BoC-GEM: Modelling the World Economy

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- *Worldwide economic developments, including the integration of large and rapidly growing economies, global current account imbalances, the recent significant movements in commodity prices, and the global financial crisis that began in 2007, need to be viewed from a consistent global perspective to determine their impact on the Canadian economy.*
- *To meet this need and to complement its existing tools, Bank of Canada staff developed BoC-GEM, an adaptation of the Global Economy Model, initially developed at the International Monetary Fund and the New York Federal Reserve.*
- *BoC-GEM divides the world into six regions, including Canada. The oil and non-energy commodity sectors, which are important for the Canadian economy, are also explicitly modelled.*
- *Bank staff use BoC-GEM for an array of applications that need to be tackled in a global and multi-sector framework. Among recent examples are the current financial crisis and the effect of the announced fiscal stimulus packages in many economies.*
- *Ongoing work focuses on introducing financial frictions and a banking sector to BoC-GEM.*

The Bank of Canada has a rich history of modelling, focusing mainly on the economies of Canada and the United States.[1] With the increasing global openness to trade in goods, services, and financial assets; the integration of large and rapidly growing economies such as China and India; the emergence of global current account imbalances; the recent large movements in the price of oil and other commodities; and the current global recession, it is necessary to view the external environment from a consistent global perspective.

To meet this need, Bank of Canada staff adopted the Global Economy Model (GEM) created at the International Monetary Fund (IMF) and the New York Federal Reserve. Like ToTEM, the Bank's main policy-analysis and projection tool for the Canadian economy, GEM is a dynamic stochastic general-equilibrium model, and is a representative-agent model with a fully optimizing framework based on microfoundations and multiple sectors of production. All markets are modelled with explicit demand and supply curves, so that all prices are endogenous. As a multi-region model, GEM includes the entire world economy and explicitly models all bilateral trade flows and relative prices, including exchange rates. GEM is capable of analyzing both large-scale global issues and country-specific issues.

Bank staff have adapted GEM to the Bank of Canada's needs by incorporating three major extensions:

(i) Canada is included as a separate region, and the country composition of the other regional blocs is different from the composition in the original GEM;

1 See Murchison and Rennison (2006) for a description of ToTEM, the Bank of Canada's model of the Canadian economy, and Gosselin and Lalonde (2005) for a description of MUSE, the Bank of Canada's model of the U.S. economy.

(ii) Oil and non-oil commodities sectors are included and, consequently, the prices of oil and non-oil commodities are endogenous; and

(iii) the calibration incorporates the views of Bank staff and the properties of the Bank's models of the Canadian and U.S. economies (ToTEM and MUSE, respectively).

Because of its composition, BoC-GEM can be used to analyze issues specific to Canada or issues elsewhere in the world, and model how they will affect Canada either directly or indirectly through effects on another country, such as the United States.

With its flexible and adaptable structure, BoC-GEM is a powerful platform for research. Recent topics include the causes and effects of the surge in oil prices between 2002 and 2006 (Elekdag et al. 2008); the consequences of a possible increase of protectionism (Maier 2008); the global impact of U.S. fiscal policy (Flood 2008); the impact of the recent stimulative fiscal policies in many economies (Lalonde, de Resende, and Snudden 2009); and the optimal choice of monetary policy regime in a multi-country framework (Coletti, Lalonde, and Muir 2008).

BoC-GEM can be used to analyze issues specific to Canada or issues elsewhere in the world, and model how they will affect Canada.

Bank staff also use BoC-GEM to generate risk scenarios around the base-case staff economic projection for questions that need a global and/or a multi-sectoral perspective, such as the recent financial turbulence and a possible boom-bust scenario in emerging Asia (see Lalonde, Maier, and Muir 2009). Results from BoC-GEM can also be used to validate or test assumptions underlying the staff economic projection, including the equilibrium price of oil, the reasons for the increase in commodity prices between 2002 and 2007, the evolution of global imbalances, and the geographic distribution of the depreciation of the U.S. real effective exchange rate.

