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COMMENTARY

Monetary Policy

When Nightmares Become Real:

Modelling Linkages between the Financial Sector and the Real Economy in the Aftermath of the Financial Crisis

Philippe Bergevin
Pierre Duguay
Paul Jenkins

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In this issue...

The models used by central banks to guide policy proved highly inadequate during the financial crisis because of their neglect of the complex linkages between the financial system and the real economy. Why? And what can be done?

The Study in Brief

The Authors of This Issue

PHILIPPE BERGEVIN is a Policy Analyst at the C.D. Howe Institute.

PIERRE DUGUAY is a former Deputy Governor at the Bank of Canada and a Research Fellow at the C.D. Howe Institute.

PAUL JENKINS is a former Senior Deputy Governor at the Bank of Canada, a Senior Distinguished Fellow at Carleton University, a CIGI Distinguished Fellow and a Senior Fellow at the C.D. Howe Institute.

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The global financial crisis revealed the multifaceted nature of the linkages between the financial sector and the real economy. Models typically used by central banks have tended to neglect the complexity of these linkages. This is rapidly changing, but the need for policymakers to understand the limitations of their models and to use them with circumspection in order to prevent (potentially substantial) avoidable costs in terms of output and employment is not. The financial crisis has posed two basic challenges to monetary authorities: the need to develop a better understanding of the linkages from the financial sector to the real economy, and the need to reconsider the policy framework.

Canada's inflation-targeting framework has proven effective in anchoring expectations and in helping shape the monetary policy response to the crisis. The models widely used by central banks to guide policy, however, have proven highly inadequate during this period because of their neglect of the complex interdependencies in the financial system and between the financial system and the real economy. Such neglect can impose substantial costs in terms of output and employment, by eliciting a suboptimal response from monetary policy authorities.

The need to factor-in a richer representation of the linkages between the financial sector and the real economy is also critically important in determining the extent to which monetary policy can, or should, be used to counteract the buildup of systemic risk in the financial system, the key issue from a policy framework perspective.

This *Commentary* looks at the models used by central banks, with a particular focus on model development and use at the Bank of Canada, to find out why financial linkages were neglected, how models were modified to support policymaking during the crisis, and what is being done to remedy their deficiencies, so that they can again be used as the mainstay for monetary policy purposes.

While considerable progress is being made in modeling the complexities of the linkages between the financial sector and the real economy, these models remain highly stylized and constrained by methodological choices, in particular a predilection for modeling the economy in a state of general equilibrium.

The *Commentary* concludes that models are and will always be, by nature and by necessity, simplified representations of the economy, and that no one model can answer all questions. Different models must be used for different purposes. The art is to determine the question that needs to be asked and to develop or select the model that will yield the appropriate insight to inform policy decisions. In this context, it is important for policymakers to have access to a range of models that complement each other, to understand the limitations of their models, and to use them with circumspection.

From the mid-1990s until the mid-2000s – the years of the "Great Moderation," as it became known – business cycle volatility declined markedly in most economies.

It was a period of benign global economic conditions: low inflation, strong growth, and low unemployment. It was also a period during which emerging market economies outperformed advanced economies, prompting the "decoupling" hypothesis, a view that was quashed by the financial crisis as growth rates across the world tumbled in unison. The crisis exposed the multifaceted way in which financial and economic shocks were felt, especially the very different experiences of advanced economies and emerging markets in terms of the channels of transmission. For emerging market economies, traditional trade channels were the dominant source of transmission. For advanced economies, it was financial linkages that provided a stronger explanation for the scale of the downturn in economic activity (Devereux and Yetman 2009).

The financial linkages and interdependencies that the crisis revealed have brought to light new complexities in analyzing the transmission of shocks and the scale of those shocks. This adds a critically new dimension to what economists need to understand in the development of analytic tools, including the economic models used for policy analysis. Economic theory has long recognized that, in the context of asymmetric information, the classical Modigliani-Miller theorem of the financial structure – which states that, under certain conditions, the market value of a firm is unaffected by how it is financed – will not hold. In the aftermath of the financial crisis, what is called for are new approaches that recognize that financial markets do not operate in a frictionless environment, but rather are fraught with agency costs, enforcement problems, and fragility from liquidity transformation and fluctuations in the state of confidence.[1] Indeed, these frictions are the main reason money is used as a means of settlement (Chiu and Lai 2007).

Important work – building on the seminal papers of, for example, Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) – is under way to address these issues. This work includes the development of models that emphasize that financial frictions can lead to enhanced propagation of shocks across countries, but they also stress that the financial sector itself might be the source of shocks (Devereux 2010).

There are clearly many lessons to be learned from the global financial crisis. One important lesson for policymakers is that financial stress, financial innovations, and changes to financial regulation can alter the linkages between the financial sector and the real economy. This has direct consequences for the transmission of monetary policy: those linkages running from the actions of the central bank through the financial sector to behaviour in the real economy. The financial crisis demonstrated that those linkages can indeed change. For example, we have seen that time-varying term, liquidity, and risk spreads are empirically relevant for explaining real activity, with consequences for the setting of the central bank policy rate to take these changing spreads into account. Conducting monetary policy at the effective lower (zero) bound for nominal interest rates is another example where traditional spreads between lending and deposit rates can become compressed at such low interest rates. We have

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1 Agency costs arise from the possibility that an agent (for example, corporate executives) might not always behave in the best interest of the principal (the corporation's shareholders, in this example). Liquidity transformation refers to the transformation of illiquid assets (e.g., loans) into liquid deposits or marketable short-term securities. That transformation rests on investors' confidence that funds will be readily available when needed.

also seen that procyclical elements of financial regulation can have important consequences for the real economy. Greater reliance on macroprudential regulation and supervision[2] to address these procyclical elements – in effect, the design and use of countercyclical macroprudential tools – raises the issue of the implications for the conduct of monetary policy.

