

# Chief Economists' Workshop: state-of-the-art modelling for central banks

By Andy Blake and Céline Gondat-Larralde of the Bank's Centre for Central Banking Studies.<sup>(1)</sup>

Since 2004 the Bank's Centre for Central Banking Studies has organised an annual Chief Economists' Workshop to provide a forum for leading central bank practitioners and academic thinkers to exchange views. The recent financial crisis has put many aspects of central banks' activities under the spotlight, and this year's Workshop offered a critical appraisal of the economic modelling frameworks used by central banks. Efforts are under way to build upon advances in research and improve those frameworks. But, at the same time, economists will need to remain humble about the inevitable limitations of their models, which will continue to be just one of many inputs to the policymaking process.

In May 2010, the Centre for Central Banking Studies at the Bank of England held its seventh Chief Economists' Workshop, taking as its theme 'state-of-the-art modelling for central banks'. The event featured three keynote academic speakers as well as talks by participants on the macroeconomic and financial models currently in use or being developed to meet the various challenges faced by central banks.<sup>(2)</sup> Central to the discussions was the question of how central banks should respond to the potential deficiencies in their modelling frameworks highlighted by the recent financial crisis. This article summarises the main points raised during the Workshop.<sup>(3)</sup>

Economic history teaches us that crises are a common feature of economic development.<sup>(4)</sup> Yet, when they eventually take place, they have been often treated as surprise events or episodes of 'bad luck'. Occasionally, crises do trigger a rethink of economics, both as a discipline and for its practitioners. For example, after the Great Depression of the 1930s, modern macroeconomic theory emerged, following Keynes's work and subsequently underpinned by the formal mathematical framework initiated by Hicks and Samuelson. There was also a significant improvement in the collection of macroeconomic data across countries, including national accounts. These theoretical and empirical advances allowed policymakers after World War II to develop a workable framework for macroeconomic policy to guide their fiscal and monetary decisions.

## The academic challenge raised by the crisis

The recent financial crisis has already triggered debate about the state of macroeconomics and financial economics.<sup>(5)</sup> One of the leading commentators to predict the fallout from the credit bubble as early as the mid-2000s was Nouriel Roubini (Stern School of Business, New York University). As a keynote speaker at the Workshop, he provided a comprehensive critique of macroeconomics.

Roubini argued that standard macroeconomic models — such as those taught in universities — do not deal well with the possibility of crises.<sup>(6)</sup> Most economic or financial crises result from structural imbalances that have built up over time — rather than a sudden and unexpected shock — meaning that they are, to some extent, 'predictable' (even if the exact timing of their unravelling is not). But standard models are largely based on equilibrium concepts.<sup>(7)</sup> As such they have, for example, limited market frictions, few externalities and

(1) The authors would like to thank Garreth Rule and Francesco Zanetti for their help in producing this article.

(2) The keynote speakers were Professors Nouriel Roubini (Stern School of Business, New York University), Andrew Lo (Sloan School of Management, Massachusetts Institute of Technology) and Alan Kirman (GREQAM, Université Aix-Marseille III). Some of the Workshop's material is available on the Bank's website at [www.bankofengland.co.uk/publications/events/ccbs\\_cew2010/introduction.htm](http://www.bankofengland.co.uk/publications/events/ccbs_cew2010/introduction.htm).

(3) This article reports the views of participants at the Workshop and does not necessarily reflect the views of the authors, the Bank or Monetary Policy Committee members.

(4) For a historical analysis of financial crises, see Reinhart and Rogoff (2009).

(5) For a summary of the debate within academia on the impact of the crisis on economic thought, see Krugman (2009), Cochrane (2009) and Spaventa (2009) among others.

(6) See Roubini and Mihm (2010) for more.

(7) In particular, these models typically focus on steady-state analysis and examine the dynamics of variables near the steady state.

contain an overly simplified financial system with complete, efficient markets, thereby implying no asset price bubbles. In addition, they do not explicitly include either political economy constraints or principal-agent issues. All of these factors were important contributors to the recent financial crisis. Over the past two decades, significant progress has been made to deal with each of these weaknesses.<sup>(1)</sup> But these microeconomic or partial-equilibrium modelling advances have been made in a piecemeal manner and are yet to be embedded into a new, single paradigm.

