other external imbalances (Kral, 2004).

The QPM incorporates the paradigm of a new Keynesian economy², with its main feature being a simplified “gap model” that explicitly formulates the role of monetary policy in the economy. This QPM model is largely based on a small stylised general equilibrium model that has been amended to replicate the characteristics of the South African economy. It is a simplified, reduced form structural behavioural model, and in some cases a rule-of-thumb (ad hoc) approach has been used to structure the model’s equations. To ensure the QPM’s relevance to the South African economy, the model needs to empirically verify that its properties are compatible and reflects some of the stylised facts of the South African economy. Econometric estimation therefore plays a rather restricted role in quantifying the relationships in the model, and it is rather the calibration of the models parameters to replicate these stylised facts that feature prominently during the development phase.

This study first identifies the key characteristics of the QPM model before briefly discussing the role of calibration and how it is used to generate a suitable set of parameters for the model in Section 2. The remainder of Section 2 is dedicated to the structure and transmission mechanism of monetary policy in the QPM. The QPM strives to replicate economic relationships in the model and Section 3 makes reference to the link between trends in the actual data and the structure of the model. Although the model has a well defined steady state, it needs to undergo a number of rigorous tests and shocks before it can be used for policy use. Section 4 makes reference to some of the results from these imposed permanent and temporary shocks. These include a temporary shock to demand, inflation, the exchange rate and an oil price shock before concluding with a monetary policy shock. The QPM also caters for a permanent shock (i.e. where the steady state is altered), and reference is made to the economic effects of a lowered inflation target in Section 4.2. Thereafter, Section 4.3 illustrates the consequences of a time delay to the implementation of monetary policy in the model. The analysis of the model is finalised in Section 5 where the QPM is used in an exercise to project the future paths of the key economic variables and most importantly the nominal interest rate. The study then concludes with a few general remarks on the use of the QPM for monetary policy formulation and implementation purposes.

2 The Quarterly Projection Model

A model does not need to be sophisticated or complex to ensure the consistency of the forecast. Laxton and Scott (2000) state that the first step towards successful inflation targeting in a small open economy is to develop a simple model of the economy, i.e. a model that embodies the policymaker’s views of the monetary policy transmission mechanism. The model may be fairly simple and practical, but will need to formalise a consensus view on how key macroeconomic variables respond to the

² The “New Keynesian” economists assume that wages and prices are inflexible, and therefore advocate models with “sticky” wages and prices. New Keynesian theorists rely mainly on this price stickiness to explain why monetary policy has such a strong influence on economic activity. (Mankiw, 2002).

policymaker's instruments over time³. However, it should also be able to evolve or improve over time (provided it retains its clarity). It is also for this purpose that the model should not become a complicated "black box" that only serves to aggravate efforts to interpret the transmission channels of monetary policy. The correct interpretation of the transmission channels is therefore essential and sometimes the actual data may be at odds with the economic intuition underlying the structure of the model. Most of the QPM parameters are therefore systematically chosen (calibrated) to ensure that the model evolves and replicates the consensus view at a given point in time.

Calibration of the parameters play an important role, since the trends and impulses generated by the model depends crucially on the selected parameter values. The final choice of the value depends on many different aspects. Berg, Karam and Laxton (2006a) suggest an eclectic approach, which is generally the practice followed in most model-using policymaking institutions. This process involves the choice of the coefficients that seem reasonable based on economic principles, available econometric evidence, and a basic understanding of how the economy functions. Then, once the choice of the parameter value has been made the model undergoes a battery of experimental shocks to examine how sensible the properties of the model are. The calibration process is therefore an iterative process in which the properties of the model are examined, changes to the coefficient values are made, and sometimes even the structure of the model is amended until the model behaves appropriately.

Parameter calibration differs to estimated regression analysis in that it refers to the process where the parameter is systematically changed to replicate a desired effect or trend once a shock is imposed on the system. This process involves (i) fixing the values of the parameters to those estimated in microeconomic studies and/or from the long-run averages of the data; (ii) simulating the model with these parameters in a series of synthetic shocks; (iii) computing the moments from the simulation results and comparing these to the actual data; and (iv) evaluating the model in terms of the distance between the two sets of moments (Ruge-Marcia, 2003). A further motivation for calibrating the parameters is related to the fact that suitable and reliable data is often difficult to obtain or is inadequate, the time series are too short and even more importantly, there have been many structural changes and revisions to the economic data. In terms of the QPM, the information content of the data is mainly related to replicating the dynamic response to an exogenous shock and the accurate estimation of the parameters becomes difficult if the data is unreliable (IMF, 2004). The QPM therefore emphasizes the choice of the structure of the model based on economic and not only econometric considerations⁴. The model furthermore needs to accommodate the intuition, views and perceptions of the economy which can only be derived from a variety of sources that includes personal experience, other models for similar countries and informative discussions with other reputable observers.

³ For optimal policy deliberation, the model would need to reflect the consensus views of policymakers which would probably be easier with a smaller model. In general, a carefully structured and well considered model-based analysis with a simple model proves to be far more superior to a badly-coordinated and under-resourced analysis with a complex model (Laxton & Scott, 2000 p.17).

⁴ Conventional econometric forecasting models with small errors are a complementary tool in good monetary policy analyses, but cannot substitute for equilibrium models that explicitly structure the economy and suggest an appropriate interest rate trajectory (Janssen and Vredin, 2004).

The aim of this article is to describe the structure, philosophy, and properties of a simplified QPM model, i.e. the so-called “gap model”. The model has the added benefit of incorporating forward looking inflation expectations which play an integral role in price formation process of the model. Another key feature is related to the models ability to reflect active monetary policy by endogenously setting policy variables such as the interest rate and exchange rate. This, in turn, allows for the forming of expectations to be used as another indirect but very important channel of the transmission mechanism (Gavura and Reľovský, 2005).

Table 1 The gap model

Text box 1 : The gap model

The focus of the gap model is to capture and replicate the essential macroeconomic relationships that are of interest to monetary policy decision makers. This includes the process of clarifying the impact of monetary policy on growth in the economy, the exchange rate and ultimately inflation.

- *The gap model provides a comprehensive view of what is happening in an economy, and what steps should be taken (in a given situation) in order for the future economic development to correspond with a targeted objective (for example an inflation target).*
- *It is a simple, yet understandable model of few equations, but one that suitably provides the basis for discussion on various policy options in a current situation. At the same time it can serve to improve communications with the public.*
- *The model is based on the key assumption that monetary policy (in practice) cannot influence the fundamental long-term equilibrium trends in the economy, and therefore only reacts in respect of the cyclical features of the economy (i.e. the deviations from their long-term equilibrium trends, for example the deviation of the gross domestic product from its potential level (or output gap), since an increase in economic activity relative to its potential would signal rising future inflationary pressures and vice versa.*
- *The gap model essentially represents business cycles, and it is these cycles or gaps from their equilibrium levels that are used to derive the projected (endogenous) interest rate path.*
- *A key feature of the gap model is that it is stable in the sense that once these business cycles have played themselves out, all the gaps will settle at zero and all of the variables will converge at their equilibrium steady states.*

The QPM therefore highlights how the interest rate functions endogenously in the model, and the usual problems associated with a constant interest rate assumption. In a model in which the output gap primarily depends on both the past and expected future path of the real policy rate, it becomes important for the policy rate to be set endogenously in a forward-looking manner. Although an assumed unchanged policy rate may at first glance appear rather informative and natural from the point of view of decision making - it can prove to be quite problematic.

The impact of monetary policy in the model now highlights a new dilemma, i.e. what should now be emphasised and viewed - is it the actual trajectory of the inflation forecast, or is it rather the trend in the interest rate path that has been generated to ensure a balanced growth path and achieve the inflation target? It is for this reason that many inflation targeting central banks have now started to place more emphasis

on the interest rate path than on the actual projected trend in inflation. In fact, some central banks such as the Reserve Bank of New Zealand (RBNZ) and Norway have become so transparent that they have actually started to publish their interest rate projection. Although they generally view this approach as the perfect tool to convey clarity and central bank transparency, they also caution that there are certain risks which deserve careful consideration (Stephens, 2004).

The QPM model therefore provides a clear explanation of the economy by making use of well defined steady states (equilibrium levels) to generate the long-run balanced growth path. All the parameters of the model have been calibrated to ensure a smooth transition to the balanced growth path. This is an important feature of the model since all the key variables (irrespective of where they start from⁵) are programmed to asymptotically trend towards their equilibrium levels in the long-run.

This is the main reason why these models are referred to as “gap-models”, as it is the gap or deviation from the steady state that is of interest to economists. Stated alternatively, the policy maker is concerned with how long it takes for the variable to return back to its equilibrium level, and more importantly what it will take (in the form of a change to the interest rate and/or exchange rate) for this imbalance to work itself through and equalize the system.

Given the forward looking nature of the model and the fact that the model is a fairly simplified abstract or explanation of reality, it cannot be expected to fit all the historical trend and data movements, structural breaks and past unsystematic features of the economy (Kral, 2004). These features are nevertheless important and would require expert explanation to take them into consideration when identifying the initial conditions.

2.1 The structure of the QPM model

The QPM offers a clear and consistent method to derive the inflation forecast and its associated policy interest rate. It also offers a structurally sound means to organise thoughts and communicate monetary policy decisions internally to senior bank staff, as well as externally in the form of public addresses and statements. In addition, the structure and results from the model can be used to encourage forward-looking agents to formulate their expectations according to the systematic reactions of the central bank.

Although the QPM is not theoretically micro-founded with optimising agents (such as a DSGE model), it is based on the new Keynesian economy paradigm. Due to the important role that monetary policy plays in the model, it uses the concept of a real monetary conditions index (MCI) to make provision and monitor monetary policy pressures.

⁵ The starting point or point of origin in the forecast is often referred to as the initial condition of the variable in the projection.

There are five important gaps that need to be highlighted and included in the QPM:

- **The inflation gap:** The deviation of the rate of CPIX inflation from the inflation target (or its steady state level).
- **The output gap:** The deviation of the level of output from its potential level. If the current rate of economic growth is the same as the potential, this gap would be zero and will therefore be at the steady state or balanced growth path.
- **The real interest rate gap:** The deviation of the real (short-term) interest rate from its neutral level. 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 exchange rate gap:** The deviation of the real exchange rate from its equilibrium level. For this purpose the historical real exchange rate equilibrium is determined by a Hodrick-Prescott filter.
- **The real monetary conditions gap (RMCI):** The deviation of the RMCI from its equilibrium level. Obviously, if the real exchange rate gap is zero and the real interest rate gap is zero, there would be no deviation in the RMCI, and this implies that the RMCI would then be at its steady state.

These gaps are then used to generate the following five key equations of the QPM (see the appendix for the actual equations in the model):

2.1.1 The aggregate demand curve equation

The aggregate demand (IS) curve is defined in a way that suggests that the cyclical component or output gap of the economy is influenced by monetary policy (via the RMCI), foreign demand, the future growth expectation and its own persistence. For consistency, both the foreign demand and domestic growth components enter the model in the form of output gaps.

2.1.2 The Phillips curve equation

The (PC) inflation equation (aggregate supply) represents a dynamic relationship containing the output gap and systematic rational expectations. Inflation expectations are primarily influenced by past inflation (90 per cent) and the future trend in inflation (10 per cent), suggesting that inflation would tend to be high if it has recently come through a period of high inflation, or if inflation is expected to be high in future⁶.

2.1.3 The uncovered interest rate parity equation

The uncovered interest rate parity (UIP) equation relates the nominal exchange rate to the movements of the interest rate between two countries and a risk premium. It therefore suggests that in the case of a positive interest rate differential (where domestic interest rates exceed foreign interest rates) - the exchange rate must

⁶ An important feature of the inflation equation is that linear homogeneity of the price parameters has been imposed to enforce the equilibrium condition that inflation will converge to the Phillips curve steady state value.

proportionately appreciate in the long-term. The differential makes provision for the carry-trade, while the risk premium is a residual that captures all the other factors that investors consider when they allocate their scarce capital resources.

2.1.4 The policy reaction function

The interest rate equation represents a “Taylor-type” monetary policy rule for setting interest rates to minimise the deviations of variables from their target. It is expressed as the weighted sum of an autoregressive term (previous rate) and the active rule of the central bank. The autoregressive nature of the policy reaction represents the conservative behaviour of the central bank, while the active rule element reacts to the deviations from the inflation target and potential output. This ensures that as inflationary pressures rise, the domestic interest rate would start to exceed its neutral level, which in turn, raises the real interest rate in an effort to constrain economic activity. The acceleration in inflation starts to diminish and revert back to target as domestic growth is lowered. The policy neutral level of the nominal interest rate reflects the level of interest rates that does not change inflation, so that once it achieves equilibrium, its effect becomes neutral and therefore does not induce (or influence) any changes in either the real or nominal variables of the economy.

2.1.5 The inflation expectations equation

The inflation expectations equation captures a weighted average of both backward (adaptive) and forward-looking (rational) agents. Since rationally behaved agents take all available information into consideration before they act, they would also take the inflation target into consideration as this has the potential to influence inflation in the future. It is worth noting that the central bank’s credibility plays an important role in determining whether inflation expectations will work in favour of the central bank. If not, the central bank may be forced to take more aggressive measures to achieve its objectives.