In this *Commentary*, we review the ways in which the linkages between the financial sector and the real economy have been altered – or our awareness of the linkages has been enhanced – in response to the financial crisis. In so doing, we pay specific attention to the implications for the transmission of monetary policy as captured through the development and use of economic policy models. In the next section, we provide an overview of economic models and their usefulness for policy purposes, laying special emphasis on recent directions in model development to deal with the issues and lessons of the global financial crisis. We then offer a brief history of model development at the Bank of Canada, showing how it has been shaped by the challenges faced by model users (policymakers). We follow this by drawing out experiences and lessons from the financial crisis for the use of models, and close the *Commentary* with some policy implications and conclusions.

Macroeconomic Models: What Are They and Why Do We Need Them?

Macroeconomic models are, by nature and by necessity, simplified representations of the economy.[3] They are widely used in academia, governments, international organizations, and corporations to understand and to attempt to predict the dynamics of macroeconomic variables such as economic growth and inflation, and to assess the implications of different policies. The models fall mainly into two broad genres: traditional macroeconometric models, which are built from the bottom up, block by block, and micro-based dynamic stochastic general equilibrium (DSGE) models, built with an explicit focus on top-down general equilibrium constraints or conditions. Because of their central use in academia and central banks, this *Commentary* concentrates on DSGE models, and particularly on what is being done to address their shortcomings underscored by the financial crisis and to capture the linkages between the financial sector and the real economy, so as to render them again a mainstay for policy purposes. For some analysts, however, the failure of DSGE models to explain the crisis relates to the top-down constraints imposed on them to ensure internal consistency. This has renewed interest in another class of models built from the bottom up: agent-based models, which relax many of the constraints of DSGE models. We return to this class of models in our concluding section.

In contrast to macroeconometric models that use mainly statistical relationships based on historical data and, hence, on past observable correlations, DSGE models are meant to provide a complete and internally consistent representation of the economy in which the behaviour of key macroeconomic variables is derived from basic economic assumptions (see Bank for International Settlements 2011). More specifically, DSGE models use the interaction of many microeconomic decisions, which are themselves based on theoretical foundations, in an attempt to describe the behaviour of the economy as a whole. These decisions are taken by "agents" – households, firms, and sometimes governments, central banks, and others in more elaborate models.

2 Macroprudential regulation and supervision focuses on the system as a whole with a view to protecting the real economy from severe disruptions in the provision of financial services. This is in contrast to microprudential regulation and supervision, which focuses on strengthening individual financial institutions with a view to protecting their creditors.

3 As Baumol and Blinder (2007) argue, "[a]bstraction from unimportant details is necessary to understand the functioning of anything as complex as the economy."

All agents in such models have stated objectives and constraints. For example, households typically want to maximize the utility they derive from consumption, subject to their budget constraints – that is, how much they can spend – which, in turn, depends on how much they are willing to work and how much wealth they have accumulated, while firms invest and hire workers to maximize profits. These agents interact in markets that "clear" – that is, supply equals demand – in every period, which leads to the "general equilibrium" attribute of these models. As their name also implies, DSGE models are dynamic, meaning that they study the economy over time and that actions are based on forward-looking expectations. They are also stochastic, meaning that variables are subject to random shocks – such as changes in tastes and technology (both domestic and foreign) – that underpin economic fluctuations. Outcomes thus might differ from expectations, but expectations are formed consistently with the structure of the model.[4]

The development of DSGE models was prompted by major shortcomings of traditional macroeconometric models. Robert Lucas, in his seminal 1976 paper, argued that econometric models based on past observable relationships cannot be relied upon to predict the effects of changes in economic policy. In his concluding remarks, he summarized his critique by stating that, "given that the structure of all econometric models consists of optimal decision rules of economic agents, and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that any change in policy will systematically alter the structure of econometric models" (41). Micro-founded models such as DSGE models, however, offer a more coherent framework. For instance, in such models, optimizing agents explicitly take into account changes in policy, and thus the predicted outcomes, provided the models are well specified, are not subject to Lucas's critique. Because of these and other characteristics, DSGE models have become dominant in academia and have made important headway as a policy tool in governmental organizations – notably central banks (Woodford 2009). Their appeal also lies in their stylized and simplified framework of the economy. By abstracting superfluous details, they more easily convey key economic relationships and allow for easier policy insights and conclusions. The art, of course, is to determine what is superfluous and what is material, for these models' simplification of the world can become their major shortcoming.

The financial crisis that started in late summer 2007 shone a bright light on some of the strong simplifying assumptions imbedded in DSGE models – in particular, their neglect of the complications, or "financial frictions," that arise from information asymmetry between lenders and borrowers and from the limited enforcement of contracts. To keep them manageable, many standard DSGE models make use of a "representative agent" – implying by assumption that everybody behaves the same way – and impose intertemporal budget constraints, effectively eliminating the possibility of default and the need for financial intermediation.[5] Furthermore, in these models, the representative consumer owns the representative firm, implying as in the Modigliani-Miller theorem that its cost of capital is independent from the structure of its financing (debt versus equity or retained earnings). It is easy to see why such simplifications render DSGE models ineffective in analyzing the causes and economic consequences of the recent financial crisis.

4 This ignores the complications that arise in the real world from model uncertainty (see Jenkins and Longworth 2002) and changing views about the structure of the economy.

5 An alternative interpretation is that, on the assumption that financial markets are complete – that is, that every contingency can be appropriately priced and insured – economic decisions will be coordinated in such a way that it will appear as though the economy were populated by a representative agent, even if agents display substantial heterogeneity in preferences and endowment. While the continued deepening of financial markets and the proliferation of risk-transfer instruments seemed to make the complete market assumption more tenable, the financial crisis cast serious doubts on the validity of that assumption and on the extent to which it should be imbedded in macro models.