Roubini emphasised that academic research should prioritise developing macroeconomic models that are better at modelling the complexity of the dynamics in the financial sector, and its interactions with the real economy. In particular, it is important to understand better the effect of asset price movements on financial intermediaries' balance sheets and their leveraging/deleveraging cycle, and ultimately on the market's liquidity in a macroeconomic context.<sup>(2)</sup>

## The convergence of central banks' modelling frameworks during the Great Moderation

Prior to the recent financial crisis, there was an emerging consensus within macroeconomic theory. This period was characterised by an unusually high degree of macroeconomic stability, with most developed countries experiencing steady output growth and low and stable inflation. Within the economic community, a 'new neoclassical synthesis' emerged, combining the strengths of the various competing approaches developed over previous decades.<sup>(3)</sup> This new generation of macroeconomic models — known as dynamic stochastic general equilibrium (DSGE) models — has become increasingly popular as policy tools in central banks. They are now widely used to help assess the causes of both cyclical and structural changes within the economy as well as to forecast the main macroeconomic variables and the effect of monetary policy changes.

These DSGE models contain features from a broad range of economic thought. They borrow from new classical models, relying on microeconomic foundations to describe decision-making by agents based on their preferences and the constraints they face. DSGE models also include 'New Keynesian' features, assuming that prices cannot costlessly and instantaneously adjust. This, in turn, gives a role to monetary policy.<sup>(4)</sup> At the heart of DSGE models are the intertemporal choices made by agents and, hence, the role played by expectations in determining current macroeconomic outcomes. These features mean that these models are well suited to exploring the interaction between policy actions and agents' behaviour, something that the older generations of macroeconomic forecasting models could not (Lucas (1976)).<sup>(5)</sup>

## Improving current policy modelling frameworks

Before the financial crisis, DSGE models typically contained only a very rudimentary description of the financial sector. In part, that was because up until then there was little evidence that financial variables played an important role in explaining business-cycle fluctuations. But it also reflected more fundamental difficulties in modelling financial system behaviour, particularly in stressed conditions when the risk of spillover, contagion and adverse feedback loops come to the fore.<sup>(6)</sup> These factors mean that financial crises may have a larger effect than crises not originating in financial markets, a feature that is difficult to incorporate into a general equilibrium model.<sup>(7)</sup>

The recent crisis has clearly demonstrated, however, that the behaviour of the financial sector can have important implications for both the real economy and monetary policy. The macroeconomic models used in central banks ahead of the crisis were not built to analyse or deal with a sudden breakdown of credit markets as witnessed in late 2008, and nor were the majority of the alternatives that were available.

Consequently, policymakers face an important challenge to their stylised modelling framework.<sup>(8)</sup> Central banks have been at the forefront of developing and operationalising sophisticated versions of these models. As a result, many DSGE models now include one or more financial frictions. For example, they may incorporate a financial-accelerator mechanism (as developed by Bernanke *et al* (1996)) to reflect the role that businesses' assets used as collateral for borrowing can play in amplifying shocks. Financial intermediaries have also been introduced into a DSGE framework by incorporating credit spreads that are affected by banks' balance sheets.<sup>(9)</sup>

The reaction of modellers to the crisis marks an important development in macroeconomic modelling. In a recent paper, Christiano *et al* (2010) argue that the current generation of models is quite capable of explaining the key channels through which monetary policy operates, for example providing a

(1) For an example of these, see Vayanos and Woolley (2008), who offer a rational theory of market momentum and reversal based on delegated portfolio management.

(2) For instance, see Brunnermeier and Sannikov (2010) for a recent example of this academic research on macroeconomic models with a financial sector.

(3) See Mankiw (2006) for a summary of the macroeconomic modelling advances since the Great Depression. The term 'new neoclassical synthesis' was coined by Goodfriend and King (1997) to describe this consensus view.

(4) See, for example, Woodford (2003).

(5) The 'Lucas Critique' argues that traditional macroeconomic models were liable to give unreliable predictions about the effects of changes in economic policy. Their estimated parameters were functions of the policy regime, rather than underlying structural behaviour, and therefore may have changed if policy changed.

(6) For instance, see Brunnermeier (2009) for an analysis of amplifying mechanisms arising from leveraged positions of financial intermediaries.

(7) See International Monetary Fund (2008) for a review of past episodes of financial stress and their implications for economic activity (Chapter 4).

(8) See Bean (2009).

(9) See Cúrdia and Woodford (2009a,b).

plausible account of pricing frictions. Further work is of course necessary and some of the weaknesses highlighted by the crisis can be improved upon as part of central banks' ongoing research programmes.

