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# The new Bank of England Quarterly Model<sup>(1)</sup>

*The Bank of England has developed a new macroeconomic model to help prepare the Monetary Policy Committee's quarterly economic projections. The new model does not represent a change in the Committee's view of how the economy works or of the role of monetary policy. Rather, recent advances in economic understanding and computational power have been used to develop a macroeconomic model with a more clearly specified and coherent economic structure than in previous models used by the Committee. This article provides an overview of the new model and includes some simple simulations to illustrate its properties.*

The Bank of England has developed a new macroeconomic model for use in preparing the Monetary Policy Committee's quarterly economic projections. The new Bank of England Quarterly Model, or BEQM, was used to an increasing extent during 2003 and is the main tool in the suite of models employed by the staff and the Monetary Policy Committee (MPC) in the construction of the projections contained in the quarterly *Inflation Report*.

This article describes the role of models at the Bank of England in helping to produce the MPC's quarterly projections, explains the motivation for the new model, and provides an overview of BEQM and the modelling approaches underlying it. It finishes by describing some simple simulations that illustrate some of the properties of the new model.<sup>(2)</sup>

## The role of models and forecasts at the Bank of England

The Bank of England is mandated by the Chancellor of the Exchequer to aim at an inflation target—at the time of writing, a 2% annual inflation rate of the Consumer Prices Index (CPI)—and uses a very short-term nominal interest rate as its instrument to pursue this target. Because of the lags between changes to interest rates and the associated effects on inflation, setting monetary policy is inherently a forward-looking exercise. Hence the quarterly *Inflation Report*, in addition to assessing the current state of the economy, contains projections for output growth and inflation up to two years out, based on assumptions of both constant and market-based

interest rates. These projections represent the Committee's best judgment of both the most likely central outcome and the range of possible alternative outcomes around that central case. A key element of the analysis contained in the *Inflation Report* is to consider the big risks and uncertainties surrounding the central projection, rather than to focus simply on the central point predictions for GDP growth and inflation.

The Bank uses numerous economic models to help produce these projections.<sup>(3)</sup> No model can do everything—all models are imperfect, precisely because they are simplifications of reality. And each projection is produced by the MPC rather than as a mechanical output from any model. Nonetheless the Bank has found, like many other policy institutions, that, when producing its economic projections, it is helpful to use a macroeconomic model as the primary organisational framework to process the various judgments and assumptions made by the Committee. This is the role now played by BEQM.

The forecast process at the Bank involves a high degree of interaction between the Bank's staff and the members of the Monetary Policy Committee. In particular, a key element of the forecast process is for Committee members to assess the extent to which different economic judgments and assumptions concerning the big issues affecting the economy could influence their view of future prospects. This process is critical to understanding the nature of the risks and uncertainties surrounding the central projection. In order to be able

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(1) This article is based on the version released on 22 April 2004.

(2) A book including a full technical account of the model and its quantitative properties will be published later.

(3) The Bank's use of economic models is discussed in more detail in Chapter 1 of Bank of England (1999), *Economic models at the Bank of England*, available at [www.bankofengland.co.uk/modcobook.htm](http://www.bankofengland.co.uk/modcobook.htm).

to carry out this sort of analysis, the main forecast model ideally needs a relatively explicit economic structure that identifies the key behavioural parameters and channels within the economy.

The importance of having a model suitable for analysing the implications of different economic judgments and assumptions is not new. This role was also central to the design of the previous macro model used by the Bank, the Medium-Term Macro Model (MTMM).<sup>(1)</sup> Indeed, the basic structure of BEQM is very similar to that of the MTMM. The aim of BEQM is not to incorporate a different view of how the economy works or of the role of monetary policy. Rather, the decision to develop a new model reflected the view that recent advances in both economic understanding and, importantly, in computational power meant that it was possible to improve upon the economic structure within the MTMM. As Professor Adrian Pagan noted in his 'Report on modelling and forecasting at the Bank of England', the MTMM was no longer 'state of the art'.<sup>(2)</sup> In particular, Professor Pagan concluded that 'It seems highly likely that [a new model] could achieve the same empirical coherence [as the MTMM] with a stronger theoretical perspective'. In doing so, this would provide the Committee with a more flexible and coherent framework to aid its economic deliberations. That, in short, is what the new model tries to achieve through a clearer articulation of the underlying structure of the economy and a more explicit identification of the role expectations play.