In addition, BoC-GEM is used to analyze global risks to financial stability: Bank staff recently used BoC-GEM to build the macroeconomic scenario for stress testing the Canadian banking system as part of the IMF's Financial Stability Assessment Program. It is important to note that BoC-GEM was used to calculate the effects of U.S. shocks on Canadian macro variables such as real gross domestic product (GDP) and that these variables were brought into a separate model of the Canadian financial sector for stress testing. In doing so, and in light of the recent financial crisis, it became evident that the financial sector in BoC-GEM needed to be enhanced to improve the model's ability to tackle financial stability issues. To address this issue, Bank staff are currently developing a version of BoC-GEM that includes financial frictions on firms and a banking sector for each of its regions. This version of the model will make it easier to simulate shocks originating from financial markets and will also take into account the role of financial frictions in the propagation of any shock.

In this article, we describe the structure and functioning of BoC-GEM. The first section describes the structure of the model. Following this, recent research and analysis based on BoC-GEM are outlined, along with key insights developed from this work. We conclude with a discussion of the lessons learned over the past four years and a look at future plans.

The Bank of Canada's Global Economy Model: BoC-GEM

BoC-GEM comprises six regional blocs: Canada, the United States, emerging Asia, Japan, a commodity-exporting bloc, and the remaining countries. Emerging Asia includes China, India, Hong Kong Special Administrative Region of China, the Republic of Korea, Malaysia, the Philippines, Singapore, and Thailand. The commodity-exporting bloc includes the largest exporters of oil and non-oil commodities—the Organization of the Petroleum Exporting Countries (OPEC), Indonesia, Norway, Russia, South Africa, Australia, New Zealand, Argentina, Brazil, Chile, and Mexico. The remaining-countries bloc includes all the other countries in the world. This effectively means the members of the European Union, since Africa has a very small economic footprint.

The entire BoC-GEM can be thought of as a system of demand, supply, and pricing functions. Each of the six regions is modelled symmetrically and consists of the following:

- firms that produce raw materials and intermediate and final goods and that demand labour from domestic consumers;
- liquidity-constrained and forward-looking consumers who consume final goods (composed of

domestic and imported components) and who supply labour inputs to firms;

- a government consisting of a fiscal authority that consumes non-tradable goods and services, financed through taxation or borrowing; and
- a monetary authority that manages short-term interest rates to provide a nominal anchor for the economy.

Five sectors produce goods from capital and labour and other factors. The five sectors are non-tradable goods (i.e., non-financial services); tradable goods (financial services and durable, semi-durable, and non-durable goods); oil and natural gas; non-oil commodities; and heating and automobile fuel. Special emphasis is placed on oil and natural gas and on other commodities because the Canadian economy is dependent on the production and export of these goods, and their prices can be volatile, since they are determined largely by global demand and supply. The production of each sector is assumed to be monopolistically competitive; i.e., firms can still enter and exit the market because each firm's goods are slightly different from those produced by its competitors. Each firm is therefore able to set a price above its marginal cost, permitting a markup.

Each region includes five sectors: non-tradable goods, tradable goods, oil and natural gas, non-oil commodities, and heating and automobile fuel.

Each region has firms that produce oil by combining capital, labour, and crude oil reserves. Oil is also combined with labour and capital to produce gasoline. Oil and other commodities can be traded across regions and are further combined with capital and labour to produce tradable and non-tradable goods. There are three intermediate goods: heating and automobile fuel, tradable goods, and non-tradable goods, all of which are combined to form a final consumption good. Tradable and non-tradable goods are also combined to form a final investment good.