The crisis was characterized notably by the losses many financial institutions outside Canada suffered, which not only affected their capital position and their ability to lend, but also cast a long shadow of uncertainty about the health of all financial institutions, sending a chill through funding markets everywhere, including Canada. When the financial system thus fails in its task of coordinating agents' decisions, when confidence is shattered and agency costs are magnified, the heterogeneity of agents and deviations from the Modigliani-Miller theorem become important, and DSGE models that ignore these features are unable either to assess the real economic consequences of disruptions in financial activity – let alone to anticipate their occurrence – or to provide policy guidance. For these and other reasons, DSGE models are currently the target of much criticism. Nobel Memorial laureate Paul Krugman has argued that most macroeconomics of the past 30 years was "spectacularly useless at best, and positively harmful at worst" (2009). Fellow Nobel laureate Joseph Stiglitz has stated that "[e]conomics is in a sorry state of affairs. Most of the economics profession failed to predict the most important economic event to occur in the history of modern "scientific" economics.…The standard models have failed" (2010).

This criticism is not shared by everyone. Another Nobel laureate, Eric Maskin, notes in an interview that economic theory in fact "did a very good job of setting the building blocks for predicting the financial crisis. It's just that no one was paying attention" (Maskin, n.d.). Specifically, these building blocks were not incorporated into standard DSGE models, which were not meant to deal with such extreme events as the financial crisis – indeed, few general purpose models are. DSGE models are simplifications of the world, and it would be unfair to judge them solely on what they cannot explain, rather than on what they can. Furthermore, there is reason to believe DSGE models can be modified to incorporate complexities of the real world economy when simplifying assumptions become material. Considerable efforts in fact have been made – starting well before the financial crisis – and continue to be made to incorporate financial frictions and to assess their materiality, as we shall now see.

Modelling Linkages between the Financial Sector and the Real Economy: A Literature Review

Two important transmission channels between the financial sector and the real economy identified in the literature are related, respectively, to the balance sheet positions of borrowers and lenders – commonly referred to as the "borrower balance sheet" and the "bank balance sheet" (or "bank capital") channels.

Bernanke and Gertler (1989) develop a general equilibrium model in which the condition of borrowers' balance sheets is a source of output dynamics. Agency costs arise because lenders have a limited ability to restrict the amount of risk borrowers are willing to take, owing to information asymmetry between lenders and borrowers. In the Bernanke-Gertler model, the increased net worth of borrowers reduces the agency costs of financing investments by increasing the borrowers' stake in the investments. The output dynamics can be explained as follows: in good economic times, the strengthened financial position of borrowers reduces borrowing costs and spurs investment, which acts to amplify the upturn; in bad times, the opposite occurs. In a subsequent paper, Carlstrom and Fuerst (1997) quantify these effects and expand the model by allowing firms to make investments in more than one period.

In another widely cited paper, Kiyotaki and Moore (1997) construct a model in which lenders cannot force borrowers to repay their debts unless they are secured by collateral. In such an economy, durable assets (such as land, buildings, and machinery) are used not only to produce goods and services, but also as collateral against which to borrow. The prices of durable assets, therefore, affect the extent to which firms can borrow; at the same time, the ability of firms to borrow affects the prices of these assets, through production and

spending. These interactions create a powerful transmission mechanism between the financial sector and the real economy, in which small, temporary shocks (for example, technology shocks) can generate large, persistent fluctuations in output and asset prices.

Bernanke, Gertler, and Gilchrist (1999) develop a fuller DSGE model in which the connection between a firm's borrowing costs and its net worth acts to amplify and propagate shocks to the macroeconomy. This framework – usually referred to as the "financial accelerator" – has established itself as the most common approach to incorporating financial frictions in DSGE models. Building on the framework established by Kiyotaki and Moore (1997), Iacoviello (2005) proposes a model in which loans and collateral constraints are tied to housing values. More recently, Christiano, Motto, and Rostagno (2010) present a DSGE model that includes both a banking sector and financial markets and in which financial shocks are responsible for a substantial portion of macroeconomic fluctuations.

The bank balance sheet channel presents a number of similarities to the firm and household balance sheet channels described above. Just as shocks to borrowers' net worth affect their ability to borrow, so shocks to the level of banks' capital affect their ability to finance their lending activity. Meh and Moran (2008) develop a DSGE model in which bank capital can help reduce the agency problem between banks and their creditors – that is, when banks invest their own capital, they behave more in line with the interest of their creditors. Consequently, the capital position of banks affects their ability to lend and influences the business cycle through what is referred to as the "bank capital channel." An adverse shock to the capital position of banks – due, for example, to writedowns on their loan portfolios – ultimately will have negative consequences for output and investment as a result of reduced bank lending. The bank capital channel can thus amplify and propagate the effect of other economic shocks on output, investment, and inflation, as such shocks affect both the profitability of bank lending and the ability of banks to attract loanable funds, which, in turn, affect lending, aggregate investment, and bank earnings.