## A more pluralistic approach to modelling for monetary and financial stability?

A single framework may not be able to incorporate the right balance between richness and parsimony that policymakers need to address both monetary and financial stability issues. Some economists clearly favour more pluralism in modelling approaches. For instance, Solow (2008), commenting on the state of macroeconomics, noted that his 'general preference is for small, transparent, tailored models, often partial equilibrium, usually aimed at understanding some little piece of the (macro-)economic mechanism'. As he went on to say, '(o)ne of the advantages of this alternative style of research is that it should be easier to accommodate relevant empirical regularities derived from behavioral economics as they become established'.<sup>(1)</sup>

This pluralistic approach is consistent with central banks' current modelling frameworks, which typically draw on a suite of models. One of the effects of the crisis could be to induce a different sort of pluralism in economic research as economists explore new modelling techniques to complement those already available — for instance, by borrowing tools from other sciences or fields. Indeed, Workshop participants suggested a number of alternative modelling paradigms, as discussed below.

### The economy as a system of interacting agents

Some of the assumptions chosen for microeconomic foundations of DSGE models may prevent economists from taking into account the direct interaction between individuals. This was explored further in a keynote session by Alan Kirman (GREQAM, Université Aix-Marseille III).<sup>(2)</sup> In this context, the economy can be viewed as a complex system composed of different agents who do not necessarily follow the generally accepted behavioural rules, such as rational behaviour. Since agents interact with each other both directly and indirectly, behaviour at the aggregate level is intrinsically different from the average behaviour of individuals. It is difficult therefore to embed this within a model with a typical representative agent, such as standard DSGE models. Instead, it is important to understand better the network governing the interaction between agents. Both the structure and evolution of this network can have significant implications for macroeconomic performance, and the emergence of crises in particular.

This approach can be extended to other systems such as the financial sector. The recent crisis has shown that the financial system was much more complex and adaptive than economists had modelled.<sup>(3)</sup>

Some of the risks to the financial sector as a whole (or 'systemic risk') come from within the system, ie they are 'endogenous'. This contrasts with most other systems — such as ecosystems or electrical grids — in which risk is typically exogenous and unpredictable. It is the role of both financial institutions and markets to create, intermediate and manage risks across states of the world and over time. But in doing so, financial companies potentially contribute to systemic risk. Financial institutions are highly connected with each other, both directly and indirectly, domestically and internationally. Partly because of the complexity of these interlinkages, financial institutions do not always take into account the impact that their own actions might have on other financial institutions. The response of those institutions can in turn create adverse feedback loops within the system.<sup>(4)</sup>

This 'network risk' has been particularly difficult to trace. That in part reflects inadequate data on the connections between financial institutions, which in turn partly reflects the low frequency of severe stress episodes during which those connections are typically revealed. But it also reflects a lack of information on how domestic financial systems are joined together globally.<sup>(5)</sup>

Initiatives are, however, already under way to improve our understanding of this 'network risk'. Efforts are being made to improve both the quantity and quality of data available to market participants and authorities. This will provide a better snapshot of the structure of the network, making it easier to spot potential weak points. In addition, economists have drawn on network techniques from other disciplines — such as ecology or epidemiology — to understand how characteristics of the financial network structure (such as the degree of interconnectedness between financial institutions) can influence the impact of shocks and how they spread. While this strand of work is fairly new, it typically shows that tipping points exist at which robust systems can suddenly swing into fragility.<sup>(6)</sup>

### The challenges in quantifying systemic risk

Network models typically include limited modelling of the behaviour of financial institutions, and in particular banks. As a result, they have limited ability to track or explain various sources of risks (eg credit risk, market risk, interest income risk)

(1) The article by Solow (2008) is a response to Chari and Kehoe (2006) on how modern macroeconomic theory has been shaping policy.

(2) See Kirman (2010).

(3) These systems are 'complex' in the sense that they are made up of multiple, interconnected elements, and 'adaptive' because they can change and learn from experience. The ecosystem is an example of a complex adaptive system. Haldane (2009) explores what other disciplines that use models based on similar complex networks can tell us about financial systems.

(4) For an analysis on the sources of systemic risk, see Bank of England (2009a).

(5) For more on authorities' needs regarding data on interconnections within the financial system, see page 46 of Bank of England (2009b).