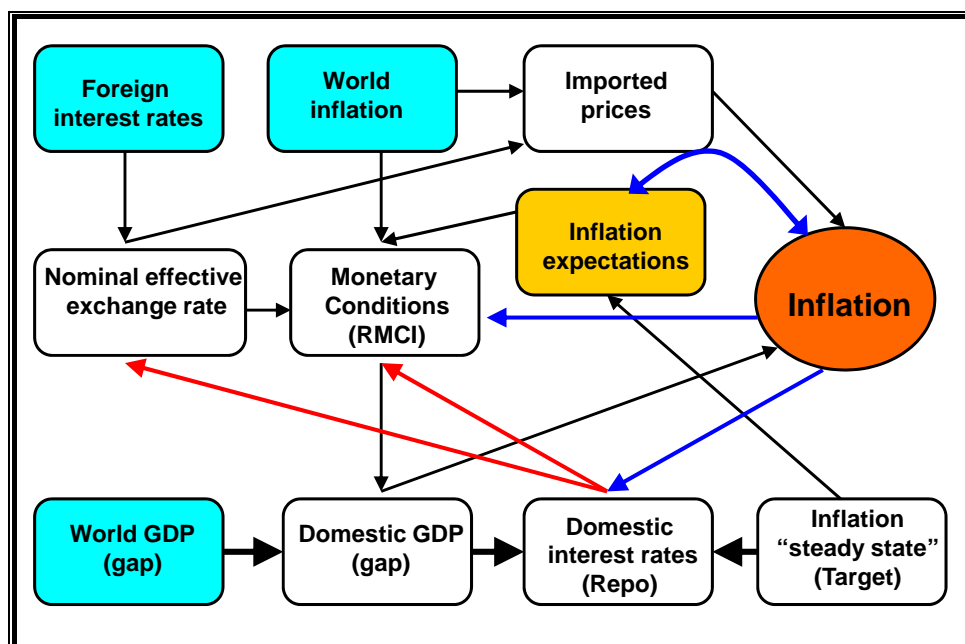
There are numerous other equations and identities in the QPM to derive variables such as core and energy inflation, nominal and real exchange rates and nominal interest rates at home and abroad within this general equilibrium framework. This is considered important in that the model needs to be structured in a manner that makes provision for the various shocks that will ultimately be used to verify its suitability for monetary policy formulation and analysis.

2.2 The transmission mechanism in the QPM

One of the aims of the QPM is to assess monetary policy so that its main emphasis is on the key factors that generate inflationary pressure. The only direct monetary policy instrument available to the South African Reserve Bank (SARB) to influence the future price level and achieve its target is via its use of the short-term repurchases interest rate (i.e. the Repo rate). Thereafter, in a small open economy (such as South Africa), the monetary policy transmission works via three distinct

channels, the real monetary conditions channel, the nominal exchange rate channel and the inflation expectations channel.

Figure 1 The transmission mechanism of monetary policy in the QPM



The role that the RMCI plays is illustrated via the influence of its individual components, i.e. the real effective exchange rate and real interest rate. The real exchange rate is used as a means to compare the relative price between domestic and foreign goods, while the real interest rate is primarily viewed as a cost for consumption and investment. The nominal effective exchange rate of the rand affects the price of imported tradable goods in South Africa, and therefore plays an important role in the transmission mechanism.

Inflation expectations also play an important role in the transmission mechanism, since it influences real demand by changing current and future consumer behavioural patterns. For instance, the SARB potentially influences public perception for future inflation by means of its monetary policy statements and the bi-annual monetary policy review. In the process (given that the central bank has a credible and reliable track record), the declared inflation trajectory would start to generate an environment where the inflation outlook of all role players in the economy converge at a consistent level of “desirable expectations” which ideally lie within the mandated inflation target⁷. In addition, stable inflation expectations helps lower the volatility of real variables such as growth in the economy, and also prevents the emergence of inflationary pressures which tend to accelerate under aggravated unstable expectations (see Barro(1995)) .

⁷ The declaration of the inflation trajectory does not necessarily mean that the public will automatically form expectations at the level of the inflation target, because rational economic agents will always consider the risk that the inflation target will not be met. However, the degree of risk generally starts to decline as the central bank gains in credibility.

Monetary policy affects the economy and stabilises inflation after a shock through two main channels. The first channel is the more traditional one in which the differential of the interest rate influences the nominal effective exchange rate, which then impacts on imported inflation. Domestic price levels and inflation expectations then react to this effect, causing actual inflation to respond fairly quickly to the change in the value of the currency (i.e. a phenomenon that holds true in most small open economies). The second refers to the reaction of the output gap or domestic demand to the implied change in monetary policy via the RMCI. In this instance, there are two effects to take into consideration, the first relates to how policy rates affect the output gap through the real interest rate, and the second refers to how the output gap reacts to a change in the nominal and real exchange rate.

To summarise, the monetary policy transmission mechanism in the QPM therefore emphasises the reaction of monetary policy to a changed economic environment. This implies a QPM interest rate trajectory that is consistent with achieving the desired steady state properties in the model after a period of time.

3 **Analysing the link between the data and theoretical structure of the QPM**

Monetary policy makers focus on the macroeconomic dynamics of an economy, i.e. the economies equilibrium and the deviation from the variables' long-run equilibrium trend (Kral, 2004). The following few graphs illustrate some of the long-run trends that economists would be interested in⁸. The graphs also highlight how some of the key variables have deviated from their long-run trends and emphasises the factors that may have contributed to this temporary deviation.

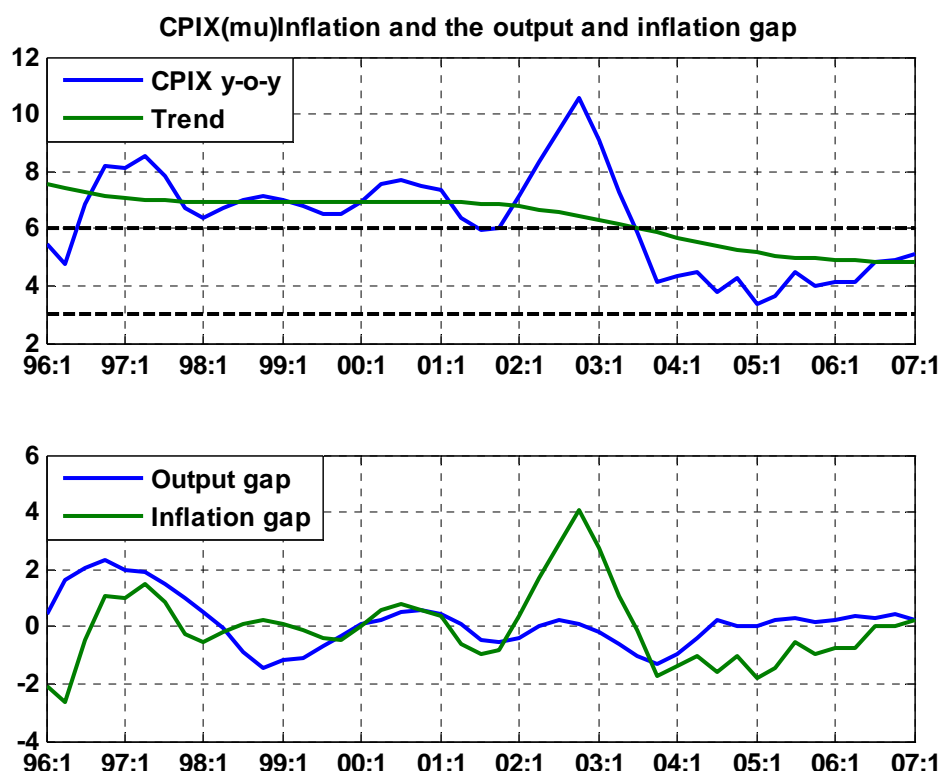
One of the key variables considered to have an important effect on the CPIX(μ) rates of inflation in the QPM is the output gap. Although there are various methods to derive the potential level of output in the output gap, the pure HP-filter method to derive trend growth followed in this study proves to be satisfactory.

The second graph in Figure 2 illustrates that there is a relationship between domestic capacity constraints (the output gap) and the inflation gap so that a rising trend in the output gap tends to raise CPIX rates of inflation and vice versa. The large deviation of actual inflation from trend inflation during 2002 also highlights another important feature of the QPM in that in order to reduce inflation, the pace of economic growth needs to be restrained via the introduction of higher domestic interest rates⁹.

⁸ In all instances, the long-run trends of the model parameters (i.e. to define the gaps) have been derived from a Hodrick-Prescott filtering process with $\lambda = 1600$ for quarterly data.

⁹ See Mboweni (2002) where the Governor states that in order to ensure long run price stability, the MPC realises that there may be negative growth effects after the introduction of a more restrictive monetary policy stance. In this case it was a 100 basis point increase in the Repo rate.

Figure 2 The output gap and its influence on CPIX(mu) rates of inflation

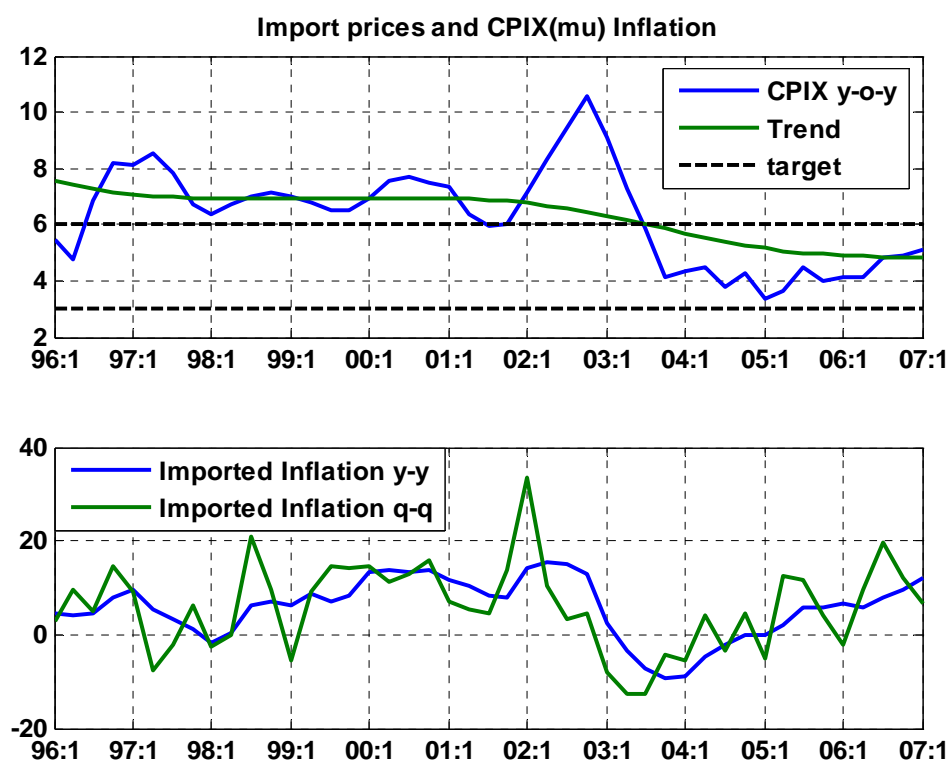


Even though the strong inflationary effect during 2002 was related to the rapid pace of depreciation over the period, there still seems to be a positive relationship between the output gap and the inflation gap. The fact that the output gap was in negative territory over much of the period from early 2003 to the middle of 2004 and only slightly positive over the remainder of the period to the second quarter of 2006 also suggests that there was not much inflationary pressure generated from capacity constraints over this period.

Another key effect on inflation is related to the exchange rate and import prices in particular. The South African economy is a small open economy, with its volume of exports and imports each contributing roughly 25 per cent of real GDP. Import prices therefore play a prominent role in generating inflationary pressures in the economy (i.e. also given the fact that the imported price component of the PPI constitutes 27 per cent of the total PPI). Associated inflationary effects emanating from an exchange rate depreciation would hence first impact on domestic input prices, before feeding through to raise CPIX(mu) rates of inflation.

Figure 3 shows that trend inflation remained relatively stable during the latter part of the 1990s, i.e. prior to the depreciation of the currency towards the end of 2001. The extent of the depreciation shock during December 2001 was so severe that it raised imported price inflation from roughly 15 per cent in the fourth quarter to more than 30 per cent at an annualised rate during the first quarter of 2002. The figure also shows that although imported inflation was on the increase over the latter part of 2004 and the second and third quarters of 2005, there may have been some other factors that managed to constrain CPIX(mu) inflation.

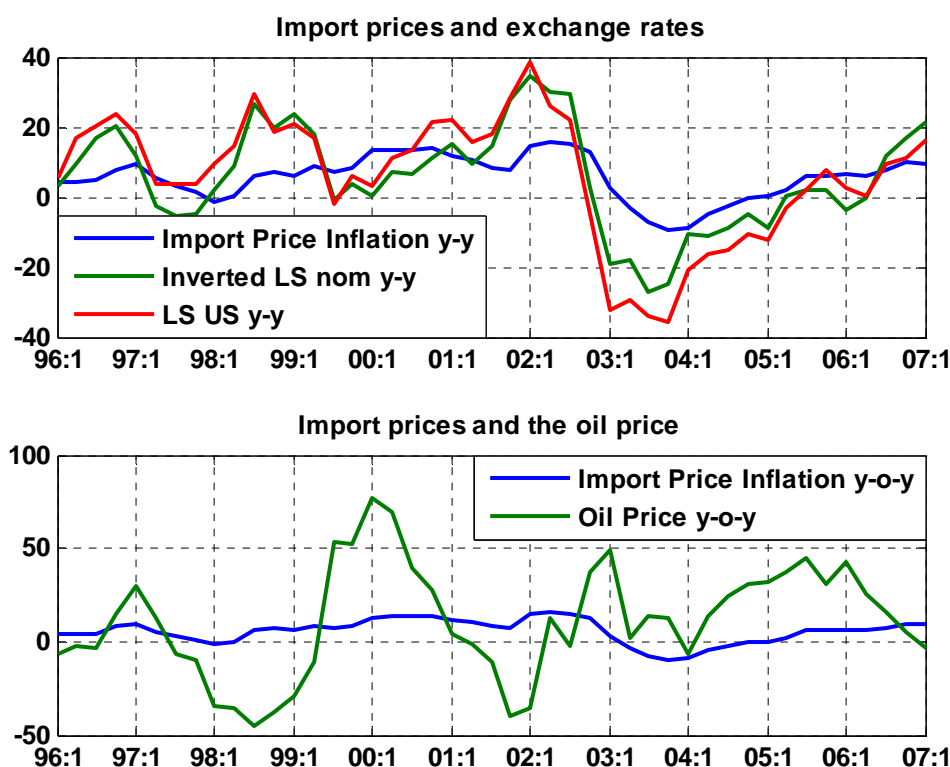
Figure 3 The import price and its influence on the CPIX(mu) rate of inflation



Besides foreign inflation, there are also other factors impacting on the import price component, such as exchange rates and oil prices. Figure 4 highlights the strong link between the year-on-year rates of change in the nominal effective exchange rate (LS nom), the Rand/US\$ (LS US) exchange rate and imported price inflation. Note that the nominal exchange rate has been inverted to illustrate how the currency depreciation towards the end of 2001 had a marked rising effect on import price inflation over the 2001 to 2002 period. The graph furthermore shows that the appreciation of the currency after December 2001 was also largely responsible for the declining trend in import price inflation over the remainder of the period to the fourth quarter of 2003.

