
Economic models at the Bank of England

*In April 1999, the Bank of England published **Economic models at the Bank of England**, a book that described the economic modelling tools that help the Monetary Policy Committee (MPC) in its work. It was made clear at the time that economic models should not be thought of as fixed in form or content, and that model development is a continual process. An **update to the book** was published in September 2000 covering model developments over the past 18 months, particularly in relation to the Bank's main macroeconometric modelling tool. The update, while giving details of the core macroeconometric model, also refers to other work within the Bank that has added to the range of models used by the MPC.*

In April 1999, the Bank of England published *Economic models at the Bank of England*, setting out the economic modelling tools that help the Monetary Policy Committee (MPC) in its work. The book included a complete listing of the Bank's core macroeconometric model (MM), and outlined other members of the suite of models used for various aspects of monetary policy analysis. It was made clear at the time that neither the MM nor the other models in use should be thought of as fixed in form or content. Indeed, many aspects of the models are regularly reviewed, and new approaches to modelling aspects of the economy are continually investigated.

An update to *Economic models* was published in September 2000.⁽¹⁾ This provides an update of the changes incorporated into the MM over the past 18 months and a written listing of the MM, to accompany its simultaneous release of the model code in electronic form. It also refers to some other work within the Bank that has added to the range of models in the suite and that is already publicly available.

This note⁽²⁾ outlines the Bank's modelling philosophy, describes the key features of the MM, highlights the main ways in which the MM has changed since April 1999, and identifies some other relevant modelling work.

Models, policy analysis and forecasting

The Bank's core macroeconometric model (MM) is the main tool for producing projections of GDP growth and inflation shown in the *Inflation Report*. The MM is built around a number of estimated econometric relationships, but some of the model properties—notably the long-run properties—are imposed in the form of parameter restrictions for theoretical consistency. There is a continual

need to evaluate and update various components of the MM. Estimated MM econometric relationships may have broken down or have changed in some way, so that research is required to investigate the causes and to test alternatives that may eventually be incorporated in the MM itself.

The Bank continues to use a range of models. Some provide inputs into the quarterly projections, while others are used to analyse specific policy questions that cannot be handled adequately within the MM. Some research may prove difficult or impossible to incorporate in the MM—for example, it may involve a different level of aggregation. It would then be run in parallel to provide a comparison with MM outputs, or to provide insights into aspects of the economy that the MM cannot address.

Occasionally, specific new policy issues arise that cannot be analysed using the existing framework, and models are set up specifically to examine the key features of the issue at hand. Examples have included the impact of the National Minimum Wage, the implementation of the Working Time Directive, and the assessment of the impact on consumer spending of the windfalls from building society demutualisations. In some cases, a purpose-built model may cease to be of use once the issue it addresses no longer has monetary policy significance. But in other cases the work is incorporated in tools that are used to assess issues of continuing relevance.

Each forecasting round requires assumptions to be made about a wide range of exogenous variables. Auxiliary models are often used to inform these judgments. Some relate, for example, to the world economy or some element of it, such as commodity prices or the level of world trade. For the assessment of world economic activity and inflation,

(1) The book and the September 2000 update are available from the Bank's web site at www.bankofengland.co.uk/modcobook.htm. Copies are also available from Publications Group, Bank of England, Threadneedle Street, London, EC2R 8AH; tel 020 7601 4030; fax 020 7601 3298; e-mail: mapublications@bankofengland.co.uk

(2) Based on the introduction to the September 2000 update. Sections 2 and 3 of the update explain the structure of the MM in more detail; Section 4 outlines the changes to the MM; Section 5 discusses the MM simulation properties; and Sections 6 and 7 provide a complete model listing, including diagnostics on estimated equations and data sources.

the MPC uses a model⁽¹⁾ of the world economy provided by the National Institute of Economic and Social Research to help form its judgments. Other models relate to aspects of the domestic economy that are not formally modelled in the MM, but where parameters may be varied or restricted as a result of the auxiliary analysis. In all cases, the assumptions incorporated in any specific forecast are a combination of those suggested by the auxiliary model and the application of the MPC's judgment. Profit margins and house prices are examples of areas where forecast assumptions are influenced by both supplementary modelling and MPC judgment.