In terms of international trade, all bilateral flows (across regions) of exports and imports of oil, commodities, and tradable goods for consumption and investment are explicitly modelled as demands for imported goods from specific regions. Internationally traded net foreign assets are assumed to be denominated in U.S. dollars. External imbalances are bounded by the assumption that regions are targeting a specific ratio of net foreign assets to GDP. The cost of holding an excess balance of assets puts upward pressure on the regions' bilateral real exchange rate for the U.S. dollar (also determined by a standard condition of uncovered interest rate parity). This leads to a decrease in the current account in the short run, eliminating the external imbalances. There is also an explicit link between the level of government debt and the level of net foreign assets, meaning that the representative agent in this model is non-Ricardian. There are further non-Ricardian elements in BoC-GEM; i.e., some consumers are subject to liquidity constraints, and the government raises revenues through distortionary taxation on labour income, capital income, and (possibly) tariffs on imports.

Depending on the region, the monetary authority targets core inflation (defined as the consumer price index excluding gasoline prices), headline CPI inflation, or a fixed nominal exchange rate in order to achieve an objective related to price stability (or price certainty) with a standard reaction function.

To match the persistence observed in the data, the model includes real adjustment costs and nominal rigidities that are allowed to differ across regions. We assume real adjustment costs in capital, investment, labour, and imports. The model also assumes the presence of large adjustment costs in the production of, and demand for, oil and commodities. Combined with a fixed factor of production (oil reserves and land), these real adjustment costs ensure that the price elasticities of demand for oil and commodities are very low (demand and supply are very inelastic) over the short and medium terms (one to five years). For instance, if the global demand for oil increases (e.g., through a permanent productivity shock in Asia), the demand for oil over the first couple of years will move along a very steep supply curve. We will observe a substantial increase of the price of oil, but only a negligible increase in the global production of oil. In the long run, the supply of oil will gradually increase, and part of the initial rise in the price of oil will be reversed.

Since the model also assumes no product differentiation in the oil market, the global price of oil moves uniformly in response to all shocks. The model relies on similar assumptions for the commodities sector but allows for more product differentiation and lower real adjustment costs than in the oil sector.

Finally, nominal rigidities are introduced in setting wages and prices of tradable and non-tradable

Box 1

Calibrating BoC-GEM

Because of the large and complex nature of the model, a full estimation of its parameters is not yet feasible. The model must therefore be calibrated, using a strategy that relies on multiple sources of information. First, we calibrate the broad features of the six regions using data relating to such factors as the relative importance of bilateral trade flows of oil, commodities, and tradable goods; the relative importance of the components of aggregate demand; the geographical distribution of oil reserves; the relative importance of each sector in the economies; and so on.

Next, to calibrate the model's parameters, we begin with the values of parameters used for previous work on GEM (e.g., Laxton and Pesenti 2003; Bayoumi, Laxton, and Pesenti 2004; Faruqee et al. 2007). We also rely on previously published work for particular economies. Some examples include:

- Canada: Murchison and Rennison (2006) using ToTEM, the Bank of Canada's projection and policy analysis model for Canada; Perrier (2005)
- Euro area: Coenen, McAdam, and Straub (2008) using the NAWM (New Area-Wide Model), the European Central Bank's DSGE model; de Walque, Smets, and Wouters (2006)
- United States: Gosselin and Lalonde (2005) using MUSE, the Bank of Canada's model of the U.S. economy; Brayton et al. (1997) for FRB/US, the Board of Governors of the Federal Reserve System's model of the United States; Erceg, Guerrieri, and Gust (2005a, 2005b) for the SIGMA DSGE model; Juillard et al. (2006)

Finally, Coletti, Lalonde, and Muir (2008) show that the two-country version of BoC-GEM is able to replicate fairly well the key features of Canadian and U.S. data.

goods. For the oil and commodities sectors, we assume perfect flexibility of prices. The strategy we followed to calibrate the model is described in Box 1.

Recent Applications

In this section, we outline some examples of recent research and analysis that employ BoC-GEM, along with the key insights of this work.[2] We begin with an overview of applications to monetary policy and issues concerning the real economy and then examine an application to questions of financial stability.