In addition to helping mitigate agency costs, bank capital is also required for regulatory purposes – notably, to meet minimum capital level requirements set by regulators. For example, Van den Heuvel (2008) presents a model in which capital requirements not only limit risk-taking on the part of banks – which arises from the moral hazard problem of deposit insurance[6] – but also entail costs by reducing the ability of banks to make loans. Both Dib (2010) and Gerali et al. (2010) propose DSGE models with financial frictions that incorporate a banking sector in which banks must raise capital from new equity issues or from retained earnings in order to meet regulatory requirements.[7]

A further dimension of the linkages between the real economy and the financial sector that has been the focus of recent research concentrates on the importance of liquidity conditions for economic dynamics. For example, Brunnermeier and Pedersen (2009) propose a model that links an asset's market liquidity (the ease with which it is traded) and traders' funding liquidity (the ease with which they can obtain funding) to model formally some of the empirical characteristics of markets' liquidity, such as their potential to dry up suddenly and fall prey to a "flight to quality." This channel has taken on increased importance as banks have become more reliant on short-term wholesale funding and interbank borrowing. Indeed, it played a key role in the recent global financial crisis. Goodhart, Sunirand, and Tsomocos (2004) propose a DSGE model that

6 Moral hazard arises from deposit insurance lowering depositors' worries about the agency problem referred to above.

7 Also related to the bank balance sheet channel is the traditional bank lending channel. This channel suggests that monetary policy, in addition to its effect on market interest rates, might work through its effect on the supply of loans offered by depository institutions (see Bernanke and Blinder 1988). A tight monetary policy is assumed to drain deposits from the system and hence to reduce lending if banks face frictions in issuing uninsured liabilities in lieu of deposits.

introduces endogenous strategic defaults on interbank borrowing, money, and agent heterogeneity. In a recent contribution, Gertler and Kiyotaki (2011) present a model that features an interbank market and allows for the modelling of the effects of unconventional monetary policy interventions. Characteristics associated with the interbank market have proven central in explaining events related to the recent financial crisis.

Model Development at the Bank of Canada

As is evident from a review of the literature, many of the theoretical building blocks linking financial sector activity and the real economy were in place before the financial crisis occurred, though a glaring exception is the role of liquidity. Clearly, there were, and remain, significant gaps in the way these linkages are modeled, but recent research offers hope that these shortcomings will be overcome. In this context, it is important to recognize the evolutionary nature of model development. No one model can answer all questions, and different models should be used for different purposes. What is critical at any point in time is first to define the questions that need to be asked, and then to develop (or select) the models that will yield the appropriate insight and knowledge to inform policy decisions. From this perspective, one may well ask why is it that central banks chose to develop and to use models that did not incorporate the possibility of financial crises, when the historical record is replete with their periodic occurrence? A closer look at model development at the Bank of Canada may provide an answer.[8]

From RDX1 to ToTEM: Experiences and Lessons from Model Development

Model building at the Bank of Canada started some forty-five years ago in the wake of the Royal Commission on Banking and Finance (the Porter Commission), when the conduct of monetary policy actually focused on credit conditions (see Helliwell 2005-06). The first model, RDX1 (which stood for Research Department eXperimental), was a relatively simple quarterly model of price, income, and expenditure determination, with a skeletal financial sector: total bank deposits were given as a multiple of the exogenous supply of bank reserves, and loan demand (linked to business and consumer spending) exerted pressure on bank liquid assets and interest rates, which, in turn, fed into spending and capital flows (see Helliwell et al. 1969).[9]

Before the ink dried on the documentation of RDX1, work started on a more fully articulated RDX2 (see Helliwell et al. 1971), with a full-fledged financial sector (which included financial intermediation) and a reaction function for monetary policy. The modelling of linkages between the real economy and the financial sector drew on James Tobin's general equilibrium approach to monetary and portfolio theory (1969) and featured a complete accounting of wealth, capital stock, government debt, and gross foreign assets and liabilities at both book and market values, together with a measure of the supply price of capital (the cost of capital as defined by Tobin). The model was developed at a time of momentous change in the Canadian economy, which included the liberalization of the financial sector launched by the Porter Commission and the return to a floating exchange rate regime. But despite its attention to integrating the supply and the demand sides of the economy and its intended focus on the dynamics of the system as a whole, the model proved ill-suited to deal with the outbreak of inflation that occurred as soon as it started to be used for policy analysis. That outbreak, together with the a rise in unemployment, exposed the shortcomings of the eclectic view of the inflation process embodied in the large-scale

8 The first part of this section draws heavily on Duguay and Longworth (1998).

9 In light of subsequent developments, one may well ask where did the demand for money fit in RDX1. The model did include a demand for transactions balances, but it merely served to establish the split between transactions and savings deposits.

econometric models of that time, in which inflation was seen as "the outcome of cost-push and demand-pull influences, with the former predominating" (Laidler 2003, 112), particularly their inadequate treatment of inflation expectations.

While there was a desire to understand the dynamics of RDX2 (see Freedman and Longworth 1975; and de Bever, Kohli, and Maxwell 1978), there was also a recognition that the model had not kept up with developments in monetary economics and that it underplayed the importance of monetary policy. Following the adoption of a target range for the growth of transaction money balances (M1) in Canada in the fall of 1975, the policy need to assess more explicitly the response of output and inflation to alternative target paths for M1 was met with simpler simulation models, calibrated to capture the major features of the Canadian economy. These models still contained a lot of details, but their structure was much simpler than that of RDX2 and their dynamics were easier to figure out. Of note, these models featured no financial sector beyond a simple demand-for-money relationship.[10]

Meanwhile, notwithstanding the obvious limitations of the model for policy analysis, a forecasting version of RDX2, dubbed RDXF (McDougall and Robertson 1981), was developed based on an encouraging evaluation of the ex post forecasting ability of a number of large-scale econometric models, including RDX2 (see Jenkins and Kenward 1977). RDXF included a fairly detailed model of the financial sector, including a model of the banking system's liquid asset and wholesale liability management (Clinton and Masson 1975), but there were limited feedbacks, if any, from financial activity to real activity.[11]

The less-than-stellar out-of-sample forecasting ability of RDXF raised questions about the wisdom of sacrificing long-run properties for some elusive forecasting ability. In any event, as the struggle to bring inflation down was proving longer and more difficult than anticipated, there was a need for a more rigorous model to inform policy decisions. In 1980, Bank of Canada researchers set out to build a small-scale model with a strong theoretical base and a well-defined steady state for use in medium-term policy analysis. The modellers paid particular attention to linking labour supply, consumption, and asset demand, modelling production technology with energy as a factor of production and – ensuring consistency of expectations to avoid false policy choices. The resulting model – SAM, for Small Annual Model (see Rose and Selody 1985) – featured multiple assets (government debt, net foreign assets, physical capital, and central bank money) but no credit market and no financial intermediation. Its usefulness for the conduct of monetary policy was limited, however, by its annual frequency and by the fact that it exhibited some short-run dynamics that were at variance with stylized facts. In particular, monetary policy worked, counterfactually, through the disequilibrium between a given supply of central bank money (currency and bank reserves) and the demand for it.