## An overview of BEQM

BEQM describes the behaviour of the UK economy at a relatively aggregated level that is closely related to the incomes and expenditures recorded in the UK National Accounts. To do this, the model contains formal descriptions of the behaviour of private domestic agents, policymakers and the rest of the world, and their interactions in markets for capital and financial assets, goods, and labour.

Firms seek to maximise profits by hiring labour and buying capital in order to produce output. Firms and workers bargain over wages and, given the outcome, firms are assumed to choose the labour they wish to employ so that the costs of any extra workers are

compensated for by the higher revenues they generate. Similarly, firms' desired level of capital is determined by the cost of capital and the return to extra investment. The output that firms produce is sold in markets for domestic consumption, investment and government purchases, as well as in housing and export markets. Firms are assumed to face varying degrees of competition in these markets, which implies that firms may receive a different profit margin from the sale of their goods in each market. The composition of total sales will therefore affect revenue and profits, so that relative demand conditions will matter as well as overall demand conditions. Firms face competition from importers for consumption and investment goods, and have to price their products in export markets so as to achieve maximum profits. In addition, various short-run factors can influence firms' behaviour, such as the short-run prospects for demand affecting the speed with which they invest.

Households consume imported and domestically produced goods. When deciding on their current level of consumption, and hence their level of saving or borrowing, households are assumed to want to keep their lifetime consumption as smooth as possible. To do this, households can borrow and save using a range of financial assets, including domestic equities, corporate debt, government debt, money, and foreign assets. In addition, in the short run, households' levels of consumption can be influenced by a variety of other factors, such as short-term fluctuations in their income and their level of confidence about the future.

The government buys output from domestic firms and pays for it by raising taxes and selling debt, in addition to a small amount of revenue that accrues from seigniorage. Total revenue also has to be sufficient to pay the cost of servicing the existing level of government debt and any government transfers. For long-run solvency, the fiscal authority may at some stage have to adjust a policy instrument—such as a tax rate—to ensure that the fiscal budget constraint is met. A variety of fiscal policy 'rules' can be considered. In general, these rules assume that any required fiscal adjustment occurs only gradually.

The monetary policy maker has the job of anchoring the nominal side of the economy. The nominal target could,

(1) The Medium-Term Macro Model is described in more detail in Bank of England (2000), *Economic models at the Bank of England: September 2000 update*, available at [www.bankofengland.co.uk/modcoupdate.htm](http://www.bankofengland.co.uk/modcoupdate.htm).

(2) Adrian Pagan (2003), 'Report on modelling and forecasting at the Bank of England', reprinted in *Bank of England Quarterly Bulletin*, Spring, pages 60–88.

in principle, be specified in terms of any nominal aggregate, such as the nominal exchange rate, the growth rate of nominal output, or the growth rate of the money stock. The default assumption is that the central bank targets an annual inflation rate of the CPI of 2%, using the short nominal interest rate as its instrument. An assumption about the policy rule used by the central bank—the monetary policy reaction function—is required for inflation to be anchored in the long run. The structure allows a variety of different reaction functions to be incorporated.

BEQM assumes that UK capital markets are ‘small’, in the sense that the demand for and supply of financial assets in the United Kingdom do not affect the level of interest rates prevailing in the rest of the world. Since all claims on domestic firms’ assets and government debt must ultimately be held either by domestic households or the rest of the world, it follows that the United Kingdom’s net foreign asset position is determined jointly by the decisions of firms and the government about how many financial liabilities to issue and by domestic households about how many of these assets to hold. The rest of the world affects these decisions via assumptions about the level of foreign real interest rates and world demand.