Monetary policy and issues in the real economy

The oil sector in a global economic framework: The surge in oil prices between 2002 and 2006

Using a version of GEM that includes Canada and a global oil market and is almost identical to BoC-GEM, Elekdag et al. (2008) analyze the causes and effects of the increase in the price of oil observed between 2002 and 2006.[3] Tight supply conditions, in combination with strong productivity growth and an increase in oil intensity both in production and consumption in emerging Asia (that are broadly consistent with the data) can account for a large share of the magnitude and persistence of the oil-price increase. Nevertheless, by itself, higher demand from emerging Asia does not seem to explain all the recent increases in the price of oil observed during that period. Supply-side factors and speculation also seem to play a role.

In research by Lalonde and Muir (2007), BoC-GEM demonstrates that the impact of an oil-price increase on the different regions of the global economy depends on two key factors:

- distinguishing between movements in the demand for oil (i.e., strong economic growth in emerging Asia) and in the supply of oil (i.e., a supply restriction similar to the one experienced following the 1973 oil-price shock); and
- whether the region is a net oil importer (e.g., the United States) or a net oil exporter (e.g. Canada).

2 For a detailed description of the properties of the model in response to stylized shocks, see Lalonde and Muir (2007).

3 Their model is a precursor of BoC-GEM.

To illustrate these points, consider a permanent increase in productivity in emerging Asia, where firms can produce goods at lower cost, which will exert downward pressure worldwide on the price of tradable goods. In turn, this will lead to positive wealth effects for all regions, which induces a global increase in consumption and output. On the other hand, in order to produce more goods and take advantage of their productivity gains, firms in emerging Asia increase their demands for inputs of production, including oil. Given that the oil supply is subject to strong real adjustment costs, there is a substantial, persistent rise in the global price of oil. For commodity importers like the United States, this creates a negative wealth effect that, over the near term, roughly cancels out the positive wealth effect induced by the fall in the price of other imported tradable goods. Therefore, in the short run, U.S. output and consumption are barely affected. For a commodity exporter such as Canada, the increase in the price of oil induces a positive wealth effect, reinforcing the positive wealth effect linked to the fall in the prices of tradable goods. Canadian output and consumption therefore increase immediately.

Strong productivity growth and an increase in oil intensity in emerging Asia can explain a large share of the oil-price increase observed between 2002 and 2006.

If we consider instead an increase in the price of oil as a result of supply restrictions by the commodity-exporting regions, the positive wealth effect associated with an increase in productivity in emerging Asia is absent. The main propagation mechanism in the world economy is the wealth effect associated with the increase in oil prices, which is negative for commodity importers and positive for commodity exporters. U.S. output therefore falls over the first few years of simulation. In Canada, consumption is increasing, but Canada's net exports are falling because of the U.S. slowdown; the fall of exports dominates the wealth effect. Canadian GDP therefore falls slightly, as opposed to increasing under an oil-price shock caused by higher productivity in emerging Asia.

Emerging Asia's impact on food and commodity prices: How should central banks respond?

Lalonde, Maier, and Muir (2009) examine the sharp increase in the price of oil and food observed between 2007 and mid-2008 and argue that economic developments over this period suggest at least three sources of uncertainty. First, it is not clear whether the run-up in commodity prices during the period is driven by supply disruptions, by strong demand for commodities, or both. Second, to assess the medium-term outlook for commodity prices, assumptions about the sources of the strong demand for commodities are required. Assuming that demand for commodities is driven, at least in part, by strong growth in emerging Asia, a possible explanation is that commodity prices have risen sharply in recent years in response to higher-than-expected potential growth in that region. This implies a permanently high demand for commodities, and that commodity prices can be expected to stay at elevated levels. An alternative interpretation is that the strong demand for commodities is due, at least in part, to a temporary demand shock in emerging Asia ("overheating"). If this is correct, there should be a swifter moderation in commodity prices when the demand shock unwinds. A third source of uncertainty is the speed with which central banks worldwide react to the rising inflationary pressures. At some point, rising inflation should lead to tighter monetary policies, which could result in a slowing of the global economy. This could prompt a relatively sharp drop in prices for energy and non-energy commodities.