Although it is the rate of change in the actual domestic price of petroleum that has the greater direct effect on CPIX rates of inflation, there is still a strong link between international crude oil prices and the domestic basic fuel price component of the petrol price. Due to the fact that oil import volumes comprise roughly 8 per cent of total import volumes, oil prices have a pronounced effect on the trend in import price inflation (especially over the 2004 to 2006 period). However, the graph also illustrates how much of the acceleration of the oil price over this period was negated by the simultaneous appreciation of the currency.

Figure 4 The oil price and factors influencing import prices



The output gap is reliant on interest rates and the real effective exchange rate¹⁰, i.e. the RMCI. The higher the RMCI from a more aggressive policy stance or an appreciation of the real effective exchange rate tends to make monetary conditions more restrictive which will in turn lower output growth and then inflation. The RMCI reflects a proportional combination of the real interest rate to the real exchange rate, which in the South African case is calibrated to reflect a ratio of 3:1, so that a 3 per cent exchange rate gap has about as much effect as a 1 per cent interest rate gap (de Jager, 1998).

Despite the data suggesting there may be evidence of a few lags, there is generally a negative relationship between the output gap and the RMCI shown in Figure 5. The graph shows that the output gap tends to rise during periods of relaxed monetary conditions (i.e. 1996-1997, and slightly after the 2001-2002 period), and conversely the contraction in economic activity during the more restrictive period of 2003-2004. The graph also shows that although the RMCI gap was in positive territory over much of the period from 2004 to 2006, the output gap still remained slightly positive as well. This is possibly related to two aspects, firstly that monetary conditions were still not restrictive enough, and secondly (a more likely explanation) is that domestic producers have adapted well to the more appreciated currency that actually prevailed over much of this period.

¹⁰ A real currency depreciation raises export volumes via the country's increased competitive position, while at the same time, import volumes are reduced on account of the higher import prices. Both these impacts raise real GDP growth.

Figure 5 The real monetary conditions index and the output gap

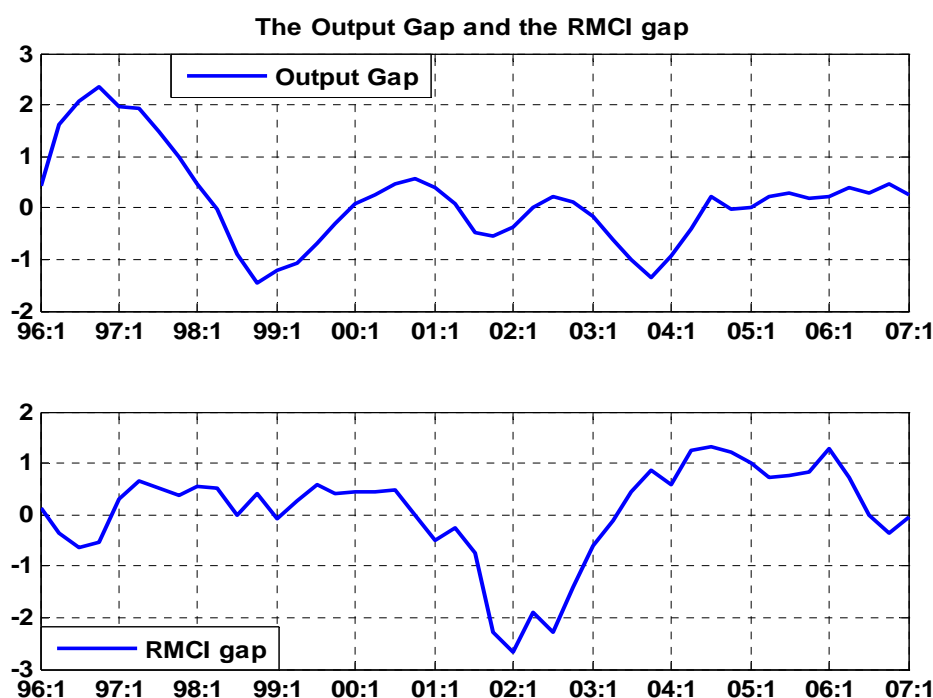
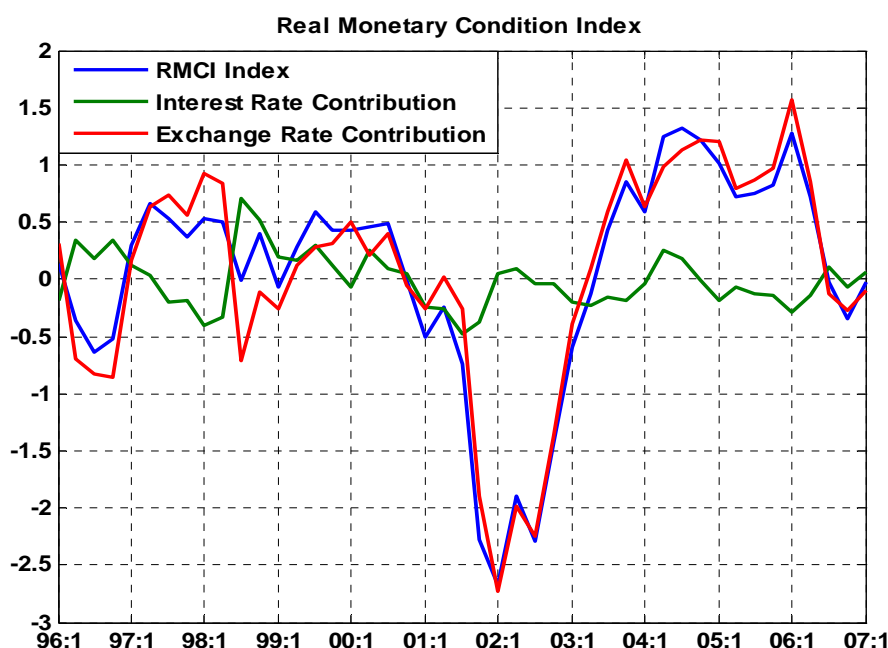


Figure 6 illustrates the respective contributions of the exchange rate and the interest rate to the RMCI. Despite its lower weight allocation and bearing in mind that all variables are reflected in gap terms, the graph shows that the real exchange rate gap plays the more prominent role in the movement of the RMCI. Not surprisingly, real interest rates are less volatile than the real exchange rate, and the fact that they tend to increase above equilibrium after periods of depreciation suggests that a policy response may have been initiated to counteract the emergence of inflationary pressures related to raised price expectations – i.e. similar to what happened after the December 2001 episode. The QPM replicates this feature so that real interest rates need to rise to constrain output growth pressure emerging from the more competitive currency, otherwise, the higher inflationary environment would merely erode the real benefits accrued from the increased domestic economic activity.

Figure 6 The components of the real monetary conditions



The next step to validate the model is to initiate a variety of shocks to the model to see how it reacts and whether this reaction is appropriate. This is an important tool to judge and interpret the models characteristics as well as understand its behaviour.

4 Shocks to the model

The dynamic behaviour of the model is analysed in the first two parts of this section, i.e. by viewing the response of various endogenous variables to a series of temporary or transitory shocks and a permanent change to the steady state inflation target. The third part of this section then reviews how key variables in the model respond to a delay in the monetary policy decision after a temporary productivity shock causes an imbalance to the system.

4.1 Temporary shocks initiated to the QPM

All shocks are performed in reference to the model's equilibrium or steady state, so that the starting values of all the variables and gaps are set at zero to ensure they originate from their steady state when the shock takes place – i.e. irrespective of what that level might actually be¹¹. The set of temporary shocks imposed on the

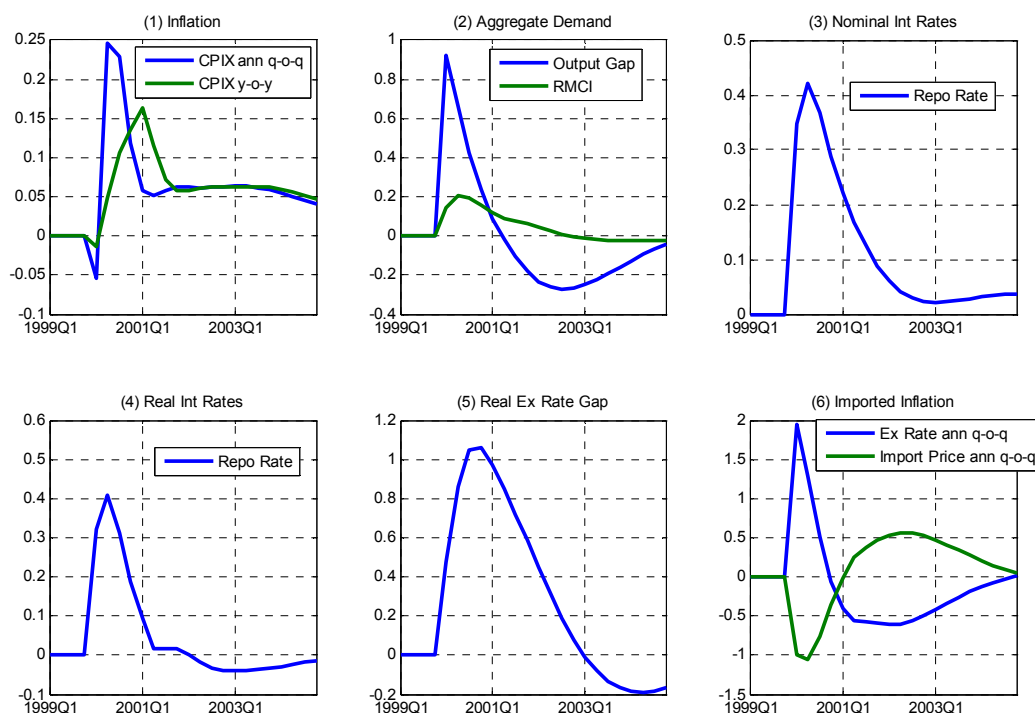
¹¹ For example, the steady state inflation target is set at 4.5 per cent (i.e. the mid point of the 3-6 per cent band), and the real exchange rate is assumed to depreciate with 1 per cent per year in steady state. It is also worth noting that these steady state values remain unchanged over all time periods.

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 variables (i.e. its transition).

4.1.1 A demand shock

The demand or domestic activity shock initiated in this experiment raises the output gap by a hypothetical one per cent in the very first quarter of the analysis. Figure 7 reveals that since the output gap creates a degree of inflationary pressure, the central bank will need to react by increasing interest rates in excess of the ensuing effect on inflationary expectations. This implies that real interest rates need to rise, and it is this effect that eventually forces the gap to return towards its steady state value of zero faster.

Figure 7 The demand shock in the QPM



The six graphs in Figure 7 reveal that with the increase in nominal and real interest rates, the real effective exchange rate starts to appreciate. Once the real exchange rate gap starts to appreciate, downward pressure is exerted on the output gap via the RMCI. It is interesting that the output gap actually has to turn negative (to less than potential) in Graph (2) after the first year in order to bring down CPIX inflation. Inflation expectations play a significant role in the transmission mechanism and would have increased from the acceleration in inflation. This makes it necessary for the central bank to keep its policy rate tighter for a while longer as it is the only instrument it has to ensure that actual output growth remains below growth potential, and thereby ensure that both inflation and inflation expectations drift back towards the target or steady state value.

The nominal interest rate in Graph (3) remains positive or above its neutral level throughout the period, whereas the real interest rate in Graph (4) becomes slightly negative as it drifts below its neutral level after the first year of the shock. This lowered real interest rate effect eventually brings the output gap in negative territory back to its equilibrium zero. Another interesting feature of the demand shock is that the real interest rate can decline to below its neutral level despite the fact that inflation (although on the decline) remains above its steady state level. This confirms that the decline in the inflation rate is related to something else than just the output gap, i.e. the appreciation of the real effective exchange rate.

The nominal exchange rate channel of the transmission mechanism seems to work at odds to the stabilizing policy of the demand shock over the short-term, in that inflation in Graph (1) declines in the very first quarter of the shock. The graphs show that directly after the monetary tightening, the nominal exchange rate starts to appreciate and cause imported price inflation and CPIX inflation to decline. The ambiguous initial price effect usually holds true for small open economies where the exchange rate pass-through is very quick. However, the nominal exchange rate then starts to depreciate in line with the gradual easing of monetary policy. Another interesting feature of the model portrayed in Graph (2) and Graph (6) is that imported price inflation is positive for the period where demand is reduced below its potential – this is directly linked to the exchange rate effect on import prices.

