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# Addendum to *Report on modelling and forecasting at the Bank of England*

*The Spring 2003 Quarterly Bulletin<sup>(1)</sup> contained a report on modelling and forecasting at the Bank of England by Adrian Pagan.<sup>(2)</sup> This article is a postscript to Professor Pagan's original report, and covers the introduction of the Bank's new macroeconomic model (the Bank of England Quarterly Model, or BEQM). The overall assessment is broadly positive, and the Bank would again like to thank Professor Pagan for the valuable insights that his report has provided.*

## Introduction

As described in my previous report,<sup>(1)</sup> a modelling and forecasting system within a central bank generally incorporates a number of models — a major model that is used for the central tasks of analysis and forecasting, and a number of auxiliary ones that are used to support this process and to examine some special features and events that arise from time to time. At the time of my previous report the main model in use at the Bank of England was what has been labelled the Medium Term Macro Model (MTMM) but a new model was being developed, which I referred to as the New Macro Model (NMM). This model has since been given the name of the Bank of England Quarterly Model (BEQM). In this addendum to my report I look at that model in more detail than was possible before and consider it broadly under the terms of reference of the previous report.

It is useful to think of the task of building a model for policy use in three stages. Indeed it is often useful to think of these as separate models, even though they are mostly a single one. The three 'models' could be referred to as:

- The conceptual model (CM)
- The data-adjusted model (DAM)
- The operational model (OM)

The conceptual model attempts to set out an overall framework for macroeconomic analysis that incorporates some of the institutional features and constraints upon policy formulation. As such it needs to provide a clear

explanation of some of the principal features of the economy under investigation eg that shocks to the macroeconomic system are often not dissipated instantaneously but instead persist for substantial periods of time. The model also seeks to incorporate many accounting identities that exist within and between the stocks and flows of the macroeconomic system. At a crude level one could think of the CM as the economic-theoretical structure of the main model. It is informed by data but only in a general way. Within BEQM the CM is what is referred to as the core model and I will refer to that in what follows as BEQM-core.

The data-adjusted model stems from a process whereby the CM is augmented by extra variables to provide a reasonably close fit to the data. In the words of Harrison *et al* (2005, page 61) this augmentation process stems from the '...choice not to include in the core model some features of the economy, such as credit market imperfections, which would risk making the core model too large and complex to be tractable', and the fact that '...the theoretical underpinnings of some aspects of these correlations, for example the degree of persistence of nominal variables, are not yet well understood'. There are many examples of variables that can usefully augment a CM eg housing price inflation may be added, based on the perception that rises in such asset prices have contributed a good deal more to consumption expenditures than would be expected from most models that rely upon consumers smoothing their consumption over time.

Finally, the operational model is the model that is used in the forecasting rounds. This may just be the DAM

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

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but, since the forecast relates to future rather than past outcomes, the operational model often makes extensive use of information pertaining to the future. Examples would be the utilisation of information supplied by the Agents, measures of confidence of consumers and investors, analysts' forecasts of equity returns, information contained in such items as stock options and oil price futures etc. Not all of this information is used at every round and it is generally not used to reconcile the conceptual model with the past data sets.

It is useful to look at BEQM under these headings from the perspective of the original terms of reference. However, I will also deal a little with the question of documentation and communication. I think it is important that the structure of models be well documented and that the properties be effectively communicated. The Bank of England has a commendable reputation for its past endeavours in this area providing a clear account of the nature of the MTMM as well as detailing a range of models that have been used in the policy process. In commenting on the documentation of BEQM I am referring to Harrison *et al* (2005), *The Bank of England Quarterly Model*.

### The conceptual model (BEQM-core)

In the description of BEQM a repeated theme is that BEQM is evolutionary rather than revolutionary ie it re-works many of the economic themes of the previous model MTMM into a consistent pattern rather than being something that overturns them. Such continuity is important in facilitating the movement from one model to another. Indeed, it would be surprising if this were not true. By their very nature central bank models are unlikely to incorporate radically new perspectives, unless there have been some severe changes in an economy. Concepts that have a proven value, rather than those that are speculative, will inevitably form the basis of the chosen CM. Moreover, the econometric techniques used to transform the CM to a DAM and OM will also be expected to be reasonably conventional. This is not to say that a model like BEQM cannot be innovative. Because it was built some time after MTMM, it is often possible to incorporate a wider range of features than before, and the range of methods that have proven to be useful has almost certainly expanded since MTMM was built.