In this study, Lalonde, Maier, and Muir (2009) build two globally consistent scenarios in which stronger-than-expected oil and food prices are caused by supply factors and a shift of world economic activity, from a less oil-intensive economy (the United States) to a more oil-intensive economy (emerging Asia). In the base case, it is also assumed that the demand for commodities from emerging Asia is driven by large and persistent permanent productivity gains. The alternative scenario assumes that the demand for commodities is strong because of a temporary positive demand shock in emerging Asia and that oil and food prices exhibit higher volatility. In Canada, there are higher inflationary pressures in the short term, even in core inflation, and relatively higher volatility in inflation, output growth, and the real exchange rate, reflecting relatively more-volatile commodity prices. There are higher global inflationary pressures, since the engine of emerging Asia's

economic growth is excess demand, which leads to a global increase in the prices of tradables. This is in contrast to the large productivity gains in the base case, which result in falling global prices for tradables, thereby mitigating inflationary pressures coming from higher demand and prices for energy and commodities.

A possible resurgence of protectionism

An increase in protectionism is possible in the current environment of global imbalances and fixed exchange rate regimes pursued by a number of countries in emerging Asia. Lalonde and Muir (2007) explore two scenarios. The first relies on the trade literature, which suggests that increases in tariffs by one region against another will benefit the region that imposes the tariff but harm the targeted region—a "beggar-thy-neighbour policy." Past experience (particularly with the Great Depression) has shown that this type of policy eventually escalates into a worldwide tariff war, and theory (and practice) demonstrate that everyone loses with such an outcome. BoC-GEM confirms the damage that would be caused by a global tariff war, using a multilateral increase in tariffs of 10 per cent to illustrate the point.

In a second case, Lalonde and Muir (2007) assume that the North American Free Trade Agreement (NAFTA)—or at least the Canada–U.S. portion of it—survives unscathed and that Canada and the United States increase tariffs only against the other three regions (commodity-exporting countries, emerging Asia, and other countries). In this case, we see a difference for Canada and the United States, as GDP falls by less in both regions than under the generalized tariff war. This is particularly the case for Canada (a fall of 0.9 per cent of GDP versus a fall of 3.5 per cent without NAFTA). Consequently, maintaining NAFTA would be a good way for Canada to protect its economy from most of the negative effects of a global resurgence of protectionism. This result is linked mainly to the large proportion of Canadian exports to the United States and to some substitution towards Canadian goods in the American market, as tariffs are raised against the other regions.

According to BoC-GEM simulations, maintaining NAFTA would be a good way for Canada to protect its economy from most of the negative effects of a global resurgence of protectionism.

The same issue is explored from a different angle in Maier (2008), who investigates whether policy-makers actually have incentives to implement protectionist policies. Specifically, this study asks whether the United States could trigger a "wave of protectionism"—a series of actions whereby countries impose import tariffs on each other to retaliate for previous protectionist actions—if it introduces tariffs on imports from emerging Asia. The study evaluates the economic consequences of tariffs and explores the conditions under which policy-makers in each region have incentives to impose them. Maier (2008) distinguishes between "benevolent" and "myopic" policy-makers: While benevolent policy-makers focus on long-term economic growth, myopic policy-makers care about short-term considerations (e.g., an upcoming election).

Benevolent policy-makers are not likely to adopt protectionist policies, since the long-term gains for countries adopting tariffs are small, if not negative. Tariffs on imports trigger an appreciation of the real exchange rate, leading to a fall in the exports of the protectionist country. The key finding is that countries will likely hurt themselves in the long run by adopting protectionist policies. Given the short-term economic benefits, however, there is some scope for myopic policy-makers to exploit political gains. Thus, the possibility of a wave of protectionism cannot be completely excluded.