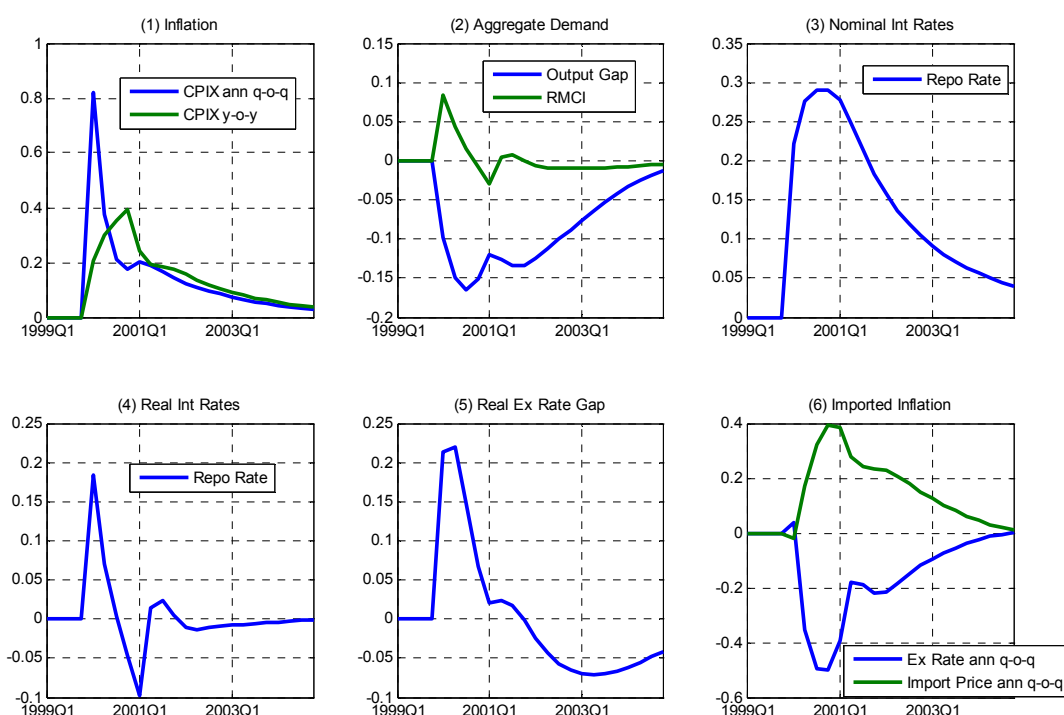
4.1.2 A supply side shock

The supply side or Phillips Curve (PC) shock in Figure 8 initiates a hypothetical increase of 1 per cent in CPIX(μ) inflation over the very first quarter of the analysis period. This type of inflation shock provides for an increase in domestic prices for a given level of domestic output, hence the reference to a supply shock.

Both the output gap and the inflation equation contain some degree of autoregressive lagged values. This implies that inflation will take a period of time to revert back to its steady state level. In fact, if the monetary authorities did not respond to the higher inflation by sufficiently raising both nominal and real interest rates, inflation would fall, but it would not decline back to its original level. The reason for this is related to the impact of inflation expectations which have been raised on account of the extended period in which inflation remains above its equilibrium level.

The supply side shock reveals that as monetary policy becomes more restrictive, domestic aggregate demand starts to weaken and cause the output gap to turn negative in much the same way as the demand shock reacted to the raised interest rate. The only exception to the demand shock is that the output gap is negative right from the start, so that actual rates of growth are less than potential over the full duration of the period under review. This negative output effect is necessary to ensure that raised inflationary expectations are constrained, and that CPIX inflation will eventually return to its steady state target.

Figure 8 The supply shock in the QPM



Nominal interest rates in Graph (3) remain positive throughout the period, whereas the real interest rate in Graph (4) turns negative by declining to below its neutral level towards the end of the first year. Although inflation persists at the higher level for longer, the negative real interest rate gap is temporary in nature and primarily designed to raise the output gap from its negative (below potential) territory back to its zero steady state. This output effect would of course also be aggravated by the real exchange rate gap that remains appreciated over much of the simulation period causing an even more restrictive RMCI.

Despite the longer term appreciation of the real exchange rate (nearly 1½ years) in Graph (5), the nominal effective exchange rate of the rand in Graph (6) appreciates only temporarily in the very first quarter, but then starts to depreciate on account of the deterioration of the differential between domestic and foreign inflation rates. This nominal depreciation of the currency does not help the stabilization process, but rather aggravates it due to the fact that the raised level of import prices adds further pressure to inflation and inflation expectations (i.e. making it more persistent).

Another aspect to keep in mind is that monetary policy is primarily concerned with year-on-year rates of CPIX inflation. Graph (1) suggests that inflation tends to remain on the increase over the first year of the simulation (due to base effects), whereas the pace of increase in quarter-on-quarter rates of inflation are only temporary and decline after the first quarter. Inflation expectations are primarily influenced by the year-on-year rates of inflation so that these expectations tend to increase in the first year after the shock has been initiated. This implies that while expectations remain on the increase, the pace of increase in the quarterly rates of inflation is on the decline. A consequence of this is that it can complicate the

stabilization policy, and since it is the only channel to reduce inflation – nominal interest rates need to remain higher to keep real interest rates sufficiently tight enough to ensure that output and inflation return to their steady state.

4.1.3 An exchange rate depreciation shock

The previous demand and supply side shocks illustrate the more direct effects on output and inflation, while the exchange rate shock is initiated to see what happens to output and inflation in the event of an external shock. From the illustration of the transmission mechanism in Figure 1, the nominal effective exchange rate is seen to work through to imported prices, which then in turn fuels both inflation and inflation expectations. In order to validate as well as quantify this channel, the nominal effective exchange rate of the rand is assumed to depreciate by 1 per cent (4 per cent annualized) in the very first quarter of the simulation period.

An economic interpretation of a temporary depreciated value of the currency can be related to instances where foreign investors become disillusioned with their ability to generate profits in the home economy, and have now decided (albeit temporarily) to remove their funds from the economy. This type of shock can also be associated to a temporary rise in the country's risk premium.

Figure 9 The exchange rate depreciation in the QPM

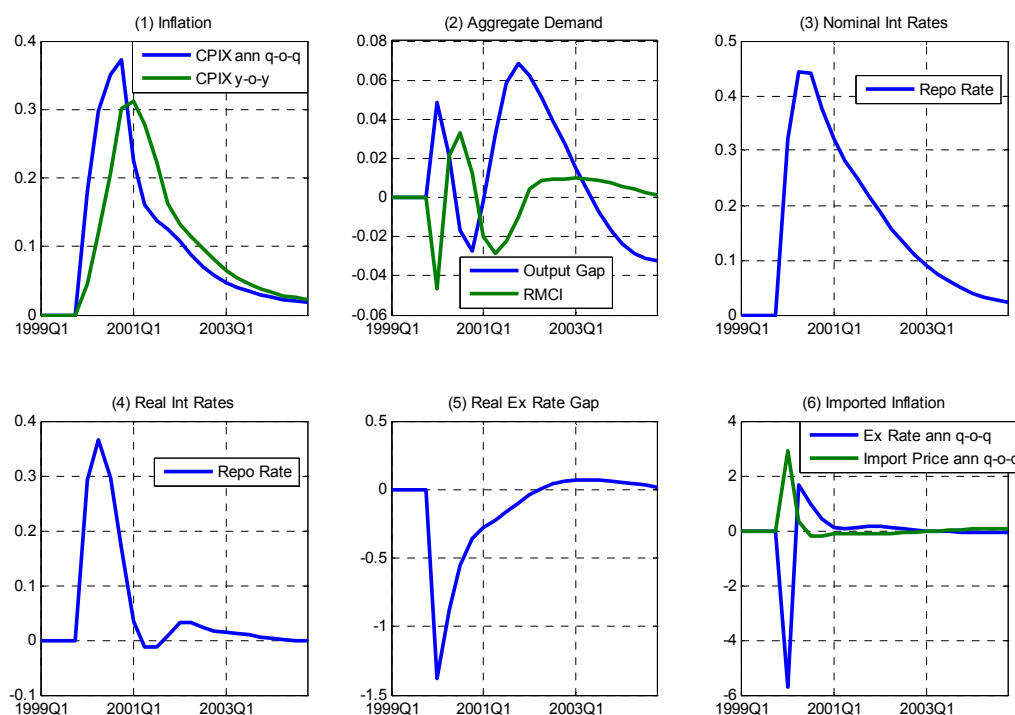


Figure 9 illustrates the effect of the shock and its consequences on real output as well as inflation. Although slight, domestic real economic activity benefits temporarily from the initial nominal and associated real depreciation of the currency (see Graph (5)). As the real exchange rate depreciation gains momentum, the RMCi is lowered

to become more accommodative in Graph (2), and it is this effect that temporarily raises the level of the output gap.

The increased inflationary effect from the output gap is amplified by the raised level of import prices from the nominal depreciation. Graph (1) shows how domestic inflationary pressures begin to increase on account of the raised level of import prices and widened output gap. This, in turn, induces a more restrictive monetary policy stance in the form of higher interest rates, i.e. so that as domestic interest rates start to increase, the output and inflation gaps start to diminish. In addition, the exchange rate would also now start to appreciate from the more improved interest rate differential. Graph (2) shows how the RMCI adjusts to above zero to become more restrictive after the initial decline from the depreciation of the currency, and it is primarily this adjustment in the RMCI that reduces output and brings inflation back towards its steady state target level.

Graph (6) in Figure 9 furthermore indicates that much of the stabilization process takes place via the secondary impact of the appreciated value of the exchange rate. This graph also shows that as the exchange rate starts to appreciate after the initial depreciation, the impact on imported inflation starts to dissipate towards the end of the first year. However, the output gap in Graph (2) remains in the positive region for a longer period of time (between two and three years after the shock) and it is this effect that prevents a quicker deceleration in inflationary pressure. In fact it is only towards the end of the third year that the output gap eventually turns negative to complete the stabilization process. More importantly, the output gap actually has to turn negative since the stabilization through the appreciated exchange rate channel is not sufficiently strong enough to bring inflation back to its steady state on its own.

This shock reflects the important role of the exchange rate channel in the stabilization process. It also shows that it may be futile to rely on demand stabilization policies after an exchange rate (or risk premium) shock, as this could be an unlikely solution in the short run. Should the exchange rate fail to sufficiently respond to an interest rate tightening, other interventions may need to be considered.

4.1.4 An oil-price shock

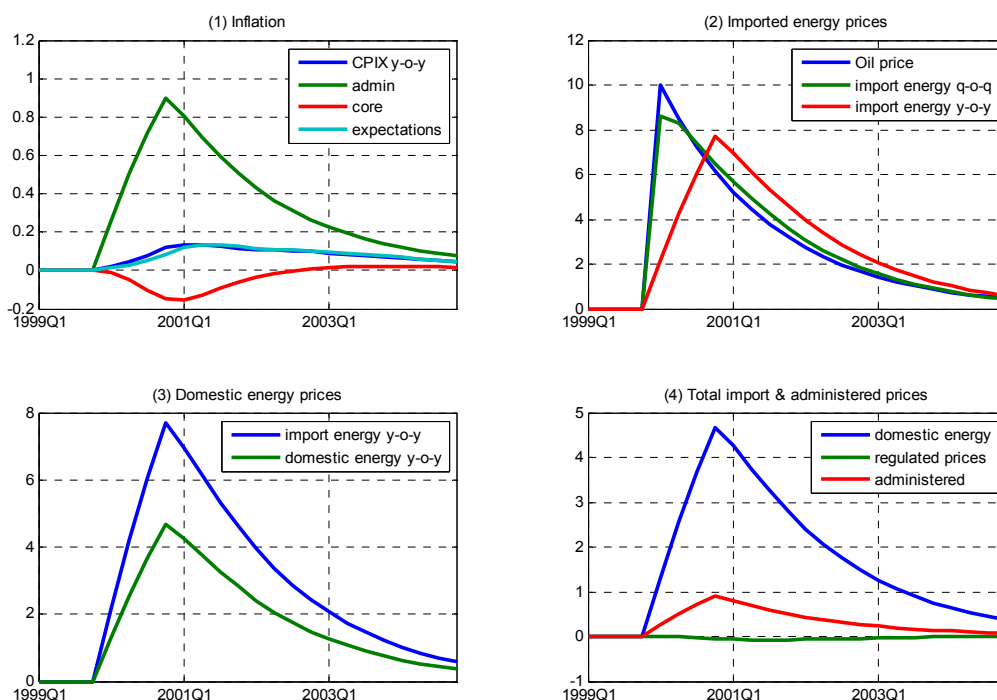
South Africa, being a small open economy, is sensitive to volatile oil prices and other associated supply side shocks. Under normal circumstances, an oil price increase raises petroleum prices on the international market and this would in turn raise the basic fuel price component of the petrol price charged domestically¹². The official petrol price is increased by the change in the basic fuel price and this raises the petrol price component of the CPIX with a weight of roughly 5 per cent. The petrol price also features in administered prices which account for 20 per cent of the total CPIX, so that petrol prices comprise approximately $\frac{1}{4}$ of the total administered prices. Therefore, for every 10 per cent increase in the oil price, only 5 per cent works directly through to increase the petrol price and influence the CPIX by means of its weight in the total index. In this scenario, the direct effect of the 10 per cent increase

¹² The basic fuel price comprises approximately half of the official petrol price charged in South Africa, i.e. with the rest consisting of wholesale and retail margins, fuel levies and other taxes.

in the oil price can be expected to add 0,25 per cent to total CPIX and roughly 1 per cent to administered price inflation.

The QPM is structured to ensure that the full effect of an increase in the oil price has a direct proportional impact on imported energy prices. Domestic energy prices are assumed to reflect only petroleum products and comprise 60 per cent imported energy prices, with the remaining 40 per cent produced domestically (for Sasol etc). Domestic energy (i.e. petrol prices) then feed directly through to the total CPIX(mu) with its official weight of slightly more than 5 per cent.