These decisions also have implications for the United Kingdom’s trade balance. Suppose, for example, UK households were assumed to want to hold only some of the domestic financial assets on offer, such that the United Kingdom maintained a net debt with the rest of the world. This would imply that, in the long run, the United Kingdom would need to have a trade surplus sufficient to meet the costs of servicing this debt. The equilibrium real exchange rate is assumed to move eventually so as to ensure that exports and imports achieve this long-run balance. This story is further complicated by the assumption that UK producers have some market power in the prices they set in world markets, so the long-run trade balance will, in general, depend on assumptions made about conditions in both financial and goods markets.

The main channels through which changes in monetary policy are transmitted to the rest of the economy are similar to those previously described by the Monetary Policy Committee.<sup>(1)</sup> The fact that prices and nominal wages move only slowly means that the central bank, by changing the nominal interest rate, has the ability to

influence real interest rates. Lower real rates tend to encourage consumers to spend more now. Lower real rates also encourage investment and spending on housing by lowering financing costs, and they make it less costly to hold inventories. The combined effect is to push up domestic demand. To meet that demand, firms will demand more of the factors used in the production of goods and services, namely capital and labour. This in turn is likely to increase the costs of these factors of production.

The fact that the UK economy is a small open economy adds an important channel through which monetary policy operates. In particular, a lower domestic real interest rate may tend to encourage a depreciation in the real exchange rate. This will lead to both a direct price effect—the prices of imported goods will rise—and a number of possible indirect (or ‘second-round’) effects, reflecting both any pass-through from higher import prices onto domestic prices and costs, and the impact of any change in competitiveness associated with the change in the real exchange rate on the United Kingdom’s trade balance.

The impact of changes in aggregate demand on prices and inflation will depend on the way in which agents—households, firms, policymakers and the rest of the world—interact with each other. Other things being equal, increased demand for workers leads to higher wage costs, which firms will typically attempt to pass on to some degree in the form of higher prices. Similarly, increases in world prices or an exchange rate depreciation create pressure on import prices. And increased demand for domestically produced goods will also create incentives for firms to raise prices.

Inflationary pressures reflect the degree of imbalance between the level of demand and the capacity of firms to meet that demand. The level of demand and potential supply will depend on both the current stance of monetary policy and the stance expected in the future. Likewise, firms’ responses to these pressures on capacity will depend on the extent to which they are likely to persist, and hence on the expected stance of monetary policy in the future. The importance of future expectations in determining current inflationary pressures underlines the central importance of monetary policy anchoring private sector expectations of the long-term inflation rate.

(1) See Monetary Policy Committee (1999), ‘The transmission mechanism of monetary policy’, reprinted in *Bank of England Quarterly Bulletin*, May, pages 161–70.

## Some key technical features of BEQM

The improved economic structure of BEQM is reflected in a number of specific features. First, it has a well defined steady state. This means that, in the long run, all variables in the model settle on paths that are growing consistently with each other in a sustainable equilibrium. This aids analysis of economic issues, since an understanding of the medium term requires an understanding not just of short-run forces, but also of where the economy is heading to in the long run. For example, a stable steady-state solution would not be compatible with a situation in which household debt was increasing without bound.

In characterising this steady state, careful attention has been paid to ‘stock-flow’ and ‘flow-flow’ accounting. This is designed to ensure that all economic flows within the economy are accounted for—all income is spent or saved, for example—and that all expenditures have implications for physical and financial stocks. This again aids the understanding of medium-term issues. For example, stock-flow consistency implies that monetary policy cannot stimulate consumption indefinitely, since this would imply an erosion of households’ net wealth, which they could not ignore forever.

Another important feature of the new model is that it contains more explicit forward-looking representations of agents’ expectations about the future. These include expectations about future labour income, aggregate demand, the exchange rate, and so on. Models with fully forward-looking agents can sometimes exhibit unrealistic dynamic properties; in particular, if households and firms are assumed to have perfect foresight, they might adjust their behaviour immediately in response to future anticipated events. But in reality the economy does not ‘jump’ about in this fashion. That partly reflects the fact that it is often costly for households and firms to change their behaviour very rapidly. In addition, firms and households do not have perfect foresight. Instead, they have to form expectations on the basis of limited information. BEQM incorporates both of these features. In particular, it is structured in such a way that assumptions about the speed of adjustment and the amount of information available to agents can be altered and changed in order to help the Committee to assess how these assumptions could affect the future path of the economy.