(6) The financial sector is typically modelled as a set of nodes (representing individual institutions) interlinked by a network of counterparty exposures. Each node, which represents an individual financial institution, is endowed with a very simplified balance sheet. See Gai and Kapadia (2010) or Haldane (2009) on financial networks.

faced by banks, how they interact and how they affect the real economy. To complement the results of network models, policymakers are developing suites of partial-equilibrium models of the banking sector, which can be used to track overall risks in the system over time or run system-wide stress tests to assess its resilience to specific adverse scenarios.<sup>(1)</sup>

One of the main modelling challenges is to account for some of the systemic feedback and contagion effects that emerged during the crisis. For instance, banks sought to raise their liquidity buffers as the crisis deepened and uncertainty increased, and this had a snowballing effect on the liquidity available to the system as a whole. Some recently developed models (for example, the Bank's Risk Assessment Model for Systemic Institutions (RAMSI)) attempt to include several of these feedback effects even though those are still difficult to validate statistically.<sup>(2)</sup> In contrast to most system-wide stress tests that were developed before the crisis, which did not typically include systemic feedbacks, these new models can actually generate system-wide instability. But while these various models have led to promising results, it is too early to say which one(s), or which combination, could become the central organising framework for central banks' assessment of systemic risk in the future.

## The limits of statistics and the importance of embedding uncertainty in central banks' models

New models can enhance our understanding of economic behaviour but it is optimistic to believe that they will generate the certainty available in other sciences. Unfortunately, as emphasised by Aikman *et al* (2010), 'policymakers are often expected to anticipate the unpredictable'.

In a keynote presentation, Andrew Lo (Sloan School of Management, Massachusetts Institute of Technology) argued that while disciplines such as physics can derive laws that

satisfactorily account for the overwhelming majority of available evidence in the field, economics is different because it does not rest on the same level of uncertainty. Models of economic systems and financial markets simply cannot be as predictive as (most of) those in physics.

Building on Knight's (1921) distinction between risk and uncertainty, Lo developed a taxonomy to characterise uncertainty levels in order to help economists understand better the limitations of their own models.<sup>(3)</sup> Without being able to conduct controlled experiments, verifying any economic theory can only be approached indirectly. This is a major factor in what Lo termed *irreducible uncertainty*. The uncertainty faced by both economists and policymakers is, at best, only 'partially reducible' given the nature of both agents' behaviour and economic data. Models can be constructed that are robust in some circumstances, but they can never be expected to explain outliers or satisfactorily account for tail risk. Once uncertainty has reached irreducible levels, any model is then outside of its 'domain of validity'. In this context, 'failures' of economic models can almost always be attributable to a mismatch between the level of uncertainty and the methods/econometric tools used to manage it.

There are two potential, non-mutually exclusive, responses to this challenge. In the medium term, policymakers' objective is to develop further their understanding of economic processes and, hence, build better models to reduce uncertainty further. But in the short run, they also have to devise strategies to manage the risks that they believe cannot be fully modelled or understood. In reality, both approaches are simultaneously applied. Improving a model can be challenging but may be worth the effort. But inevitably, given the nature of economics, there will always be uncertainty. And any user of models, whether an academic or a policymaker, needs to understand the limits of what their models can be used for. The 'physics envy' that economists suffer from should ultimately help them by making them more humble about the limitations of their own models and improving their understanding of the uncertainties they face.

(1) By running a system-wide stress test, policymakers analyse the impact of an adverse scenario at the level of the financial system, as opposed to analysing it at the level of an individual institution.

(2) For more on the Bank's RAMSI, see Aikman *et al* (2009). The Oesterreichische Nationalbank was one of the first to develop such an integrated quantitative framework for systemic risk analysis ('Systemic Risk Monitor') by combining standard models for market and credit risks with an interbank network model to account for the possibility of default cascades.

(3) Lo and Mueller (2010) splits uncertainty into five levels: 'perfect certainty', 'risk without uncertainty', 'fully reducible uncertainty', 'partially reducible uncertainty' and the final 'irreducible uncertainty'.