Figure 10 The effect of the oil price on inflation in QPM

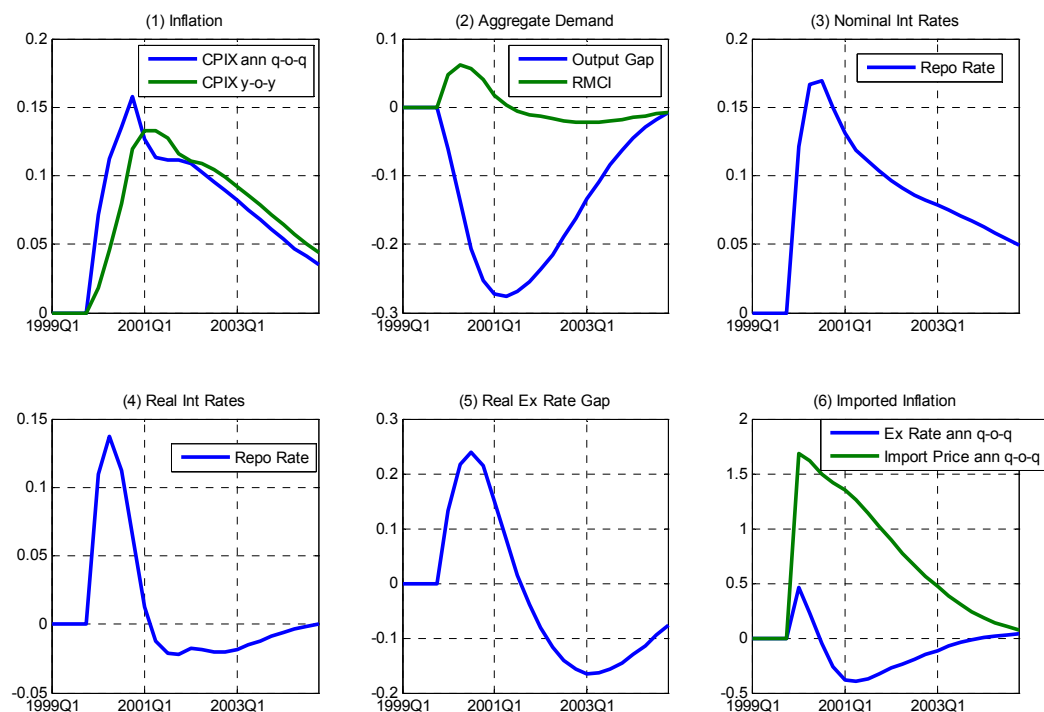


Graph (2) in Figure 10 shows that with a 10 per cent increase in the dollar oil price, imported energy prices (reflecting the oil price in rand), reacts to a slightly less extent at approximately 8½ per cent. Since import energy prices comprise 60 per cent of domestic energy prices, more than half of this effect feeds through to domestic petrol prices (roughly 4½ per cent as shown on Graph (3)). Graph (4) illustrates that with a 10 per cent increase in oil prices domestic energy (petrol) can increase by 4½ per cent and administered prices with slightly below one per cent (0,9 per cent). Other administered prices excluding petrol are referred to as regulated prices, but as expected these do not change significantly.

The impact of the oil price on CPIX inflation is interesting in that Graph (1) shows that as petrol prices affect administered prices, total CPIX(mu) increases to slightly below 0,2 per cent (i.e. a little below anticipated from the direct impact of 0,25 per cent). The graph furthermore shows that the total effect (direct and indirect) on CPIX(mu) is diminished due to the declining effect on core inflation (CPIX excluding petrol and

regulated prices). In this instance core inflation reacts to the higher interest rates generated by the inflationary effect of higher petrol prices.

Figure 11 The overall effect of the oil price on key variables in the QPM



In terms of the rest of the simulation, the effects are fairly similar to the previous exercises in that the higher nominal and real interest rate (induced from the raised level of CPIX inflation) causes an appreciation of the real effective exchange rate. The tighter monetary conditions (RMCI) from the real exchange rate and interest rate then start to create a negative output gap which eventually exerts downward pressure on prices and eventually brings inflation back towards its steady state target.

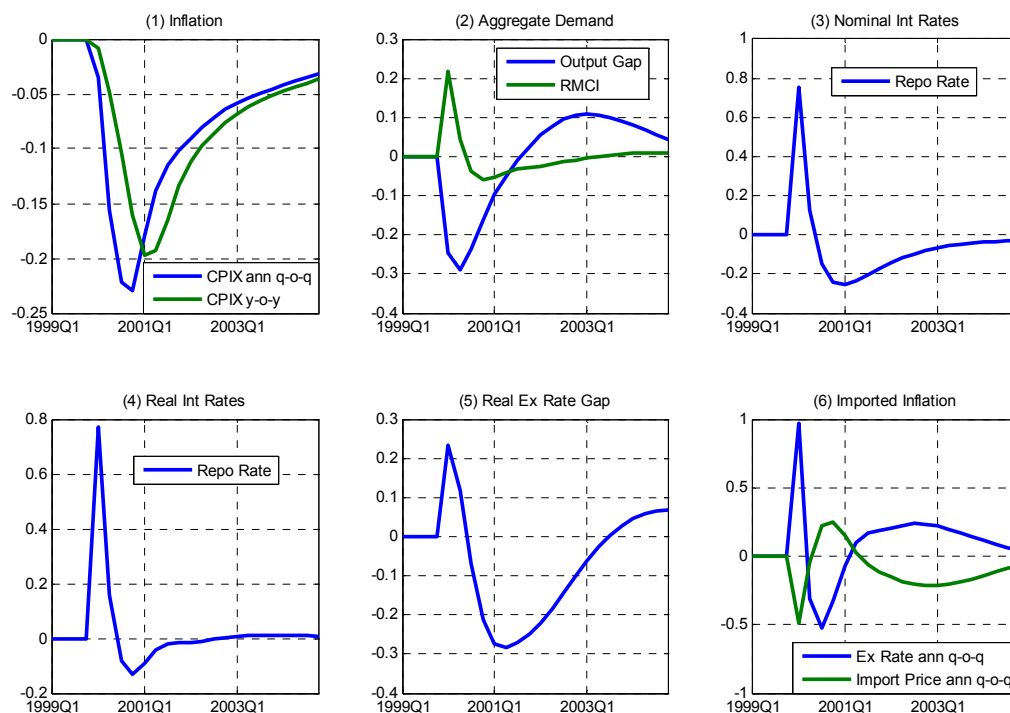
4.1.5 An increase in interest rates (Repo rate)

This shock where the interest rate is hypothetically raised is considerably different from the same shock to the structural estimated model in which the exogenous interest rate is assumed to remain constant over the forecast period. Usually, in this type of model, a policy shock of this nature would imply that interest rates would rise with 100 basis points and remain there for a considerable time period. This is not the case in QPM.

Given that the model economy originates from its steady state, there would be no real reason for any policy interference in the first place. The hypothetical increase in the interest rate is therefore viewed in the QPM as an unnecessary policy shock and can actually be viewed as a mistake that should never have taken place. The QPM sees the shock in this light, and the effect of this unexpected shock to the system

would need to be corrected, i.e. the policy maker immediately observes the error and attempts to undo the impact of the higher interest rate shock¹³. Of course the initial shock to QPM (100 basis points) in the first quarter can be extended to two or three quarters, but this would mean that the policy rule in the model needs to react even more aggressively to rectify the imposed imbalance.

Figure 12 The effect of more restrictive monetary policy in the QPM



The graphs illustrated in Figure 12 nevertheless show what happens in QPM after an unanticipated interest rate shock is imposed on the system. The higher level of interest rates causes the real exchange rate to rise, which will in turn cause monetary conditions to become more restrictive (i.e. the raised level of the RMCI in Graph (2)). Economic activity reacts to the more restrictive monetary conditions and this starts to create a negative output gap where actual GDP growth declines to below potential. Another aspect to consider is that as the nominal exchange rate starts to appreciate (from the interest and inflation differential) imported inflation starts to decline – although this effect will only be temporary in nature (see Graph (6)). The interest rate trends shown in Graphs (3) and (4) furthermore illustrate that as both the imported price component and the pace of demand induced inflation starts to fall, monetary policy reacts and interest rates start to decline. The decline in the nominal interest rate is significant in that it actually has to fall below its pre-shock level in order to stabilize the economy – this is done by first eliminating the lower output gap, and then by stimulating real output to above potential until the equilibrium is reached.

¹³ Effective policy decisions are only known ex post. QPM anchors price expectations to the systematic and predictable reaction of monetary policy to shocks (simplified by a Taylor type rule), and will therefore always strive to correct the imbalance or mistake in this instance (Benes, Hargreaves and Vavra, 2003).

4.2 Permanent or steady state shocks initiated to the QPM

In this section, the transition of the economy from one steady state to a new steady state is analysed, for example, what happens to the economy if the steady state inflation target was lowered with one percentage point? This is usually an important issue for policy makers in that once the inflation target is well anchored and expectations are attuned to that level, the policy makers may feel obliged to lower the target to a level more consistent with rates of inflation in its major trading partner countries.

4.2.1 A decline in the steady state inflation rate (target)

This type of shock therefore involves a permanent change to one of the exogenously set steady state parameters. In this scenario only the inflation target is changed which would still ensure that the balanced growth path and the equilibrium in the model remains intact. Given this alternative scenario, the model is then solved and compared to the original inflation target baseline to examine what happens to the transition trend in real output, real and nominal interest and exchange rates, and inflation over the short to medium term.

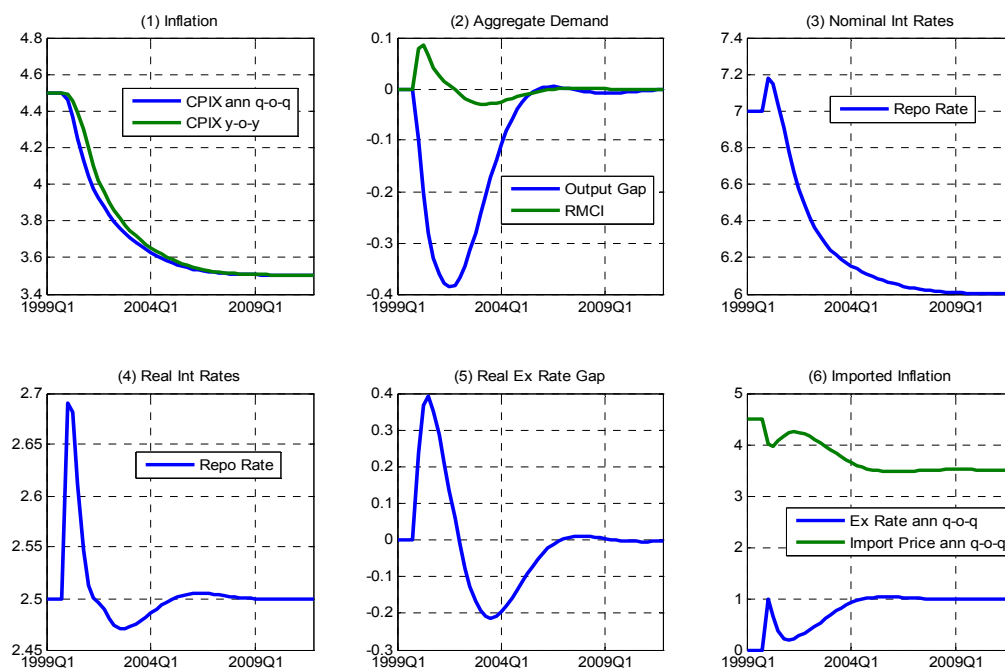
The graphs are different to the previous section as they depict the actual level of the steady state and how the transition takes place when the economy drifts from the original state to the newly defined steady state. A fundamental property of the QPM is that the central bank is **autonomous** and has enough **credibility** to ensure that market participants will adjust their inflation expectations to the newly proclaimed inflation target. The forward looking nature of the model (linked to central bank credibility) implies a smooth and immediate transition as economic agents adjust their expectations to the new inflation target. However, the interest rate path shown in Graph (3) of Figure 13 reveals that in order to lower inflation permanently, the central bank would first need to tighten monetary policy with nearly 25 basis points¹⁴.

Despite the initial increase in the interest rate, all the graphs in Figure 13 reveal a smooth transition to the new steady state. The trajectory in Graph (1) shows that as domestic inflation drifts towards the new steady state target (from 4½ to 3½ per cent), the inflation rate differential would in turn become distorted. Foreign inflation remains at 4½ per cent in steady state, so in equilibrium this distortion is fed through to the exchange rate. The local currency consequently starts to appreciate by this discrepancy (see the 1 per cent rate of appreciation in Graph (6)). This appreciation has the desired effect that local import prices also grow at 1 per cent below the original 4½ per cent, and implies that local currency import prices grow by a lower 3½ percent in the new equilibrium. Real interest rates remain unchanged between the two scenarios so that nominal interest rates converge to a new level that is also 1 per

¹⁴ If the central bank has full credibility, there should be an immediate decline in both interest rates and inflation as agents adjust their expectations to the new level of the target. The fact that the QPM suggests an initial increase in interest rates is possibly linked to the degree of forward looking behaviour contained in the model.

cent below the initial 7 per cent (see Graph (3)), i.e. in order to preserve the equilibrium real interest rate.

Figure 13 The effect of a disinflationary shock (new steady state) in QPM



4.3 A delayed policy response to an external shock to QPM

The following shock shows what happens in the QPM if there was a hypothetical temporary output (productivity) shock to the economy and the monetary authorities are reluctant to react immediately to the shock. Given this type of temporary shock to QPM, monetary policy reacts instantaneously to correct the imbalance, since the raised output gap automatically leads to increased inflationary pressure and expectations. In this alternative scenario, a situation is imposed where monetary policy makers decide to delay their reaction by keeping the Repo rate unchanged for a further two quarters. This shock therefore intends to show the economic consequence of a delayed policy reaction to inflation, output and the future trajectory of the nominal interest rate. The key variables that need to be analysed in this experiment are firstly the extent to which inflation is raised on account of the delayed policy response, and secondly the eventual increase in interest rates that would now be required to bring the economy back to its steady state equilibrium.