The global impact of U.S. fiscal policy

BoC-GEM can also be used to investigate the global implications not only of U.S. trade policy but of its fiscal policy as well. Flood (2008) examines the global macroeconomic implications of the expiration of tax relief from the Alternative Minimum Tax (AMT) at the end of the 2007 tax year and the expiration in 2011 of the Bush administration's tax cuts. The author also examines the impact of the expected increase in expenditures under entitlement programs relating to population aging and escalating health care costs.

The expiration of previously enacted tax cuts in the United States imposes short-run costs on the economy. The increase in tax revenues is assumed to allow the government to reduce its level of debt in the long run, however, thereby permitting the U.S. economy and the rest of the world to benefit from the reduction in government borrowing as real interest rates decline, and stimulating global economic growth. The rest of the world also benefits from a redistribution of wealth linked to a partial reversal of global current account imbalances that is associated with the decline in U.S. government debt.

Nonetheless, the U.S. economy is facing a challenging period ahead as its population ages and expenditures on entitlement programs and health care rise rapidly over the coming decades. Since the increase in federal revenues associated with the expiration of previously enacted tax cuts is not nearly large enough to finance the expected increase in entitlement-program spending, a rise in government debt will crowd out economic growth in the United States and abroad. This suggests that the economic damage associated with the expected spending increases might be avoided by adjusting policy through some combination of a decrease in program spending and an increase in program revenues. The sooner these policy adjustments are completed, the smaller will be the negative economic impact of the expected debt-financed increases in entitlement-program spending.

The global impact of the recent fiscal stimulus

Most countries responded to the current global recession by implementing fiscal stimulus policies, with the United States, Japan, and China using particularly large stimulus packages. Lalonde, de Resende, and Snudden (2009) use BoC-GEM to examine the impact on the world economy of the fiscal stimulus policies announced by different countries. The authors also compare the effect of purely domestic fiscal stimulus with that of synchronized global fiscal stimulus. For each region, the authors consider two alternatives: (i) the fiscal shock occurs only in the domestic economy, with no fiscal stimulus in the remaining five regions of the world; and (ii) fiscal shocks occur simultaneously in all regions. Each region-specific fiscal stimulus is decomposed into reductions in labour income tax and in the tax on corporate profits, increases in government purchases of investment and consumption goods, increases in government services, increases in personal transfers, and increases in general and targeted lump-sum transfers.

The fiscal shocks are calibrated to mimic the actual profiles of the announced stimulus packages in different regions, based on information from the Organisation for Economic Co-operation and Development. The impact of the stimuli is magnified by accommodative monetary policy in response to the global recession and by the lower bound on interest rates. The main results are as follows:

- Simultaneous fiscal stimulus has a peak effect on the level of the world's GDP of close to 2 per cent. In the United States, the peak effect is close to 3 per cent. The timing of these peak responses is highly uncertain.
- All regions benefit from a globally coordinated fiscal stimulus relative to a purely domestic stimulus. The distribution of gains across regions depends on each region's trade patterns.
- Regions that have net import positions of investment and consumption goods will have higher leakages into imports from domestic stimulus, and negative terms-of-trade shocks from the synchronized fiscal stimulus packages. In addition, net exporters of crude oil and commodity goods experience positive terms-of-trade shocks under coordination, since oil and commodity prices rise by 40 per cent and 7 per cent, respectively.

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For any given region, the potential gains from synchronized global fiscal stimulus depend negatively on the size of its economy and on the size of the domestic fiscal stimulus, and positively on the proportion of tax cuts in the overall stimulus and on its degree of openness to trade.

Choosing the optimal monetary policy regime in a multi-country framework

The Bank of Canada has recently embarked on a research program to examine inflation targeting versus price-level targeting. Coletti, Lalonde, and Muir (2008) use a Canada–United States, two-sector (tradable and non-tradable goods) version of BoC-GEM to address some open economy questions regarding the optimal choice for Canada—inflation targeting or price-level targeting. From the perspective of Canadian monetary policy, the authors attempt to answer three questions:

- In a multi-country framework, and with the object of reducing the variance of inflation and the output gap, which is the "optimal" Canadian monetary policy framework—inflation targeting or price-level targeting?