These features are not new: some or all of them are present in many other models currently used by policy institutions, such as the Bank of Canada’s Quarterly Projection Model, the FRB/US model at the US Federal Reserve Board of Governors, and the Reserve Bank of New Zealand’s FPS model. Indeed, these features were often an explicit aim of pioneering work on macro modelling in the United Kingdom over the past 25 years, such as the Liverpool model, the London Business School model, the COMPACT model, and various models at the Cambridge Economic Policy Group and the National Institute of Economic and Social Research. The implementation in BEQM may differ in technical details, reflecting decisions made on how to satisfy the particular demands of forecasting at the Bank, but the basic ideas and motivations are the same.

## Some illustrative simulation results

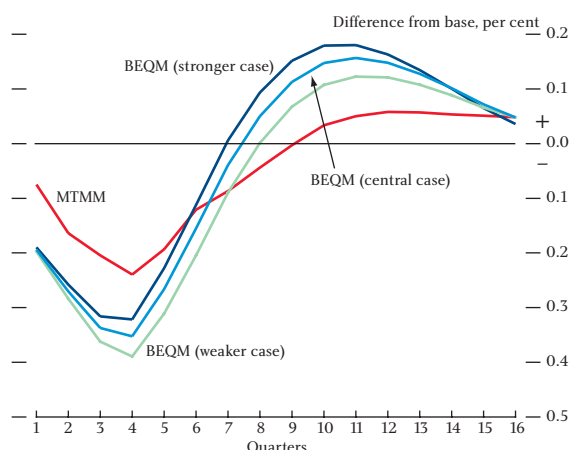
It is possible to gain some understanding of the properties of the new model by conducting some simple simulations. The simulations discussed below focus on the effects of changes in the short-term nominal interest rate on output and inflation.<sup>(1)</sup> A major caveat is appropriate here. Simulation analyses are highly stylised, offering an insight into what happens in a model when one economic variable is altered—in this case the short-term nominal interest rate—and ‘all other things are assumed to be equal’. But in reality other things are not equal. The short-term nominal interest rate is not changed without reason, but rather in response to the variety of disturbances affecting the economy. The precise effect of a change in the short-term nominal interest rate will depend on the exact causes of the change, on whether this change was anticipated by households and firms, on the credibility of the monetary policy regime and a host of other factors. So simulations can be used to provide only an illustration of the properties of a model. They cannot be used mechanically to predict how the economy—or even a model—will react to actual changes in economic variables.

Charts 1 and 2 illustrate the effect of a temporary change in the short-term nominal interest rate on output and inflation respectively. The simulation considers the effect of an unanticipated 1 percentage point rise in the short-term nominal interest rate for one year.<sup>(2)</sup> Interest rates beyond the first year in this simulation are

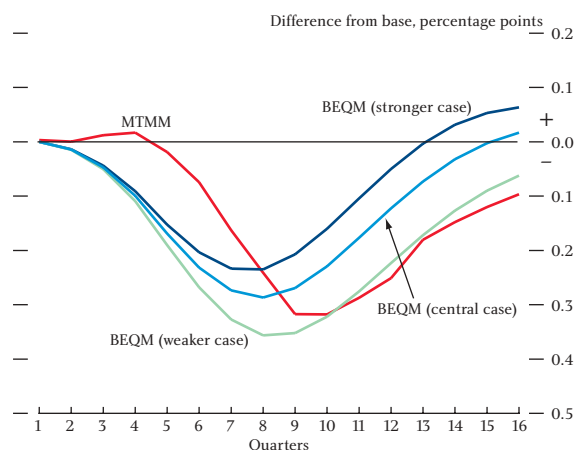
(1) A more detailed discussion of the properties of BEQM will be provided in the forthcoming book.

(2) This is the same simulation as that considered for the MTMM on pages 17–18 of Bank of England (2000), *Economic models at the Bank of England: September 2000 update*, available at [www.bankofengland.co.uk/modcoupdate.htm](http://www.bankofengland.co.uk/modcoupdate.htm).