In building their CM the modellers stated the following objective (page 11): 'To incorporate theory that is rich enough to be able to handle a wide range of economic

analysis and investigation, while remaining tractable, internally consistent, coherent and easily understood.' My feeling is that this objective has been achieved. BEQM-core incorporates an impressive number of features that are widely regarded as being important in capturing movements in the economy. It is also my belief that BEQM is sufficiently innovative that it will be a reference point for many central banks when they come to design the CM that is to gird their macroeconomic analysis.

Taking a broad view, one of the innovative aspects of BEQM-core is the degree of integration in the modelling of decisions by agents in an economy. Many policy models in the past have had a CM which simply determined a set of interrelationships between variables. These might be considered as capturing the relative patterns of behaviour of the variables entering them when looked at over reasonable periods of time and are often referred to as 'long-run' equilibrium relations. Once there is a departure from such relations in a particular historical period one expects forces to trigger a set of adjustments to restore them. The speed of such adjustments is generally determined by considering how quickly the relations were restored when the economy was subject to some shocks in history. Effectively this was a major step in the chosen CM becoming a DAM. Technically, it was done by specifying some parametric class of adjustment schemes, with the data being used to estimate these parameters. Perhaps the most prominent example of this scheme today is the Federal Reserve model of the US economy (FRB-US). In BEQM-core the relations between variables involved in decisions, and the adjustments needed to restore such relationships, are determined simultaneously.

There are always features of a CM that may not appeal to outside observers. Examples in terms of BEQM-core might be the way in which inertia is introduced into inflation rates, how persistence is imposed upon consumption decisions, the way in which wage determination is modelled, and the values assigned to some of the parameters of the model. Such dissent can be a very healthy response if it encourages those observers to show how their alternate vision would produce a better CM. However, listing a complete set of the items that might be deemed controversial seems inappropriate in this report. The decisions taken by builders of CMs have to be rooted in what is tractable and what is familiar to policymakers, and one needs to recognise these constraints when making criticisms of the particular choices made.

Documentation of BEQM-core is very good. Indeed I felt that this could easily be used as a text on how one builds CMs. It explains many of the choices made in simple terms and is a good guide to much modern macroeconomic theory. It also provides a very good feel for the 'art' of quantifying the parameters of the core model ie how data informs the choices of parameter values for the CM. Because of the size and complexity of BEQM the number of parameters that have to be quantified is far larger than is typically discussed in academic research and teaching and so the analysis provided in the document should be of interest to those engaged in macroeconomic research more generally.

### The data-adjusted model (BEQM/non-core)

In building the DAM the project had the following objective (page 11): 'to make this theoretically tight model match the data as well as the previous model.' To do this BEQM adopts a novel approach of utilising the output of the CM (BEQM-core) as the reference point and then proposing a list of variables that are to augment the CM so as to narrow the gap between the CM model output and the data. These are non-core variables and the DAM is described in the BEQM documentation as being part of the non-core model. The error between the CM and the data is therefore partially explained by these augmenting variables. Such an error correction approach has been used for many years in macroeconomic modelling, but not quite in the way that it is adopted in BEQM. The procedure developed by the modelling team is a very useful way of moving between the CM and the DAM and I expect it to influence many future modellers.

How does one judge a DAM? At a minimum one would like information on three ways of describing the performance of the model. These are:

- the operating characteristics of the model in response to particular shocks;
- the extent to which the modifications made in producing the DAM infringe upon the desirable features of the CM; and
- the tracking ability of the model over an historical data period.

In the BEQM documentation the impact of a number of shocks upon variables in the full model is described. Clear explanations are provided on the economic rationale for the particular responses observed. There is

also good reference to what previous literature would lead one to expect about them. However, I must confess to a desire to see the separate responses from both BEQM-core and BEQM in order to gain some appreciation of the contribution of the non-core components to these responses, although it has to be recognised that it is the complete model response that should influence any judgement about the 'quality' of BEQM.

Much thought was given to ensuring that the constraints enforced in BEQM-core also held in BEQM. An exception was that, while output in BEQM-core must lie on a production function ie it is produced using the quantity of factors and utilisation rates which are the product of optimal decisions, this is not true for BEQM, at least in the short run. The existence of a mystery factor of production (or unexplained rises in factor utilisation) was often criticised in the macroeconomic models of the 1970s, and I found it a little unsettling that a similar feature also appears in BEQM. What significance should be attached to this depends on how large the variation in factors or their utilisation rates needs to be to produce observed output, and some analysis of this would have been welcome.