Where the Bank does not have the tools to hand for analysing a specific issue, it will seek out the best available analysis from the academic literature or from the research work of other central banks and research institutes. For this reason, Bank staff are encouraged to keep abreast of the relevant academic literature and to contribute to it by publication of working papers,⁽²⁾ contributions to professional journals, and presenting their work at conferences. The Bank also runs a seminar series, addressed both by outside experts and by internal staff. The general philosophy with which the Bank approaches modelling and forecasting in particular, and monetary policy analysis in general, is one of pluralism and openness.

General characteristics of the macroeconometric model

The Bank's core macroeconometric model (MM) consists of about 20 key equations determining endogenous variables. There are a further 90 or so identities defining relationships between variables, and there are about 30 exogenous variables whose paths have to be set, as discussed above.

GDP is determined in the short term by the components of aggregate demand—private consumption, investment (including inventory investment), government consumption, and net exports.

In the longer term GDP is determined by supply-side factors, which determine potential output. Domestic firms are modelled as producing a single composite good using an aggregate production function of the Cobb-Douglas form. So output is determined in the long run by evolution of the capital stock, the labour supply and total factor productivity. These variables are assumed to be unaffected by the price level or the inflation rate (so the model exhibits long-run monetary neutrality and super-neutrality).

Price level dynamics and the adjustment of actual output towards potential are broadly determined by the interaction between aggregate demand and supply, augmented by explicit relationships for aspects of wage and price-setting. These relationships are consistent with the view that firms

set domestic output prices as a cyclically varying mark-up over unit labour costs. RPIY is determined by an equation linking retail prices to domestic output prices and import prices. Firms are also assumed to determine the level of employment, and real wages are determined by bargaining in an imperfectly competitive labour market. Inflation expectations have an explicit role in wage determination. But price responses are sluggish, so there is slow adjustment towards both real and nominal equilibria.

The appropriate assumptions under which to run the model depend on the exercise at hand. For example, short-run forecasting typically requires different assumptions from those used for long-run simulations, and for either purpose a wide range of alternative assumptions could be made. For the main *Inflation Report* forecasts, nominal short-term interest rates are assumed to be constant over the forecast period, but an alternative is also presented in which rates follow the path implied by market expectations. When using the MM for simulation purposes, the short rate can be set according to a policy rule linking short-term nominal interest rates to the monetary policy target but the nature of this rule can take many different forms. Different exchange rate assumptions can be used in both the construction of projections and for simulations. A range of possible treatments is also available for the evolution of net financial wealth, and for inflation expectations.

A further example of where different assumptions may be used for different purposes relates to government spending. The *Inflation Report* projections incorporate announced government spending plans, but some alternative assumption is needed in longer-term simulations, as spending plans are not announced for more than a few years at a time. In this case, a common assumption is that government consumption growth is fixed either in nominal or real terms.

Changes to the MM

The main areas of the MM in which changes have been introduced since the *Economic models* book was published in April 1999 are:

- The consumption function now incorporates a new measure of labour income, which includes self-employment incomes (mixed incomes). Gross housing wealth and net financial wealth now have a separate role in the dynamics. And the real (short) interest rate matters in the long run, while nominal short rates affect the dynamics.
- There is a new equation for house prices, which depend on average earnings and the long real rate in the long run, while GDP enters the dynamics (in addition to earnings).

(1) The National Institute Global Economic Model (NiGEM).

(2) A list of recent working papers is provided on pages 425–26. A full list is available on the Bank's web site at www.bankofengland.co.uk/workingpapers/index.htm, where abstracts of all papers may also be found. Papers published since January 1997 are available in full in PDF format.

- Both export and import equations have been modified as a result of estimation on new data, the main effect being to lower slightly the relative price elasticities.
- RPIY is determined by a modified relationship that weights domestic and import prices.