**Chart 1**  
**Response of GDP level to nominal interest rate increase**



**Chart 2**  
**Response of annual inflation rate to nominal interest rate increase**



determined by a monetary policy rule that assumes interest rates are set so as to return inflation to base. Charts 1 and 2 show the effects of this simulation in BEQM, together with the most recently published simulations for the MTMM.<sup>(1)</sup> To illustrate the sensitivity of the simulations to different assumptions, Charts 1 and 2 show three different simulations for the new model, based on different assumptions about the form of the monetary policy rule, in which monetary policy is assumed to respond more or less strongly to deviations of inflation from target.

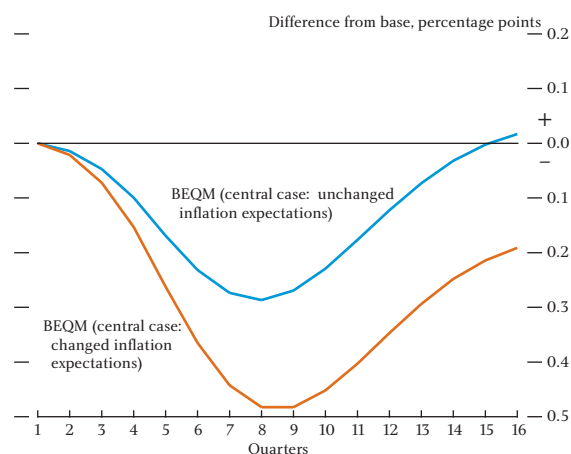
The responses of output and inflation to the temporary change in interest rates are similar in the two models.

The maximum effect on the level of real activity occurs after about one year and on inflation after about two years. The demand effects come through a little more quickly in BEQM, reflecting in part the fact that consumption responds more strongly in the short run to interest rate changes in the new model. Further out, the effects of the temporary change in interest rates on inflation are somewhat less persistent in the new model, reflecting the fact that households and firms are forward looking and that they expect monetary policy will be set so as to return inflation to base.

### Response to nominal interest rate increase

The responses of output and inflation to a change in interest rates will also depend on the credibility of the inflation target. In particular, as inflation expectations become more firmly anchored around the inflation target—the inflation target becomes more credible—a change in the short-term interest rate is likely to have less impact on activity and inflation.<sup>(2)</sup> The simulations illustrated in Charts 1 and 2 are based on the assumption that the temporary change in interest rates does not affect households' and firms' long-run inflation expectations. To illustrate the sensitivity of these simulations to this assumption, Chart 3 compares the response of inflation in the central case with a situation in which households and firms perceive that the unexpected increase in interest rates may have been triggered by a reduction in the targeted rate of

**Chart 3**  
**Response of annual CPI inflation to nominal interest rate increase**



(1) The BEQM simulation is based on a similar monetary policy rule and similar fiscal policy assumptions to those used in the original MTMM simulations. The BEQM simulations show the impact of changes in interest rates on annual CPI inflation. In contrast, the MTMM simulation shows the response of annual RPIX inflation. However, this difference does not significantly affect the comparison.

(2) For a more detailed discussion of the impact of monetary policy credibility on the sensitivity of the economy to changes in interest rates, see the box on pages 10–11 of the February 2004 *Inflation Report*.

inflation.<sup>(1)</sup> The response of inflation to the change in interest rates in this case is significantly greater and, as such, underlines the importance of monetary policy credibility in determining the sensitivity of the economy to changes in interest rates.

## Conclusion

The Bank of England has developed a new macroeconomic model for use in preparing the MPC's quarterly economic projections. This model uses recent

advances in economic understanding and computational power to develop and improve upon existing models used at the Bank. The new model does not represent a change in the Committee's view of how the economy works or of the role of monetary policy. Indeed, the sensitivity of output and inflation to temporary changes in interest rates is broadly similar to that in existing models used at the Bank. However, the model does provide the Committee with a more flexible and coherent framework to aid its economic deliberations.

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(1) This simulation is sensitive to the precise assumptions made about the change in expected inflation. The simulation shown in Chart 3 is based on the assumption that the unexpected increase in interest rates causes firms and households to revise down their expected level of inflation in the long run by around 0.2 percentage points.