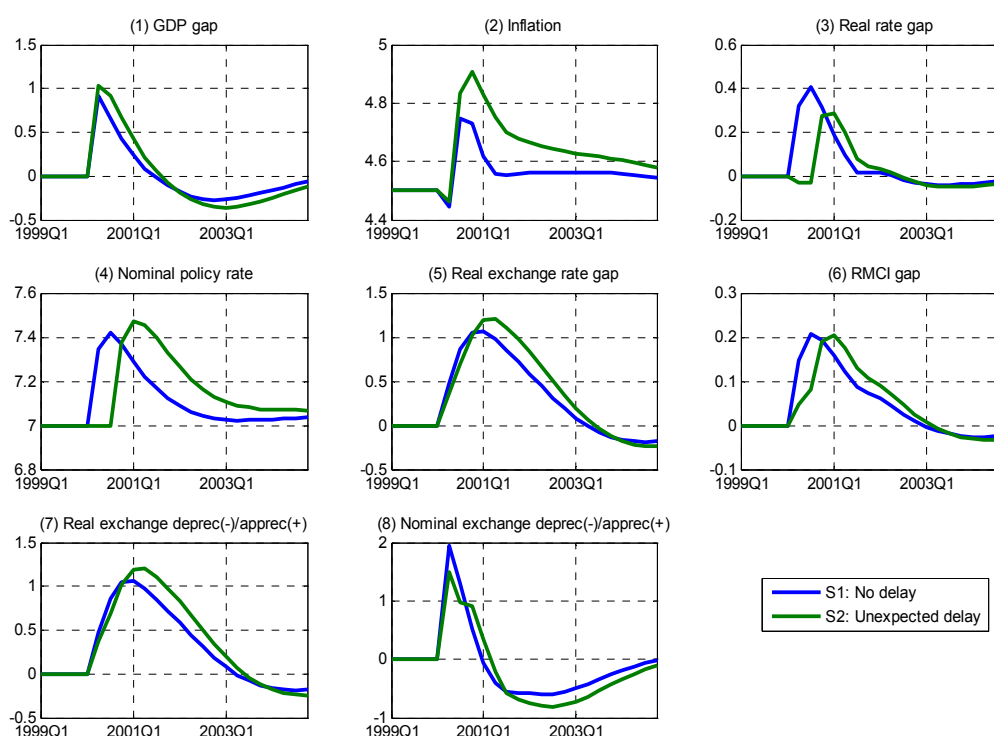
This QPM is consequently simulated twice in an effort to compare the development of the economy following a 1 per cent demand side shock in the two independent scenarios. The first is where monetary policy is allowed to react immediately to the productivity shock (similar to the shock in Section 4.1), while the second allows for a delay of two quarters before policy is allowed to react to the equilibrium imbalance:

S1 : The MPC reacts to the shock immediately.

S2 : The MPC reacts to the shock with some delay (2 quarters).

The various graphs in Figure 14 compare the model's response in both scenarios. As a result of the time delay in S2, the nominal interest rate in Graph (4) now needs to increase over and above what would initially have been required had there been no delay in the monetary policy reaction. Inflation deteriorates in reaction to the raised productivity level, but this becomes more pronounced in S2 since CPIX(mu) inflation can be expected to increase by nearly 0,2 per cent more than S1 on account of the one quarter delay (see Graph (2)). This effect will obviously be aggravated the longer the period elapses between the shock and the policy response.

Figure 14 The effect of the delayed response of monetary policy in QPM



The output gap in Graph (1) also tends to last a little longer in the delayed response scenario and it is this that aggravates inflationary pressure. The reason for this is that since the nominal interest rate remains fixed in the first two quarters, it has no power to eliminate the excess output pressures as otherwise illustrated in the first scenario. In fact, the fixed interest rate causes an initial decline in real interest rates via the higher inflation expectations that have been generated (i.e. depicted by S2's real interest rate gap decline in the very first quarter in Graph (3)). The dynamics of the inflation process start to accelerate and the central bank needs to react even more aggressively to ensure inflation returns back to its steady state target.

Another interesting aspect is that the initial real interest rate effect is largely nullified by the appreciated value of the currency (see S2 in Graph (5)), since the currency now has to remain appreciated over an extended period of time to lower inflationary

pressures emanating from the output gap. To suppress or constrain these inflationary pressures, the output gap in Graph (1) will need to turn negative, since these losses in output are necessary to return inflation to its target. This experiment clearly highlights what influence monetary policy has on maintaining price stability and without the suitable reaction of monetary policy to the shock - inflation expectations would clearly start to accelerate and aggravate actual inflation.

5 **Forecasting with the QPM**

The QPM is now used to generate a forecast over a three year period from 2007 to 2009, where the emphasis in the forecast shifts from the actual forecast of inflation to the required monetary policy stance that would ensure inflation returns to its steady state target. This exercise illustrates the importance of the initial conditions of the model (i.e. the starting points, which in this instance would be 2006q4). Another feature of the QPM forecast is that it is an unconditional forecast, which means that apart from the models long-run steady state equilibrium values, there are no other long term assumed trends in variables such as the oil price, exchange rate or even residual values for the equations etc., all of which have the potential to affect the future path of key economic variables.

Time lags associated with the release of official quarterly data means that there may be high frequency data available for some of the months prior to the published end of quarter release. These early indicators can effectively be used as preliminary values to set the current and even next few quarters for a specific variable. In this way, first round information is collected to formulate the initial conditions (or the near term forecast of the key variables of the model).

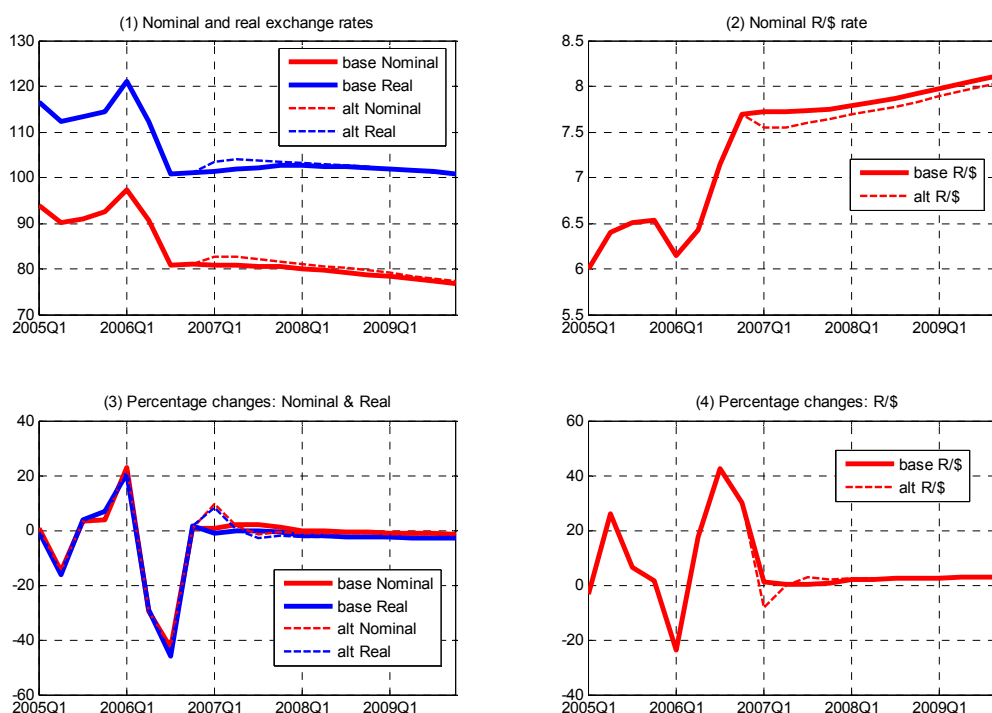
The deviation of the current or prevailing economic situation from its equilibrium level (steady state) is very important in the context of the gap model, so that only once these initial conditions have been finalised will the actual projection phase begin. In this experiment, the model is simulated under two different scenarios to illustrate the importance of the initial conditions. The first scenario refers to a baseline scenario in which the model is allowed to react immediately to prevailing imbalances (gaps), while the second scenario makes use of preliminary information to generate an assumed short-term trend over the next two quarters of the projection period. The alternative simulation therefore incorporates an assumed short-term appreciated outlook for the nominal effective exchange rate over the first and second quarters of 2007 (i.e. one that differs from the unconditional baseline projection for the nominal exchange rate). The monthly nominal exchange rate is available with very little or no time lag, which makes it easier to formulate an assumed trend for this variable over the immediate short-term¹⁵.

The graphs illustrated in Figure 15 depict what happens to the level of the nominal and real effective exchange rate as well as the R/\$ exchange rate. Note that a

¹⁵ This assumption is hypothetical and used for illustration purposes only. Generally, there are numerous other assumptions relating to the short term outlook - these can include assumptions on the interest rate, output gap and even the rate of inflation etc.

declining trend in the nominal and real effective exchange rate and a rising trend in the R/\$ exchange rate is associated with a depreciation in the value of the domestic currency.

Figure 15 Forecasting with the QPM– the real, nominal and R/\$ exchange rates

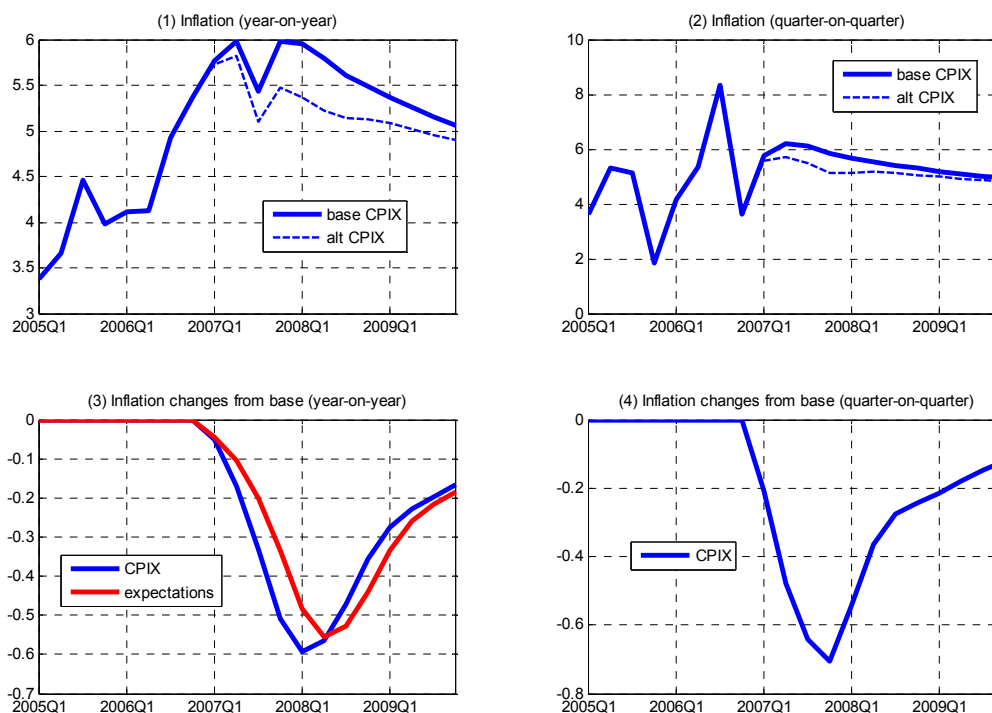


Graphs (1) and (2) of Figure 15 show that in the long run, the trajectory of the nominal and real effective exchange rates gravitate towards an imposed 1 per cent steady state level of real effective exchange rate depreciation. The R/\$ exchange rate is assumed to be inversely proportional to the nominal effective exchange rate, suggesting that any change in the nominal rate has the exact same impact on the R/\$ rate. This has the desired property that the R/\$ exchange rate will also gravitate to some constant steady state level (see the solid baseline levels of Graphs (3) and (4)). The dotted alternatives illustrated in Graph (3) show the extent of the assumed appreciation of the currency amounting to slightly less than 10 per cent at an annualised rate in the first quarter of 2007, i.e. relative to the constant level or no quarterly change of the unconditional baseline forecast.

Graphs (1) and (2) in Figure 16 show the year-on-year and annualised quarterly rates of inflation over the three-year projection period from 2007 to 2009. The baseline forecast for CPIX rates of inflation in Graph (1) suggests that inflation will increase to 5¾ per cent and 6 per cent in the first and second quarter of 2007. A slight decline back to 5½ per cent is projected for the third quarter, before inflation resumes growth momentum to reach 6 per cent in the fourth quarter of 2007 and first quarter of 2008. Thereafter, inflation gradually starts to decline to slightly above the 5 per cent level by the end of the simulation period in 2009. The quarterly annualised rates of CPIX inflation in Graph (2) show that inflation will increase from the 4 per cent in the fourth quarter of 2006 to reach roughly 6 per cent during the first three quarters of 2007,

thereafter the quarterly inflation trend is projected to resume a gradual decline to 5 per cent by the end of 2009.

Figure 16 Forecasting with the QPM– Base and near term forecast (Inflation rates)

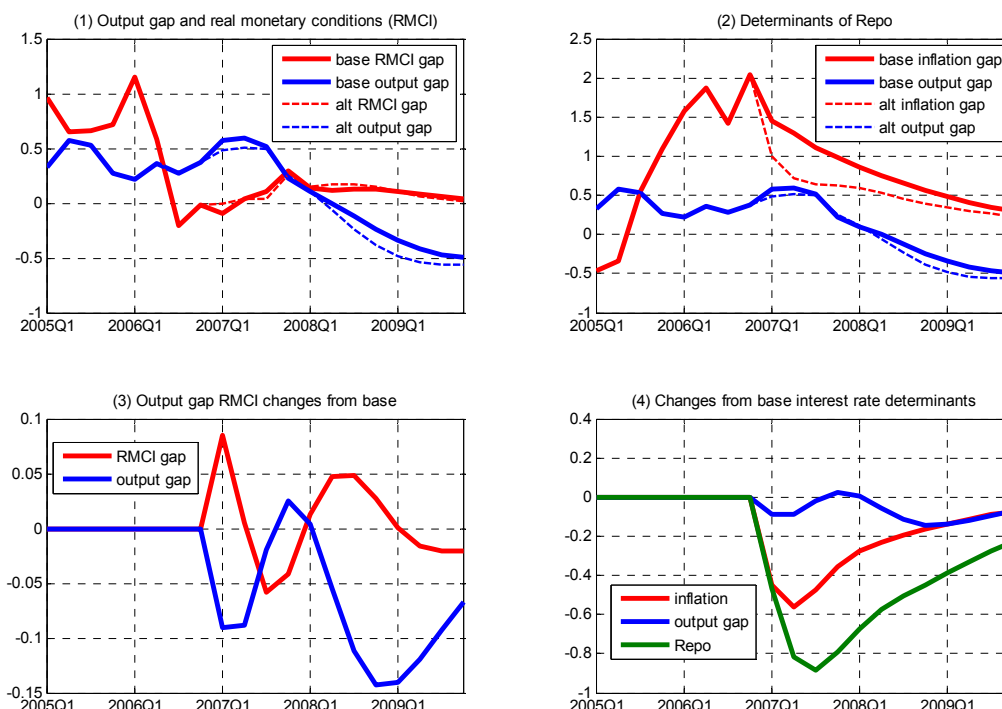


The dotted lines in Figure 16 reflect the extent that the level of inflation and inflation expectations is lowered in response to the more appreciated value of the currency imposed in the alternative scenario. Graph (3) illustrates that although expectations are on the decline they do so at a rate that is slightly slower than the decline in actual CPIX inflation. This is related to the fact that price expectations in the model is both forward and backward looking in nature, and since it has a pronounced effect on actual inflation - it plays a prominent role in the price formation process. The role of expectations in the model also illustrates the extreme importance for the central bank to lower inflation expectations in its efforts to reduce target inflation. Obviously, the more credible the central bank, the quicker inflation expectations and the actual rate of inflation will tend to gravitate back towards the steady state target level.