Following the setting of price stability as the goal of monetary policy – as announced by then Bank of Canada governor John Crow (1988) – economic projections by Bank staff were brought to centre stage in the formulation of monetary policy (Duguay and Poloz 1994). Accordingly, a projection model that could also be used for policy

10 The search for a new nominal anchor after the Bank of Canada stopped targeting M1 was informed by an even smaller, four-equation model (output gap, inflation, money demand, and the exchange rate) with a well-defined steady state, plus a policy rule for setting interest rates (see Longworth and Poloz 1986).

11 At the time, the projection exercise was supplemented with a detailed (judgmental) projection of credit market activity as a check for consistency and a way of identifying possible points of pressure in credit markets. However, the ex post equality of savings and investment ensured the equality of aggregate demand and supply for funds, and the fungibility of capital (when markets are working), together with the absence of significant restrictions on bank intermediation, meant there was a multiplicity of scenarios that were consistent with the projection of income and expenditures.

analysis was developed in consultation with senior management. That model, QPM (for Quarterly Projection Model; see Poloz, Rose, and Tetlow 1994), became the workhorse of staff projections from 1993 to 2005.[12] Like SAM, QPM was rigorously grounded in theory and focused on the important role of expectations, price rigidities, and the relationship between income flows and asset stocks (public debt, net foreign assets, physical capital, and household wealth). It excluded credit markets, as work on modelling financial frictions suggested that imperfections in credit markets were responsible for only a small amplification of the real effects of monetary policy, which originated primarily from price rigidities (see Atta-Mensah and Dib 2003; see also Bank of Canada 1995, 1999).[13] Monetary policy established the anchor for inflation expectations by adjusting interest rates to keep inflation on target. It affected household spending through the slope of the yield curve and financial wealth, business investment through short-term and long-term interest rates, net exports through the real exchange rate, and inflation through inflation expectations and the pressure of aggregate demand on capacity.

In December 2005, QPM was replaced by ToTEM (for Terms of Trade Economic Model; see Fenton and Murchison 2006; and Murchison and Rennison 2006) an open-economy DSGE model that takes advantage of new advances in techniques to tie the modelling of the economy, both in and out of steady state, to a set of fundamental assumptions about its structure.[14] These advances also allow ToTEM to accommodate multiple goods and to do a better job than QPM could of capturing important international linkages – notably, the relationships among commodity prices, the real exchange rate, and gross domestic product (GDP). In ToTEM, consumption and investment decisions depend on the entire expected future path of short-term real interest rates, and the exchange rate is similarly influenced by expectations about future interest rate differentials. Thus, the expected duration of a change in the policy interest rate is as important as the size of the change in influencing economic decisions. That feature became important to modelling the response of the economy to monetary policy when the policy rate reached its lower bound in April 2009.

Like SAM and QPM, ToTEM takes a top-down approach to get at the key macroeconomic relationships and variables important to the conduct of monetary policy. As a DSGE model, it focuses on imposing intertemporal constraints on the choices made by rational agents. While this provides a useful discipline for policy analysis, as it preempts the exploitation of free lunches or false policy choices, the discipline imposed by these constraints tends to be more effective and more continuous than that exerted in the real world by financial markets. Thus, the model is ill-suited to capture episodes of financial stress characterized by a sudden, often excessive, tightening of market discipline and lending standards after a period of lax lending.

It should be noted, however, that ToTEM's projection, like QPM's before it, represents only one input, albeit a central one, in the Bank of Canada's conduct of monetary policy. In a desire to tap information from financial activity, Bank staff have developed alternative models, ranging from single equations relating GDP to various interest rate spreads, credit, and money growth to

12 Because the Bank puts a premium on the story line behind the projection, it never had much use for forecasts produced by pure time series models.

13 Credit shocks, however, were found to have substantial real effects on macroeconomic variables. Boivin, Kiley, and Mishkin (2010) reach a similar conclusion; they find only modest effects of financial frictions on the monetary transmission mechanism, and conclude that these frictions seem more important as a source of shocks to which monetary policy must respond than as an element of the transmission mechanism.

14 QPM, by contrast, used distinct models to describe the steady state and the dynamic path of the economy from current conditions to the steady state. Heavy filtering of key variables was also necessary to deal with the complication that the Canadian economy had not always been headed toward the same steady state.

small models of the financial accelerator (see Coletti and Murchison 2002; Christensen, Fung, and Meh 2006). The latter models have proved particularly useful in assessing the strength of household spending arising from housing appreciation, given that neither ToTEM nor QPM explicitly model the housing sector.

The Bank has also built its own model of the global economy, BoC-GEM (Lalonde and Muir 2007), a five-sector, five-region DSGE model adapted from the original GEM developed at the International Monetary Fund (Pesenti 2008), to examine the implications for Canada of different resolutions of global current account imbalances (Beaton, de Resende et al. 2010).[15] In BoC-GEM, the world is divided into five regions – Canada, the United States, emerging Asia, commodity producers (including OPEC), and the rest of the world (dominated by Japan and the European Union) – and production is grouped into five sectors: crude oil, non-energy commodities, and retail production of fuel, tradable goods, and nontradable goods.