- When facing terms-of-trade shocks, is it optimal to target inflation or the price level?
- Does the "optimal" regime in Canada depend on the policy regime chosen by the U.S. Federal Reserve?

Using economic data in combination with the model, the authors identify 23 different historical Canadian and U.S. shocks and use a stochastic simulation methodology to identify a simple monetary rule that minimizes the combined variances of inflation and the output gap under either inflation targeting or price-level targeting. Given the historical distribution of shocks and the calibration of the model, targeting the price level gives a slightly better macroeconomic outcome than targeting inflation. The authors also conclude that shocks that induce a negative correlation between inflation and the output gap (price/wage markup and labour supply shocks) favour an inflation-targeting regime; shocks that generate a positive correlation between inflation and the output gap (productivity and demand shocks) favour price-level targeting. The variance of the Canadian terms of trade is dominated by the latter category of shocks. Price-level targeting therefore provides a better macroeconomic outcome for shocks affecting the terms of trade. Finally, the U.S. choice of monetary policy framework does not affect the choice of the "optimal" monetary policy framework in Canada.

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Financial stability questions

BoC-GEM has also been applied to financial stability questions at the Bank. To date, these projects have taken the form of macro-financial stress testing, the purpose of which is to assess the resilience of a segment of the financial system in the face of "rare but plausible" events that have either resulted in vulnerabilities in the past or could do so in the future. The events considered are typically a collection of shocks (incorporated into a macroeconomic model such as BoC-GEM) to form a macroeconomic scenario, with the objective of assessing the impact of such a scenario on a set of financial institutions. The impacts on the balance sheets of the financial institutions are modelled using a secondary set of models.

Since BoC-GEM does not yet explicitly model the financial sector or the effects of equity wealth and housing wealth on consumption, we have created a modified version of the model that tries to replicate these effects. First, we introduced an exogenous spread between the corporate and the risk-free interest rate. Second, we relied on shocks to consumption to replicate the wealth effects of a decline in equity or housing prices. In the future, we will incorporate the financial sector effects into BoC-GEM directly.

The first example of the use of the modified BoC-GEM for the purpose of assessing financial stability took place in 2007, when Canada's financial system was the subject of a Financial Sector Assessment Program (FSAP) update. (The FSAP is a joint IMF–World Bank program aimed at helping countries to identify vulnerabilities in their financial system and to determine needed reforms.) Among other things, Canada's 2007 FSAP update included a stress-testing component.[4]

The modified BoC-GEM was first used to assess financial stability in 2007, when Canada's financial system was the subject of a Financial Sector Assessment Program update.

The stress test was based on a macroeconomic scenario, generated by BoC-GEM, of a disorderly adjustment of global imbalances brought about by a downward revision to expectations of productivity growth in the United States. The scenario originated in the historically high rate of trend labour productivity growth experienced in the latter half of the 1990s and the early 2000s in the United States. As expectations of long-term labour productivity growth in the United States were gradually revised upward to 2 per cent and higher, perceived rates of return on U.S. investments were boosted. This led to increased investment demand as well as increased capital inflows and a stronger U.S. dollar. In addition, expectations of higher permanent incomes led to an increase in consumption and a drop in the savings rate. All of these factors led to a rise in imports and an expansion of the U.S. current account deficit (Ferguson 2005).

4 See Coletti et al. (2008) for an outline of the complete methodology, including the macroeconomic scenario, and further modelling of the financial sector.