Graph (2) of Figure 17 shows the two determinants of the interest rate, i.e. the inflation gap and the output gap. Although on a declining trend, the inflation gap (deviation of inflation from target) remains positive, which means that interest rates need to remain more restrictive. Although output gap pressures diminish and actually become negative from the middle of 2008 (where actual output is below potential), the inflation gap is still in positive territory over the latter part of the forecast period. This is another reason why the RMCI needs to remain more restrictive, since the only way higher interest rates can cause a decline in inflation is via the RMCI impact on domestic output. Note that this may even cause a temporary

decline in output relative to potential as illustrated towards the end of the 2008 and 2009 period.

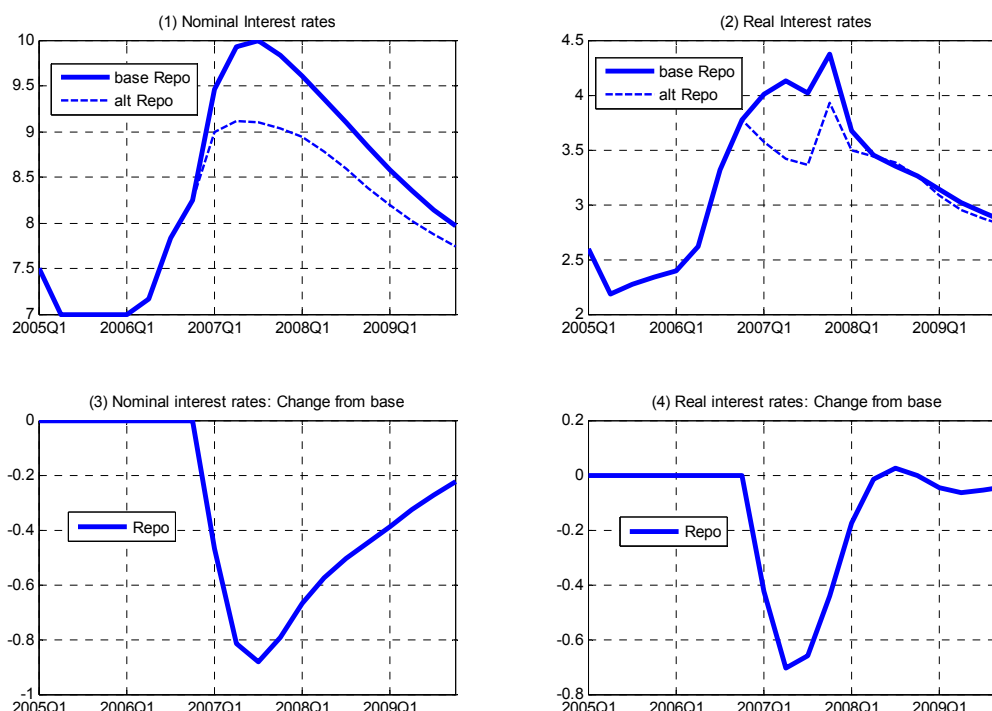
Figure 17 Forecasting with the QPM– Base and near term forecast (Output)



The dotted alternatives of Graphs (2) and (4) in Figure 17 also illustrate that as lower import prices from the appreciated value of the currency act to reduce the domestic inflationary gap closer towards its steady state target, the nominal interest rate can also be relaxed (i.e. relative to the baseline). The variables in Graph (4) furthermore reveal that in this instance, - given the projected trends in the exchange rate and output gap, the $\frac{1}{2}$ percentage point decline in inflation could lower the domestic nominal interest rate by as much as 0,8 per cent during the second and third quarter of 2007.

Graph (1) in Figure 18 reveals that in order achieve equilibrium, nominal interest rates in the baseline scenario need to increase with nearly 100 basis points in the first quarter of the forecast period, i.e. from 8,3 per cent in the fourth quarter of 2006 to slightly below 9½ per cent in the first quarter of 2007. Since baseline inflation (in Graph (1) of Figure 19) is on a rising trend from the second quarter of 2006 to the first quarter of 2007 and remains at roughly this level for the duration of 2007 it necessarily implies that base real interest rates need to show a similar rising trend over the same period. Graph (2) illustrates the rising trend in real interest rates, and the fact that they would need to remain relatively high over much of the 2007 period (i.e. in the region of 4 per cent to 4½ per cent). This is a necessary condition to ensure that inflation starts to decline back towards target.

Figure 18 Forecasting with the QPM– Base and the near term forecast (Interest rates)



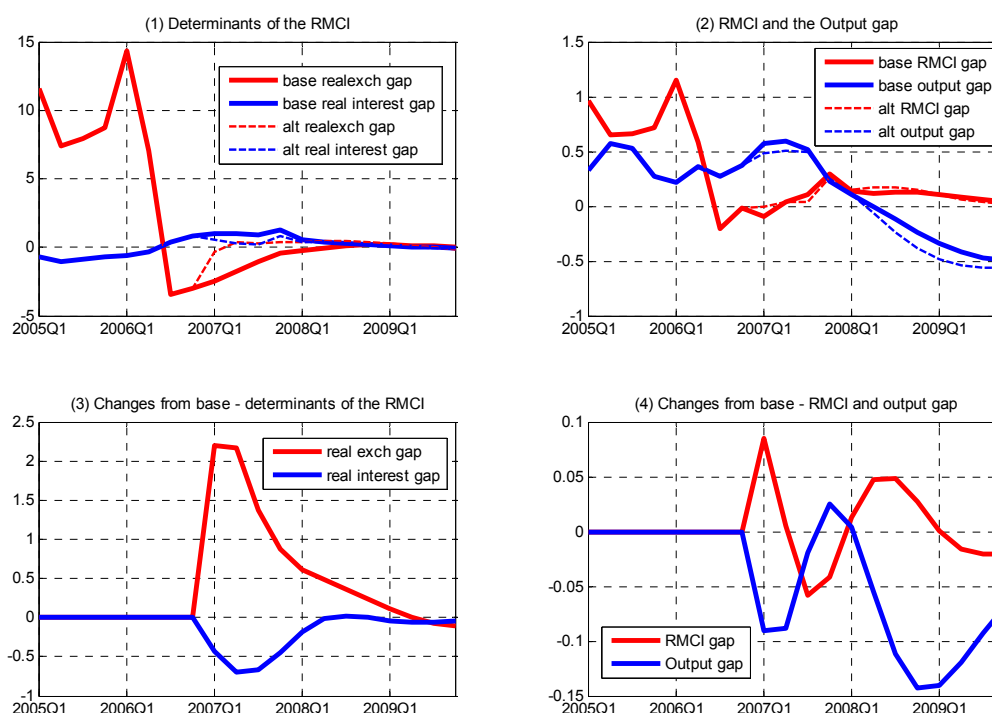
The situation is changed when considering the alternative scenario in which an appreciated value of the exchange rate is imposed on the unconditional forecast for inflation. Both the dotted alternatives of Graphs (1) and (2) in Figure 16 reveal that as inflation pressures are relieved from the appreciated value of the currency (see Figures 15 and 17), nominal and real interest rates need not increase to the same extent as the baseline to bring inflation and inflation expectations back towards the steady-state target. As a result, nominal interest rates in the alternative of Graph (3) can be 80 basis points lower from the second to the fourth quarter of 2007 (i.e. declining from roughly 10 per cent to slightly more than 9 per cent over this period).

Interest rates play a prominent role in lowering inflation via the RMCI impact on the output gap. Graph (2) in Figure 19 shows that although output was performing at between $\frac{1}{4}$ per cent and $\frac{1}{2}$ per cent above its potential during the first two quarters of 2006, the RMCI was in the more restrictive territory (positive gap) of roughly 1 per cent over the same period. This is attributed to the appreciated real value of the currency at that time, and once the exchange rate started to depreciate towards its equilibrium level in the third and fourth quarter of 2006, the RMCI followed suit to close the gap. Over the first two quarters of the forecast period in 2007, output gap pressures persist, which in turn suggests that the RMCI should at least remain positive (or more restrictive) to reduce these pressures and ultimately inflation.

The four graphs in Figure 19 compare what happens to real monetary conditions and the output gap in both the baseline and alternative scenarios. Graph (1) shows that towards the end of 2006, real interest rates were fairly close to their neutral value (i.e. where the gap was less than 1 per cent). However, the real effective exchange rate of the rand was significantly depreciated (roughly 5 per cent) in relation to its

equilibrium level. The assumption to appreciate the nominal exchange rate during the first two quarters of 2007 would therefore significantly diminish the real exchange rate gap and in the process also reduce ensuing import price inflationary pressure. It is also important to note that since inflation remains above target and output gap pressures remain in positive territory, the RMCI gap needs to be raised to reduce inflation. This is another reason why the RMCI needs to remain in positive territory, i.e. despite the fact that the exchange rate gap originates from a more accommodative initial condition (see Graphs (1) and (2)).

Figure 19 Forecasting with the QPM– Base and the near term forecast (RMCI)



The dotted alternatives of the more appreciated value of the rand shown above illustrate that with the real appreciation of the currency, the real exchange rate gap widens in Graph (3). Inflationary price pressures would be reduced, which would in the process lower the nominal interest rate and cause the real interest rate gap to decline as well. However, as the real interest rate gap declines relative to the baseline, it still remains slightly above its neutral level to ensure the gradual decline of the output gap to its equilibrium steady state (see Graph (1)).

Explaining the use of the QPM in the forecasting process and the various graphs shown in this section help to illustrate why it becomes important for a central bank to make use of a suitable general equilibrium model (as a supplementary tool) in its suite of models. In addition, the policy transmission mechanism can at times become vague in the more conventional structural equation type of model once many alternative scenarios are introduced to the system. In contrast, the QPM offers a gap model forecast that has the ability to generate an economically interpretable and theoretically consistent model solution. However, it should be re-emphasised that the key features of the QPM model are generated by the models underlying structure and its associated calibrated parameter coefficients, while the forecast itself depends

heavily on the initial conditions of the models key variables. The results of the model forecast and its endogenous interest rate path is therefore by no means intended to prescribe a set path for monetary policy, but should rather be viewed in the context of supplementing debate in the policy decision making process.

6 Concluding remarks

Macroeconomic models continue to play an important role in monetary policy formulation and implementation, and this role becomes even more important in an inflation targeting policy environment. The QPM discussed here is viewed as an essential addition to the SARB's suite of models, as it is quite different from the conventional estimated regression model. Whereas the conventional model relies heavily on the data and reliability of statistics in determining its estimated coefficients, the QPM is a calibrated structural model in which the parameter values are selected to replicate the key characteristics and relationships in the economy. This implies that the economic structure of the QPM is more important than purely estimating a relationship that suitably fits the data.

The simplified structure of the QPM also assists the process of monetary policy decision making by making it easier for policymakers to structure their way of thinking within a theoretically consistent framework. In turn, this process can improve communication with the general public. Communication remains a key feature in an inflation targeting environment and the use of the QPM to elucidate the transmission channels of monetary policy and explain the policy stance taken will help to coordinate expectations towards a desired end result.

The QPM in this study has four key equations (1) an aggregate demand or IS curve that relates real economic activity to past and expected future growth and prevailing real monetary conditions; (2) a price setting or Phillips curve for core inflation that relates current inflation to both past and future price changes, the output gap, and the previous change in the real exchange rate; (3) an uncovered interest rate parity condition for the nominal effective exchange rate; and (4) a monetary policy rule that sets the Repo interest rate as a function of the output gap and the expected difference of future inflation from the target level. The model expresses these variables in terms of their deviation from equilibrium level, hence the reference to the so-called "gap" model.

A key feature of the QPM gap model is that the emphasis shifts from a forecast of the future trend in inflation to the analysis of the trajectory of the nominal Repo as the major policy instrument to anchor inflation and inflation expectations. Although the policy reaction function may not describe the optimal way to design monetary policy, it nevertheless offers a "reasonable" description of how policy should be expected to react under various economic situations. The introduction of an endogenous forward looking Repo rate to the model hence represents a fundamental change from the more conventional models in which the assumption of a constant interest rate may be controversial.

The QPM described here represents an alternative small structural model of the South African economy and should therefore not be seen as a substitute for some (or all) of the official inflation targeting models in the SARB's suite of models. In fact, this model should rather be seen as a natural extension of the bank's efforts to clarify and explain the major channels of the monetary policy transmission mechanism. There are numerous challenges associated with the use of this type of model for monetary policy analysis, and analysts need to be cautious when calibrating the parameters of the model. Although the impulse response functions of the QPM seem plausible, further quantitative analysis is encouraged in future studies to validate and compare these impulse responses to other types of models within the Bank's suite of modelling tools.