Current Challenges: Incorporating Financial Frictions

The Bank of Canada's efforts to incorporate financial frictions into its DSGE models of the Canadian and global economies have focused on three elements: the financial accelerator (Christensen and Dib 2008), bank capital (Meh and Moran 2008; Dib 2010), and the interbank market (Dib 2010).[16] The three channels are yet to be introduced into the Bank's core projection model, ToTEM, but they have been incorporated into its global economy model.[17] The resulting model (BoC-GEM-Fin) has been used both to assess the impact of stronger capital and liquidity requirements (de Resende, Dib, and Perevalov 2010) and to evaluate the role of financial channels in the propagation of US shocks to Canada (Beaton, Lalonde, and Snudden 2010).

In BoC-GEM-Fin, entrepreneurs finance their capital expenditures using their net worth and bank loans, obtained from domestic and foreign banks, at a risk premium related to the entrepreneurs' equity stake. The model considers two types of households: liquidity-constrained, hand-to-mouth households that spend all their disposable income (from wages and transfers) and neither save nor dissave, and forward-looking households that smooth their lifetime consumption. The latter save part of their income in the form of domestic and US government debt, the only internationally traded asset in this model, bank deposits, and bank capital.

The model also assumes two types of banks: savings banks, which collect fully insured deposits from forward-looking households and invest in domestic government debt or lend on the interbank market, and lending banks, which combine loans received on the interbank market and capital raised from households to supply loans to entrepreneurs.[18] Lending banks choose their leverage ratio, subject to a regulatory minimum. The chosen leverage increases with the value of bank capital, a source of procyclicality, and decreases as the prime loan rate or the minimum capital requirement increases. Because lending

15 The model can also provide a consistency check on the staff projection based on ToTEM and MUSE, the staff Model of the US Economy (Gosselin and Lalonde 2005).

16 In parallel, as a contribution to the promotion of financial stability, the Bank is also developing a framework for assessing macrofinancial risk, focusing on interlinkages and common exposures among financial institutions and on relating sectoral default probabilities to macroeconomic variables.

17 A description of the modifications introduced in ToTEM to inform policy in the aftermath of the financial crisis is given in Dorich, Mendes, and Zhang (2011) and discussed in the next section of this *Commentary*.

18 Lending banks can also receive cash injections from the central bank (quantitative easing) or swap part of their risky assets for government bonds from the central bank (credit easing). In four of the five regions, the central bank targets inflation; in emerging Asia, the central bank maintains a fixed exchange rate to the US dollar.

banks can default, the interbank rate depends on both the cost of monitoring related to the amount of loans, and the probability of default. The deposit rate is set as a markdown from the interbank rate, and the business loan rate as a markup over the marginal cost of lending plus a risk premium. Defaults by lending banks, which increase with the policy rate, raise the marginal cost of interbank borrowing and the cost of raising bank capital. Increases in bank capital increase the availability of credit.

In this model, financial frictions are found to amplify and propagate the effects of shocks, and higher capital requirements are found to attenuate them.[19] The financial accelerator is particularly important in generating a strong positive correlation between business investment and consumption and between domestic demand in Canada and the United States, two features of the data that traditional DSGE models have difficulty reproducing. The existence of nominal debt contracts implies that unexpected changes in the price level will have real effects on the economy by altering the ratio of debt to entrepreneur net worth. Similarly, a currency depreciation raises the value of foreign bank loans to entrepreneur net worth.

The model suggests that US financial shocks are transmitted to Canada primarily via real channels (trade, the exchange rate, and commodity prices), with international loan flows – that is, a drop in US bank lending to Canadian firms – accounting for about 20 percent of the Canadian response. This may underestimate the international transmission of financial shocks, however, as the only direct transmission channel the model captures is from international loan flows.[20] In particular, interbank markets are domestic, thus pre-empting the type of contagion that we saw in the recent financial crisis. On the other hand, with bank loans as the only source of external finance to entrepreneurs, the model may overstate bank balance sheet effects.

The Bank of Canada's efforts to incorporate financial frictions in a DSGE model show that frictions can make a material difference in the transmission of shocks through the economy, but these models have yet to be expanded in a number of directions if they are to capture relevant characteristics of finance in the real world. Specifically, they need to factor in household borrowing, given the central contribution that mortgage finance and house price dynamics have made historically to economic fluctuations and financial crises (Christensen forthcoming); they need to offer a fuller menu of assets and liabilities to households, entrepreneurs, and financial institutions, one that keeps abreast of developments in financial practices, such as securitization; and they must allow for variations in market liquidity, which was a major factor in the financial crisis.

Overall, the model development work by the Bank of Canada over the years gives clear meaning to the evolutionary nature of models, particularly those used for policy purposes. At each turn in the redesign and development of their models, researchers at the Bank were motivated by advances in economic theory and by the practical policy needs of the Bank to meet its mandate. Another critically important factor in this evolution has been rapidly advancing technological capabilities now used in the design, estimation, and simulation of models, which far exceed those of just several years ago.

Experiences and Lessons from the Financial Crisis for the Use of Models

Perhaps the most basic lesson from the global financial crisis is that a misunderstanding of the complex nature of the interdependencies in today's financial systems can impose substantial costs on the real economy in terms of lost output and employment. This lesson has spawned considerable additional efforts to address this

19 Meh (forthcoming) shows that countercyclical capital requirements further attenuate the effects of (demand) shocks. Note that, in Meh, bank capital can be accumulated only from retained earnings, which amplifies the response of loans to changes in leverage.