In addition, there are other small modifications resulting from data revisions and definitional changes affecting the capital stock, investment, trade prices, earnings, employment, non-labour income and the GDP deflator. There are minor changes to the treatment of value-added tax and special duties (affecting the link from RPIY to RPIX), and a new equation for the government expenditure deflator has been introduced.

The simulation properties of the MM, in terms of both timing and scale of responses, have not been affected substantially by the recent changes. For example, an unanticipated change in the short-term interest rate for four quarters still has its maximum impact on inflation after about nine quarters, and the order of magnitude is similar to that shown in the book. The current MM suggests that unanticipated changes in interest rates have a slightly faster impact on real GDP than previously, with the peak impact being felt after four rather than five quarters. The size of the impact is comparable with the earlier version of the MM.

Other models added to the suite

There has been a large amount of work within the Bank of England over the past two years designed to throw light on specific monetary policy related issues. Some of this research feeds into the background analysis prepared as input to the quarterly forecasting round, while other work feeds into monthly briefings to highlight specific issues on an *ad hoc* basis. Specific examples can be found in the

papers published in the Bank's working paper series; a selection of such research is highlighted here.

- A series of papers has investigated the impact of model uncertainty on actual and optimal monetary policy.⁽¹⁾
- Further work using structural vector autoregressions has been done. One example was aimed at identifying monetary policy shocks from the many other shocks that hit the economy, by imposing *a priori* restrictions.⁽²⁾ Another example used related methods to investigate the empirical relationship between different measures of 'gaps' (output, employment, and capacity utilisation) by the imposition of restrictions implied by economic theory.⁽³⁾
- Small-scale aggregated models have also been used to investigate the relationship between optimal monetary policy and inflation projections.⁽⁴⁾
- Optimising models have been used to investigate several issues of relevance to monetary policy. For example, one model has been used to investigate the determinants of the changing behaviour of mark-ups over time.⁽⁵⁾ Another paper has examined the potential impact of the labour market reforms of the 1980s on the wage-setting and employment decisions of firms.⁽⁶⁾
- Further work has been done on Phillips curve type models; this work may be published in due course.
- There has also been considerable work on developing tools for extracting and interpreting information from financial markets, for example about interest rate and inflation expectations.⁽⁷⁾

(1) Hall, Salmon, Yates and Batini (1999), 'Uncertainty and simple monetary policy rules—an illustration for the United Kingdom', *Bank of England Working Paper, No 96*; Martin and Salmon (1999), 'Should uncertain monetary policy-makers do less?', *Bank of England Working Paper, No 99*; and Martin (1999), 'Caution and gradualism in monetary policy under uncertainty', *Bank of England Working Paper, No 105*.

(2) Dhar, Pain and Thomas (2000), 'A small structural empirical model of the UK monetary transmission mechanism', *Bank of England Working Paper, No 113*.

(3) Astley and Yates (1999), 'Inflation and real disequilibria', *Bank of England Working Paper, No 103*. (This paper was referred to in the April 1999 book, but was published subsequently.)

(4) Batini and Nelson (2000), 'Optimal horizons for inflation targeting', *Bank of England Working Paper, No 119*.

(5) Britton, Larsen and Small (2000), 'Imperfect competition and the dynamics of mark-ups', *Bank of England Working Paper, No 110*.

(6) Millard (2000), 'The effects of increased labour market flexibility in the United Kingdom: theory and practice', *Bank of England Working Paper, No 109*.

(7) Anderson and Sleath (1999), 'New estimates of the UK real and nominal yield curves', *Bank of England Quarterly Bulletin, November, pages 384–92*; Clews, Panigirtzoglou and Proudman (2000), 'Recent developments in extracting information from options markets', *Bank of England Quarterly Bulletin, February, pages 50–60*; and Bliss and Panigirtzoglou (2000), 'Testing the stability of implied probability density functions', *Bank of England Working Paper, No 114*.