Some information was provided concerning the tracking performance of BEQM, in the form of prediction errors. These suggest that BEQM does track the data more closely than MTMM, thus satisfying the objective set out above. In older models it was often the case that a dynamic simulation was performed to evaluate the utility of the model. Although no comparison is given here that is exactly of this type, the 13 quarter-ahead forecast is probably a reasonable substitute, and it shows a very strong preference for BEQM over MTMM in the tracking of inflation, although slightly weaker in terms of GDP. Also provided is a comparison of BEQM-core tracking performance relative to MTMM which shows quite dramatically how much the adjustments made in moving to the DAM improve the tracking performance in the longer term as well as a single quarter ahead. Such a result reinforced my desire, expressed above, to see a decomposition of any BEQM comparisons into the relative contributions made from the core and non-core parts of the model.

Documentation of the DAM is quite good, although I think it to be less complete than for the CM. The equations used to transform BEQM-core to BEQM-DAM are well set out, and each one provides concrete and

useful information on how this task is performed. I was less happy with the information provided concerning how the predicted paths of variables from the core model were constructed. Any CM model has within it a range of shocks, some of them being observable and some unobservable. Productivity shocks are generally unobservable whereas items like world demand are observable. There is a general description in the documentation of how observable shocks were constructed over an historical period, but not of unobservable ones. It seems that no unobservable shocks were present in the experiment to measure tracking performance, which might be regarded as surprising given the productivity movements over a period like the 1990s.

A further qualm I had about the information provided on tracking performance was that it was mainly of a summary nature ie it represents an average over history. Although valuable, it might well be supplemented with information relating to particular episodes. Thus the tracking performance in the period after 1997, when there was a strong exchange rate, is of interest.

### The operational model

In building the OM the project had the following objective (page 11): ‘To make the model reliable and efficient under different forecasting assumptions, and amenable to the imposition of judgemental adjustments and conditioning paths.’

It is difficult for a reviewer to comment on the extent to which this objective has been achieved. The opinions of the ultimate users of the model — policy advisors and the MPC — constitute the source material for providing an answer. I interviewed a small number of people from each group, seeking their opinions about whether BEQM was a useful model in their deliberations. It would seem that the advisors found it to be a useful tool and felt that the extra flexibility of BEQM (compared to MTMM) enabled scenarios to be constructed that could be given a sounder economic rationale. Moreover, the non-core additions were a useful technique for enabling the MPC to impose their opinions about economic

developments which would have been hard to explain within the core model.

The model has also proven to be stable and to solve quickly. In general the presence of a strong CM in the form of BEQM-core meant that more attention was being paid to the economic issues and a little less to how adjustments should be made to capture known deficiencies in a model like MTMM. This seemed to be an opinion shared by the MPC members I spoke to, although it was clearly difficult for them to move away from an older model, whose deficiencies were well known, to one where there had been only a short period of operational use, and so its idiosyncrasies were not fully understood. On balance however I would conclude that the objective has been achieved.

### Summary

From the comments I have made above I would conclude that the construction of BEQM has been a success. It seems to provide a more satisfactory vehicle than MTMM for the discussion of outcomes and the policy responses that should be made to them, as well as producing superior forecasting performance over the medium term. Building a model such as this is not a trivial task and there was no guarantee of success. One of the reasons for the project being so fruitful was the careful attention paid to the process of model construction: this involved selecting a talented group of researchers with a mixture of theoretical and quantitative skills, the provision of an intranet site that thoroughly documented developments in the model at all stages, a regular briefing of staff in the Monetary Analysis divisions of the Bank about progress, and an involvement of some representatives of the MPC in the formulation of the CM. All of these were crucial elements in eventually producing a successful product. Although this process is not detailed in the documentation of BEQM it is very important and should be regarded as an essential part of constructing future macroeconomic models of this type. In conclusion I would like to congratulate all those who participated in some way in the construction of BEQM and to thank the people who spent many hours discussing with me the details of the model and their experiences with it.

### References

Harrison, R, Nikolov, K, Quinn, M, Ramsay, G, Scott, A and Thomas, R (2005), *The Bank of England Quarterly Model*, Bank of England.