20 Domestic financial frictions, however, amplify the effect of shocks to US financial conditions by some 10 to 15 percent.

shortcoming through renewed focus and work on model development. The immediate needs of the financial crisis, however, required central banks to be innovative and to adapt their existing set of tools, including their models of the economy, to respond to rapidly unfolding developments.

In its conduct of monetary policy in response to the crisis, the Bank of Canada engaged in measures beyond its normal reliance on changes to the target overnight interest rate. First, while not considered monetary policy per se, it took extraordinary measures to provide liquidity in previously unused ways to help unlock funding markets that had ceased to function because of the heightened uncertainties associated with the collapse of global markets.[21] Second, with the target overnight rate having been lowered to the effective lower bound of 0.25 percent, the Bank made a conditional statement to keep the policy rate at that level for a specified period to put additional downward pressure on interest rates further out the yield curve. Third, the Bank was prepared to engage in quantitative or credit easing if required,[22] though, in the end, neither was required. In relying on, or considering the use of, these unconventional techniques for conducting monetary policy, the Bank consistently anchored its decisionmaking within its inflation-targeting framework.[23] The fundamental challenge facing the Bank through this period was judging the size and duration of the economic and financial shocks hitting the economy and the size and duration of the policy response required to counter these shocks in order to put the economy back on a growth path consistent with achieving its 2 percent inflation target.

How the Bank came to these judgments involved a multifaceted approach to getting past the shortcomings of its models, and other tools to handle the unprecedented situation it faced. In the case of widening interest rate spreads, especially the rising borrowing costs for households and businesses in relation to risk-free government yields, the Bank made assessments about the extent to which these spreads, or risk premiums, would widen and how long it would take for them to return to normal. These spreads reflected both the cost of raising funds by financial institutions and the creditworthiness of the customers of these institutions. From a policy perspective, the normal response to such widening spreads is to offset them through a reduction in the risk-free overnight policy rate. This is partly what the Bank's reduction in the overnight rate to the effective lower bound and its commitment, conditional on the outlook for inflation, to hold the policy rate at that level until the second quarter of 2010 were intended to do.[24]

In working this analysis through, however, the core ToTEM model had to be modified to provide additional understanding and policy analysis. By construction, ToTEM could not capture all the real economic consequences of disturbances originating from the financial sector that occurred in 2007 through 2009. Over that period, the financial crisis was introduced in the model as an exogenous disturbance to the spread between the effective consumer and business loan rates and the expected future path of the policy rate. The model was also modified to allow for segmented asset markets and imperfect substitutability between long-term and short-term securities (Dorich, Mendes, and Zhang forthcoming). These

21 For a review of central bank liquidity facilities during the crisis, see Bank of Canada (2011, 27-36).

22 Quantitative easing "refers to the outright purchase of financial assets through the creation of excess settlement balances," while credit easing "refers to purchases of private sector assets in certain markets that are important to the functioning of the financial system but that are temporarily impaired" (Bank of Canada 2009, p. 26).

23 Of particular importance within this framework is the payoff from anchoring inflation expectations at the 2 percent inflation target; see Carney (2009).

24 These policy actions were also directed at countering a drop in aggregate demand, which warranted a reduction in the effective cost of borrowing faced by businesses and households.

modifications were critical because they enabled the model to work through the implications of these financial conditions for the real economy and thus for inflation relative to the Bank's target, and then back through the model's reaction function to calibrate the required policy response in terms of adjusting the target overnight rate.[25] The modified model was also used to assess the economic impact of moving to stronger capital and liquidity requirements for banks, once the impact of stronger requirements on lending spreads was established through a satellite accounting model.

Another important use made of ToTEM was to let it solve at negative nominal interest rates. With actual policy rates at the effective lower bound, it was important to be able to continue to calibrate what interest rate response would, in principle, be appropriate to offset a possible additional negative shock to the economy.[26] This had application in two specific ways. First, given the Bank's inability to move the policy rate lower, it would be possible, using the model without the zero-lower-bound constraint, to translate these results (that is, the implied additional basis point easing) into a decision about how long to maintain the policy rate at the effective lower bound to get the same policy impulse – that is, how long the policy rate would be kept low does matter. This is essentially the analysis that led the Bank to make its conditional commitment to keep its target rate at the effective lower bound until the second quarter of 2010. Second, in considering the use of quantitative or credit easing, it would be necessary to attempt to calibrate what a particular amount of either type of easing would mean in terms of an equivalent movement in interest rates. The logic here again runs from an assessment of the size and duration of a shock to the economy to the policy response needed to offset the shock and return inflation to its 2 percent target. As noted above, although neither quantitative nor credit easing was needed, the analysis – including the adaptation of ToTEM – had been done to position the Bank to act if required.

Some Policy Implications and Conclusions

The recent global financial crisis posed a number of direct challenges to the economics profession, ranging from theory to the implementation of policy. For monetary policy, the challenges are of two basic types: the need to develop better policy tools and the need to reconsider policy frameworks.

Better Models

The most compelling criticisms of DSGE models, and macro models more generally, perhaps lie in their use rather than in their construction. The "art" in the science of model development is knowing what issues the model is designed to address and then using the model in such a way as to extract the right insights. In the words of Myron Scholes, famous for the Black-Scholes model that describes financial markets and derivative instruments, "[t]here are models, and there are those who use the models."[27]

To recap, DSGE models, which have become the mainstay for central banks, rely on three strong assumptions: first, that economic agents are rational and homogeneous in behaviour; second, that markets clear in an equilibrium state; and, third, that institutional structures and financial interdependencies do not matter for macroeconomic stability. As we have documented, these models proved highly inadequate both during the crisis and in capturing some of the buildup in systemic risks in the leadup to that crisis. The

25 However, the model attributed a relatively small role to widening credit spreads as a factor depressing aggregate demand in Canada during the financial crisis, which suggests that other linkages between financial activity and the real economy might have been more important.