This study also shows how the QPM can be used for forecasting purposes, and how monetary policy reacts given a certain set of assumptions. The baseline forecast suggests that the model gives a suitable reflection on what can be expected from the South African economy over the short-to-near term. However, the specification and structure of the QPM is certainly not cast in stone and should only be accepted once it has successfully completed a rigorous testing and forecasting phase. This emphasises two crucial points, the first, that the process of building a model for forecasting and policy analysis usually evolves over a number of years, and secondly, that the model does not have to be highly sophisticated for it to be considered useful for policy formulation.

In conclusion, since the results of the model rely heavily on the calibrated parameter coefficients and their initial conditions, the actual forecast of the endogenous interest rate path that has been generated by the model should not be used to prescribe a set path for monetary policy. The underlying structure of the model and its results should therefore merely be seen as an alternative tool to supplement further debate in the policy decision making process.

References

- Barro, R J. 1995. "Inflation and Economic Growth," *NBER Working Papers* 5326, National Bureau of Economic Research, Inc, October.
- Benes, J, Hargreaves, D and Vavra, D. 2004. "Performing Analysis with a simple linear New-Keynesian model", lectures and programs prepared by Jaromir Benes from the Czech National Bank, David Hargreaves from the Reserve Bank of New Zealand and David Vavra from the Czech National Bank, the lecture was delivered to participants of an IMF Workshop on Inflation Targeting held in Kiev, November 15-19.
- Berg, A, Karam, P and Laxton, D. 2006a. "A Practical Model-Based Approach to Monetary Policy Analysis—Overview", *IMF Working Paper Series* WP/06/80, Policy Development and Review Department, Research Department, and IMF Institute, International Monetary Fund, Washington D.C. March.
- Berg, A, Karam, P and Laxton, D. 2006b. "Practical Model-Based Monetary Policy Analysis—A How-To Guide", *IMF Working Paper Series* WP/06/81, Policy Development and Review Department, Research Department, and IMF Institute, International Monetary Fund, Washington D.C. March.
- Coletti, D. 2004. "Constructing the Staff Economic Projection at the Bank of Canada", a paper delivered by Don Coletti from the Bank of Canada at the seminar on "Practical experience with inflation targeting", International Conference held at the Czech National Bank May 13-14.
- de Jager, S. 1998. "Monetary Conditions Indices as Intermediate Monetary Policy Indicators", *South African Reserve Bank Departmental Memorandum Series*, Economics Department, No DM116, South African Reserve Bank, July.
- Gavura, M and Reľovský, B. 2005. "A simple model of the transmission mechanism of slovakia's economy, its structure and properties", Miroslav Gavura, Branislav Reľovský, National Bank of Slovakia, BIATEC, Volume XIII, 4
- International Monetary Fund. 2004. "GEM: A new international macroeconomic model", prepared by the IMF Research Department, International Monetary Fund, Washington.
- Jansson, P and Vredin, A. 2004. "Preparing the Monetary Policy Decision in an Inflation-Targeting Central Bank: The Case of Sveriges Riksbank". a paper delivered by Per Jansson and Anders Vredin from the Sveriges Riksbank at the seminar on "Practical experience with inflation targeting", International Conference held at the Czech National Bank May 13-14.
- Král, P. 2004. "Forecasting and Policy Analysis System in the Czech National Bank", a paper delivered by Petr Král from the Czech National Bank at the seminar on "Practical experience with inflation targeting", International Conference held at the Czech National Bank May 13-14.
- Laxton, D and Scott, A.. 2000. "On developing a structured forecasting and policy analysis system designed to support inflation-forecast targeting (IFT)", Conference on inflation targeting, Central Bank of Turkey, Ankara, October 19. [Online] available from : http://www.tcmb.gov.tr/yeni/evds/yayin/kitaplar/enf_kitap/2-Douglas_Laxton.pdf

Lucas, R E. 1976. "Econometric policy evaluation: A critique" in K Brunner and A Meltzer (eds). *The Philips Curve and the Labor Market (Carnegie-Rochester Conference Series, vol 1)*. Amsterdam: North-Holland.

Mankiw, N Gregory. 2002. "New Keynesian Economics". *The Concise Encyclopedia of Economics*. Indianapolis: Liberty Fund, Inc., ed. David R. Henderson, <http://econlib.org/LIBRARY/Enc/NewKeynesianEconomics.html>.

Mboweni, T T. 2002. "Statement of the Monetary Policy Committee: after a meeting of the Monetary Policy Committee in Pretoria 2002-03-14", South African Reserve Bank, Pretoria, 14th March.

Ruge-Murcia, F J. 2003. "Methods to estimate dynamic stochastic general equilibrium models", Department of Economic Sciences and CIREQ. University of Montreal: Mimeo.

Smal, M M and de Jager, S. 2001. "The Monetary Transmission Mechanism in South Africa", South African Reserve Bank Occasional Paper series, No 16, South African Reserve Bank, September.

Smit, B W, Le Roux, J C Mathuloe, P T , Mjandana P N, and Steinbach, M R. 2006. "A review of alternative approaches to macro-econometric modelling", *South African Reserve Bank Discussion Paper Series*, No DP/06/03, South African Reserve Bank, March.

Stevens, D. 2004. "The Reserve Bank's Forecasting and Policy System", The Reserve Bank of New Zealand Economics Department, The Reserve Bank of New Zealand, August. <http://www.rbnz.govt.nz/research/fps/index.html>

Wikipedia contributors. 2006. "Rational expectations". Wikipedia, The Free Encyclopedia. Retrieved April 11, 2006 from http://en.wikipedia.org/w/index.php?title=Rational_expectations&oldid=42639825.

Appendix :

The structure of the key equations in the QPM

Note that the calibrated parameters are shaded in yellow :

Inflation : Energy prices (petrol)

$$\begin{aligned}\text{PIE_ENERGY} &= \text{PIE_ENERGY_C01} * \text{PIE_M_ENERGY4} \\ &+ \text{PIE_ENERGY_C02} * (\text{E0_PIE4}) \\ &+ (1 - \text{PIE_ENERGY_C01} - \text{PIE_ENERGY_C02}) * \text{PIE_ENERGY}\{-1\} \\ &+ 0.25 * \text{LGDP_GAP}\{-1\} \\ &+ \text{RES_PIE_ENERGY};\end{aligned}$$

$$\text{PIE_ENERGY_C01} = 0,60 - (\text{assumed } 60\% \text{ of petrol is imported})$$

$$\text{PIE_ENERGY_C02} = 0,38 - (\text{assumed parameter for expectations})$$

Inflation : Regulated prices (Administered prices less petrol)

$$\begin{aligned}\text{PIE_REG} &= \text{PIE_REG_C01} * \text{PIE_REG}\{-1\} \\ &+ (1 - \text{PIE_REG_C01}) * (\text{PIE_CORE}) \\ &+ \text{RES_PIE_REG};\end{aligned}$$

$$\text{PIE_REG_C01} = 0,85 - (\text{assumed } 85\% \text{ related to autoregressive factor})$$

Inflation : Core (Headline CPIX less Administered prices)

$$\begin{aligned}\text{PIE_CORE} &= \text{PIE_CORE_C01} * (\text{PIE_M_XENERGY4} + \text{LZ_EQ} - \text{LZ_EQ}\{-4\}) \\ &+ \text{PIE_CORE_C02} * \text{E0_PIE4} \\ &+ (1 - \text{PIE_CORE_C01} - \text{PIE_CORE_C02}) * \text{PIE_CORE}\{-1\} \\ &+ \text{PIE_CORE_C03} * \text{LGDP_GAP}\{-1\} \\ &+ \text{RES_PIE_CORE};\end{aligned}$$

$$\text{PIE_CORE_C01} = 0,27 - (\text{assumed } 27\% \text{ related to import prices excl energy})$$

$$\text{PIE_CORE_C02} = 0,33 - (\text{assumed } 1/3 \text{ or } 33\% \text{ related to expectations})$$

$$\text{PIE_CORE_C03} = 0,50 - (\text{assumed } 50\% \text{ related to the output gap})$$

Inflation : Headline CPIX

$$\begin{aligned}\text{PIE} &= \text{LWT_REG} * \text{PIE_REG} \\ &+ \text{LWT_ENERGY} * \text{PIE_ENERGY} \\ &+ (1 - \text{LWT_REG} - \text{LWT_ENERGY}) * \text{PIE_CORE};\end{aligned}$$

$$\text{LWT_REG} = 0,15 - (\text{assumed } 15\% \text{ related to administered prices excl petrol})$$

$$\text{LWT_ENERGY} = 0,06 - (\text{assumed } 6\% \text{ related to petrol prices})$$

NB : this ensures that administered prices are roughly 21% of total CPIX

Inflation : Expectations (year-on-year and quarter-on- quarter)

$$\begin{aligned}\text{E0_PIE4} &= \text{E0_PIE4_C01} * \text{PIE4}\{4\} + (1 - \text{E0_PIE4_C01}) * \text{PIE4}\{-1\} + \text{RES_E0_PIE4}; \\ \text{E0_PIE1} &= \text{E0_PIE1_C01} * \text{PIE}\{1\} + (1 - \text{E0_PIE1_C01}) * \text{PIE4}\{-1\} + \text{RES_E0_PIE1};\end{aligned}$$

$$\text{E0_PIE4_C01} = 0,10$$

$$\text{E0_PIE1_C01} = 0,10$$

NB : this ensures that expectations are 10% forward looking and 90% backward looking

Nominal effective exchange rate

$$\begin{aligned} \text{LS_NOM} &= \text{LS_NOM_C01} * \text{LS_NOM}\{-1\} \\ &+ (1 - \text{LS_NOM_C01}) * (\text{LS_NOM}\{-1\} - 2/4 * (\text{E0_PIE1} - \text{W_E0_PIE1} - \text{DOT_LZ_EQ})) \\ &+ 1/4 * (\text{RS4} - \text{W_RS4} - \text{PREM}) \\ &+ \text{RES_LS_NOM}; \end{aligned}$$

$$\text{LS_NOM_C01} = 0,50 - (\text{assumed } 50\% \text{ related to autoregressive factor})$$

Real effective exchange rate

$$\text{LZ} = \text{LZ}\{-1\} + \text{DOT_LS_NOM}/4 + \text{PIE}/4 - \text{W_PIE}/4 + \text{RES_LZ};$$

Real Monetary Conditions index (RMCI)

$$\text{RMCI_GAP} = \text{RMCI_GAP_C01} * (\text{RR4_GAP}) + \text{RMCI_GAP_C02} * \text{LZ_GAP};$$

$$\text{RMCI_GAP_C01} = 0,3 \text{ (assumed weight of real interest rate is 3 times greater than the real exchange rate)}$$

$$\text{RMCI_GAP_C02} = 0,1 \text{ (assumed weight of real exchange rate is 3 times less than the real interest rate)}$$

NB : this ensures the 3:1 ratio in the RMCI

Nominal Repurchases rate (Repo)

$$\begin{aligned} \text{RS} &= \text{RS_C03} * \text{RS}\{-1\} \\ &+ (1 - \text{RS_C03}) * (\text{RS_EQ} + \text{RS_C01} * \text{PIE4_GAP} + \text{RS_C02} * \text{LGDP_GAP}) \\ &+ \text{RES_RS}; \end{aligned}$$

$$\text{RS_C01} = 1,0 - (\text{assumed } 100\% \text{ related to the inflation gap})$$

$$\text{RS_C02} = 0,4 - (\text{assumed } 40\% \text{ related to the output gap})$$

$$\text{RS_C03} = 0,5 - (\text{assumed } 50\% \text{ related to autoregressive factor})$$

NB : this is more of an inflation rule – since the full emphasis lies more on the inflation gap and roughly half is attributed to the output gap

Output gap

$$\begin{aligned} \text{LGDP_GAP} &= \text{LGDP_GAP_C01} * \text{LGDP_GAP}\{-1\} + (1 - \text{LGDP_GAP_C01}) * \text{LGDP_GAP}\{+1\} \\ &- \text{RMCI_GAP} \\ &+ \text{LGDP_GAP_C02} * \text{W_LGDP_GAP} \\ &+ \text{RES_LGDP_GAP}; \end{aligned}$$

$$\text{LGDP_GAP_C01} = 0,90 - (\text{assumed } 90\% \text{ related to autoregressive factor})$$

$$\text{LGDP_GAP_C02} = 0,40 - (\text{assumed } 40\% \text{ related to world output gap})$$

Variable definitions:

DOT_LS_NOM	log change in the nominal effective exchange rate (quarter-on-quarter)
DOT_LZ_EQ	log change in the real effective exchange rate (quarter-on-quarter)
E0_PIE1	inflation expectations (quarter-on-quarter annualised)
E0_PIE4	inflation expectations (year-on-year)
LGDP_GAP	output gap (log change from equilibrium level)
LS_NOM	log of the nominal effective exchange rate
LZ	log of the real effective exchange rate
LZ_EQ	log of the equilibrium real effective exchange rate
LZ_GAP	log of the real effective exchange rate gap
PIE	CPIX(mu) rates of inflation (quarter-on-quarter annualised)

PIE_CORE	rates of core inflation (year-on-year)
PIE_ENERGY	rates of inflation in energy prices (year-on-year) : petroleum prices
PIE_M_ENERGY4	rates of inflation in imported energy prices (year-on-year)
PIE_M_XENERGY4	rates of imported inflation excluding energy prices (year-on-year)
PIE_REG	rates of inflation in regulated prices (year-on-year)
PIE4	CPIX(mu) rates of inflation (year-on-year)
PIE4_GAP	inflation gap : CPIX(mu)
PREM	risk premium in the nominal effective exchange rate
RMCI_GAP	gap in the real monetary conditions index
RR4_GAP	gap in the short term real interest rate (Repori)
RS	nominal short term nominal interest rate (Repori)
RS_EQ	equilibrium level of the nominal short term interest rate (Repori)
RS4	long term nominal interest rate (yield on 10 year government bonds)
W_E0_PIE1	rest of the world inflation expectations (quarter-on-quarter annualised)
W_LGDP_GAP	rest of the world inflation output gap (log change)
W_PIE	rest of the world inflation (year-on-year)
W_RS4	rest of the world long term nominal interest rate