In this scenario, it is assumed that expectations of a permanent rise in the growth of labour productivity in the United States are overly optimistic. Economic agents revise their expectations for future productivity growth down to 1.1 per cent per year for the next 10 years. The resulting downward revision to permanent income growth and to expected rates of return on investment leads to a retrenchment in demand, which offsets the decline in the growth in the economy's productive capacity. Increased economic uncertainty also causes declines in consumer and business confidence, leading to a retrenchment in consumption and investment expenditures. Heightened uncertainty is also assumed to lead foreigners to sell off U.S.-dollar assets, causing a rapid depreciation in the U.S. dollar. The resulting deterioration in the balance sheets of consumers and firms leads to a significant rise in the risk spread, further magnifying the economic slowdown. The growth of Canadian trend labour productivity is also assumed to slow to about 0.8 per cent over the next 10 years. As in the United States, a similar but smaller fall in consumer and business confidence is assumed to occur in Canada. Canadian commercial interest rate premiums also rise as a result of the economic downturn and this further exacerbates the weakness in Canadian GDP growth.

Taken as a package, the shocks are extremely large by historical standards. In the United States, the recession embodied in the scenario is even more severe than that experienced in 1981–82. All of these factors, including the recession in the United States, an appreciated Canada–U.S. real exchange rate, falling world commodity prices, the downward revision of expectations for the growth of domestic trend labour productivity, losses in domestic consumer and business confidence, and the rise in domestic financial risk premiums, lead to a significant recession in Canada. In terms of cumulative output loss, the domestic recession embodied in the scenario is about one-third larger than the recession of 1990–91.

Lessons from the Past and Future Developments

BoC-GEM is a very useful tool to tackle a broad range of issues pertinent to the current economic context,

Box 2

Introducing a Financial Sector into BoC-GEM

To introduce a financial sector into BoC-GEM, we explicitly use the framework developed in Dib (2009), in which two types of heterogeneous banks offer different banking services and interact in an interbank market. Loans are generated using interbank borrowing and bank capital, which satisfies the banks' capital requirement. With their monopoly power and the capacity to set nominal deposit and loan prime rates, banks optimally choose their portfolio compositions and may endogenously default on interbank borrowing and bank capital.

This framework allows two types of financial frictions to be modelled. First is the channel for corporate balance sheets (Bernanke, Gertler, and Gilchrist 1999)—commonly referred to as the BGG financial accelerator channel—which represents the demand side of credit markets. For lending banks to learn the net worth of the firm requesting funds, they must incur auditing costs, which drive up the real return that firms pay on their loans. As the net worth of the firm decreases, the amount of auditing required goes up, thereby increasing the risk premium demanded by bank shareholders. Second, the supply side of credit is modelled using bank balance-sheet channels. In this case, the banks' behaviour directly affects the supply of credit through the following channels: (i) bank capital and price expectations for bank capital; (ii) monopoly power in setting nominal interest rates (subject to nominal rigidities) for deposit and lending, which imply moving spreads over business cycles; (iii) the optimal choice of the banks' portfolio composition between interbank lending and holdings of risk-free assets; (iv) the optimal choice of the bank leverage ratio, subject to bank capital requirements; (v) the default-risk channel that arises from endogenous strategic or necessary defaults on interbank borrowing and/or bank capital; and (vi) the marginal cost of raising external bank capital. In addition, central banks can inject liquidity into lending banks using open market operations.

such as the recent movements in commodity prices and the adjustment of global imbalances. International linkages are well defined by bilateral trade and exchange rates, and a broad range of terms-of-trade and wealth effects are explicitly modelled, as are the prices of commodities and tradable goods. By using BoC-GEM, especially for issues in emerging Asia and the Financial Sector Assessment Program, Bank staff have been able to identify two main areas of the model that need improvement. The first is the financial sector, which can be enhanced by introducing financial frictions and a banking sector. The goal is to introduce a broader set of financial shocks into the model, and to allow financial accelerators to amplify the effect of all the shocks included in the model. Box 2 describes the new financial sector in BoC-GEM in more detail.

The second improvement is the introduction of a semi-finished goods sector in the model. This will result in a more realistic emerging Asia bloc because a significant share of the trade of many of these countries consists of importing parts and exporting assembled goods.

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