26 Alternatively, the size and duration of a shock that had already occurred might have been underestimated.

27 "Financial Economics: Efficiency and Beyond," *Economist*, July 16, 2009.

crisis was characterized by behaviour that did not fit perfectly rational models, by markets that failed to clear, by conditions far from equilibrium, and by major macroeconomic disruptions propagated through financial system interdependencies and linkages to the real economy.

The model development work we have described in this *Commentary* represents important progress in addressing these issues by incorporating into the DSGE models financial accelerator effects, bank capital, and the interbank market. But from a policy perspective, is that enough? As mentioned earlier, the intertemporal discipline imposed by DSGE models is more effective and more continuous than that observed in the real world. Furthermore, the stylized form in which financial frictions tend to be introduced in DSGE models suggests that the modelling choices are being driven by methodological, rather than empirical, considerations.

In contrast to DSGE models, agent-based models are not constrained to market-clearing conditions, and attempt to capture the sort of nonequilibrium conditions observed during the financial crisis – involving, for example, the uncoordinated off loading of assets in illiquid markets. Agent-based models try to account for the heterogeneity of agents – households, firms, and governments – and assign particular behavioural rules to each agent in a bottom-up approach (see Beinhocker 2006; Akerlof and Shiller 2009). In addition, agent-based models explicitly model the network and institutional structure of the financial system and interdependencies with the real economy. As the collapse of Lehman Brothers demonstrated, the financial system's micro structure can have macro consequences, which points to the importance of incorporating network structure in our understanding of the linkages between the financial sector and the real economy and systemic risks. For these reasons, agent-based models are seen as capturing aspects of reality that DSGE models cannot, and therefore are able to provide additional insights for policy purposes. One difficulty with rule-of-thumb behaviour that ignores fundamental economic laws is that it is subject to unpredictable reversal as those laws ultimately reassert themselves. In the end, however, all models must make simplifying assumptions in their structure, including about the behaviour of agents.

The contrast and choice, then, between top-down DSGE models and bottom-up agent-based models seem to turn on the tradeoff between internal coherence and richness of empirical detail.

Policy Frameworks

As far as policy frameworks are concerned, the central issue is to what extent, if at all, there is overlap between the conduct of monetary policy directed to achieving price stability and the potential for monetary policy to help prevent the buildup of financial imbalances. In other words, do the monetary authorities need to have, as part of their remit or mandate, responsibility for financial stability, or at least some aspects of financial stability?

This key question is one of three that the Bank of Canada has been addressing in the leadup to the renewal, by the end of this year, of the inflation-control target agreement with the federal government (see Bank of Canada 2010).[28] It is now generally recognized that the first line of defence against the buildup of financial imbalances should be the use of macroprudential tools, such as countercyclical capital buffers and loan-to-value ratios in mortgage lending (see Carney 2009; and Yellen 2010). Recognition of this point, however, does not preclude the need

28 The three questions the Bank has posed in its research program are, first, should the 2 percent inflation target be lowered; second, are there merits in moving to price-level targeting; and, third, should monetary policy be used to counteract financial imbalances. These questions have already prompted some discussion and responses; see, for example, Bergevin and Laidler (2010); Melino (2011); and Ragan (2011).

for monetary policy to assume some responsibility for financial stability matters.[29]

While the use of monetary policy to counteract financial imbalances has not been the focus of this *Commentary*, a critically important aspect in considering it is the need to better understand the linkages between the financial sector and the real economy. Both Bergevin and Laidler (2010) and Melino (2011) agree that the problem with defining the response of monetary policy to a buildup of financial imbalances lies with the models that are used to guide policymakers, rather than with the inflation-targeting framework. As Melino puts it, "the current state of knowledge does not give us enough confidence that the risks are real, or that manipulating the target rate would help reduce these risks sufficiently, to deviate from the inflation target" (p. 10).

This represents another reason the work on model development we have described in this *Commentary* should be viewed as a central response to the global financial crisis. We have argued that the way in which these linkages have altered needs to be understood for the conduct of monetary policy. This includes the implications of a move to a macroprudential approach to regulation and supervision, as Boivin, Kiley, and Mishkin (2010) also argue. Put differently, the model development now under way should help develop a better understanding of the interactions between the conduct of monetary policy and the use of macroprudential tools.[30]

Conclusion

To conclude, it is important, especially for policymakers, to understand both the uses of models and their limitations. Models, if used properly, are an aid to deepening our understanding of the real and financial sectors of the economy and the linkages between the two. Used this way, models provide options and scenarios for the design of policies. They enable "what-if" questions to be asked. They do not replace the need for judgment. To quote Keynes, "Economics is a science of thinking in terms of models joined to the art of choosing models which are relevant to the contemporary world" (Moggridge 1973, 296). Nowhere is this more important than when dealing with financial markets, where practices and institutions are constantly evolving. In today's complex world, this amounts to the need for a range of models that complement one another to enable policymakers to draw out the insights required in the conduct of policy.

29 If monetary policy were to assume some responsibility for financial stability matters, the governance structure for the conduct of monetary policy would need to be clear about this added responsibility. As Laidler (1999) notes, the current governance structure, with the clear objective of a 2 percent inflation target, tools and instruments to achieve the target, and accountability through transparency has served Canada well. Without a clear and strong governance structure, the accountability of the Bank would suffer and it would risk loss of credibility.

30 Two examples (a variable cap on the mortgage loan-to-value ratio, and a countercyclical capital buffer) are discussed in Christensen (forthcoming) and Meh (forthcoming).

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