## References

- Aikman, D, Alessandri, P, Eklund, B, Gai, P, Kapadia, S, Martin, E, Mora, N, Sterne, G and Willison, M (2009), 'Funding liquidity risk in a quantitative model of systemic stability', *Bank of England Working Paper no. 372*.
- Aikman, D, Barrett, P, Kapadia, S, King, M, Proudman, J, Taylor, T, de Weymarn, I and Yates, T (2010), 'Uncertainty in macroeconomic policy making: art or science?', paper delivered to the Royal Society Conference on 'Handling Uncertainty in Science', March.
- Bank of England (2009a), 'The role of macroprudential policy', *Bank of England Discussion Paper*, November.
- Bank of England (2009b), *Financial Stability Report*, June.
- Bean, C (2009), 'The Great Moderation, the Great Panic and the Great Contraction', Schumpeter Lecture, Annual Congress of the European Economic Association, Barcelona, August, available at [www.bankofengland.co.uk/publications/speeches/2009/speech399.pdf](http://www.bankofengland.co.uk/publications/speeches/2009/speech399.pdf).
- Bernanke, B S, Gertler, M L and Gilchrist, S (1996), 'The financial accelerator and the flight to quality', *The Review of Economics and Statistics*, Vol. 78(1), pages 1–15.
- Brunnermeier, M K (2009), 'Deciphering the liquidity and credit crunch', *Journal of Economic Perspectives*, Vol. 23(1), pages 77–100.
- Brunnermeier, M K and Sannikov, Y (2010), 'A macroeconomic model with a financial sector', available at [www.princeton.edu/~markus/research/papers/macro\\_finance.pdf](http://www.princeton.edu/~markus/research/papers/macro_finance.pdf).
- Chari, V V and Kehoe, P J (2006), 'Modern macroeconomics in practice: how theory is shaping policy', *Journal of Economic Perspectives*, Vol. 20(4), pages 3–28.
- Christiano, L J, Trabandt, M and Walentin, K (2010), 'DSGE models for monetary policy analysis', *NBER Working Paper no. 16074*.
- Cochrane, J H (2009), 'How did Paul Krugman get it so wrong?', available at [http://faculty.chicagobooth.edu/john.cochrane/research/Papers/krugman\\_response.htm](http://faculty.chicagobooth.edu/john.cochrane/research/Papers/krugman_response.htm).
- Cúrdia, V and Woodford, M D (2009a), 'Credit spreads and monetary policy', *NBER Working Paper no. 15289*.
- Cúrdia, V and Woodford, M D (2009b), 'Conventional and unconventional monetary policy', *Federal Reserve Bank of New York Staff Report No. 404*.
- Gai, P and Kapadia, S (2010), 'Contagion in financial networks', *Bank of England Working Paper no. 383*.
- Goodfriend, M S and King, R G (1997), 'The new neoclassical synthesis and the role of monetary policy', in Bernanke, B S and Rotemberg, J J (eds), *NBER Macroeconomics Annual*, Cambridge, MA: MIT Press, pages 231–83.
- Haldane, A (2009), 'Rethinking the financial network', available at [www.bankofengland.co.uk/publications/speeches/2009/speech386.pdf](http://www.bankofengland.co.uk/publications/speeches/2009/speech386.pdf).
- International Monetary Fund (2008), 'Financial stress and economic downturns', *World Economic Outlook*, Chapter 4, pages 129–58.
- Kirman, A (2010), 'The economic crisis is a crisis of economic theory', available at [www.bankofengland.co.uk/publications/events/ccbs\\_cew2010/paper\\_kirman.pdf](http://www.bankofengland.co.uk/publications/events/ccbs_cew2010/paper_kirman.pdf).
- Knight, F H (1921), *Risk, uncertainty and profit*, Boston, MA: Houghton Mifflin Co.
- Krugman, P R (2009), 'How did the economists get it so wrong?', *The New York Times*, 2 September.
- Lo, A W and Mueller, M T (2010), 'WARNING: physics envy may be hazardous to your wealth!', available at <http://web.mit.edu/alo/www/Papers/physics8.pdf>.
- Lucas, R E (1976), 'Econometric policy evaluation: a critique', *Carnegie-Rochester Conference Series on Public Policy*, Vol. 1, pages 19–46.
- Mankiw, N G (2006), 'The macroeconomist as scientist and engineer', *Journal of Economic Perspectives*, Vol. 20(4), pages 29–46.
- Reinhart, C M and Rogoff, K S (2009), *This time is different: eight centuries of financial folly*, Princeton University Press, Princeton and Oxford.
- Roubini, N and Mihm, S (2010), *Crisis economics: a crash course in the future of finance*, Allen Lane.
- Solow, R (2008), 'Comments: the state of macroeconomics', *Journal of Economic Perspectives*, Vol. 22(1), pages 243–45.
- Spaventa, L (2009), 'Economists and economics: what does the crisis tell us?', *CEPR Policy Insight no. 38*.
- Vayanos, D and Woolley, P (2008), 'An institutional theory of momentum and reversal', *NBER Working Paper no. 14523*.
- Woodford, M D (2003), *Interest and prices: foundations of a theory of monetary policy*, Princeton University Press.