Bank of Canada Review

Autumn 2006

Special Issue
Models for Monetary Policy

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SPECIAL ISSUE
MODELS FOR MONETARY POLICY

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Effective with this issue, Governor David Dodge's speeches and the summary tables (A1, Key Monetary Variables, and A2, Major Financial and Economic Indicators) will no longer be published in the *Bank of Canada Review*. Complete texts of the Governor's speeches in both official languages are available on the Bank's website (www.bankofcanada.ca).

Summary Tables A1 and A2 are published monthly in *Bank of Canada Banking and Financial Statistics.* See p. 2 for information on how to obtain copies.

Cover

The “pretended” Bank of Upper Canada — Kingston (1819-22)

Although Kingston was the commercial centre of Upper Canada (now the province of Ontario) in the early part of the nineteenth century, it lacked the banking services that would help to maintain its strong economic growth. To meet chronic shortages of cash and to inject some capital into the local economy, efforts to establish a bank in the town began as early as 1810. In 1817, a group of Kingston merchants applied to the government for a charter to open a bank.

Unfortunately, royal assent for the legislation that would establish a bank arrived after the original bill had expired. While some of the merchants applied for another charter, others decided they could wait no longer. Articles of Association were drafted in 1818, shares in the new bank were offered for sale, and a board of directors was elected. In 1819 the Bank of Upper Canada finally opened in Kingston, but despite its official name, it operated as a private, unincorporated bank without a charter. Given the instability of the monetary system at the time, a charter, which reflected legal status, was imperative for the credibility and longevity of any bank.

At first, the lack of a charter did not seem to pose a problem. When cracks began to appear in the bank’s operations in 1821, however, as a result of internal conflicts between the bank’s president and some of its directors, strong criticisms began to be voiced against the institution. Soon afterwards, the bank was declared “illegal,” and by 1822 it had closed its doors. The bank’s main rival, also named the Bank of Upper Canada, incorporated in 1821 and based in York (now Toronto), began to use the term “pretended” to distinguish itself as a legitimate chartered bank from the unchartered and legally unrecognized bank in Kingston. As well, the term was later used in the government legislation intended to settle the affairs of the Kingston bank. Ironically, the bank’s affairs lingered in political limbo long after it had ceased to exist.

During its short history, the pretended Bank of Upper Canada issued notes in denominations of $1, $2, $5, and $10. Like other bank notes in the early nineteenth century, they contained some important security features still used today. These included engraved vignettes with meticulous fine-line work that was difficult to reproduce and ornate lathework patterns framing the notes. The $10 note, featured on the cover, shows an engraved view of Kingston harbour to the right and, on the left, the gun towers of Fort Henry. The note is part of the National Currency Collection of the Bank of Canada.

Photography by Gord Carter

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Models for Monetary Policy

Paul Fenton, Guest Editor

The Bank of Canada has a rich history of building and using macroeconomic models for policy analysis and economic projections. The first model—named RDX1 for Research Department experimental—was constructed in the mid-1960s. Since then, as economic modelling techniques and computing power have advanced, the Bank has periodically built new models with a view to remaining state of the art in the tools supporting monetary policy formulation. Two articles in this special issue of the *Review* focus on new models recently developed at the Bank, while a third describes the Bank's research into developing models that will include a greater role for financial variables.

Because monetary policy actions affect spending and inflation with a lag, policy decisions must be based on a view of how the future will unfold. To mitigate the risks associated with model and data uncertainty, the Bank has put in place a comprehensive process that brings a wide range of information and analysis to bear in making monetary policy decisions. A fundamental element of the process is the staff economic projection. Staff at the Bank of Canada use carefully articulated economic models, along with judgment, to forecast the evolution of the Canadian economy and to examine alternative scenarios. The projection provides the reference point from which the implications of other sources of information are assessed.

The Bank's new model for Canada is described in "ToTEM: The Bank of Canada's New Projection and Policy-Analysis Model." As part of a new generation of dynamic stochastic general-equilibrium macroeconomic models, ToTEM has a richer, more realistic structure than was previously possible. Its multiple goods set-up, including a commodity-producing sector, allows ToTEM to inform the staff's judgment on a wider variety of shocks.

Canada has a very open economy, which is broadly integrated into the global economy. Accordingly, analyzing and forecasting economic developments in the rest of the world play a critical role in the formulation of Canadian monetary policy. Recently, Bank staff have introduced a new macroeconometric model of the U.S. economy (MUSE) and a new model of the European Union (NEUQ). These models are described in "MUSE: The Bank of Canada's New Projection Model of the U. S. Economy."

"Modelling Financial Channels for Monetary Policy Analysis" describes the Bank's ongoing research into developing models in which financial variables play an active role in the transmission of monetary policy. Such models could help analyze information from the financial side of the economy and provide an overall view of the implications of financial developments for the current economic outlook. This research is part of the Bank's strategy for dealing with data and model uncertainty in the formulation of monetary policy decisions.

"A New Effective Exchange Rate Index for the Canadian Dollar" describes a new index that captures recent changes in Canada's trade patterns, including the rise in importance of China and Mexico, and gives a more comprehensive measure of Canada's trade competitiveness.

ToTEM: The Bank of Canada's New Projection and Policy-Analysis Model

Paul Fenton and Stephen Murchison, Research Department

- *When the Quarterly Projection Model (QPM) was first used in 1993 as the Bank's main projection and policy-analysis tool, it was considered state of the art among central bank models.*
- *Since QPM's introduction, refinements in modelling techniques, combined with enormous increases in computing power, have led to the development of a new generation of macroeconomic models, commonly referred to as dynamic stochastic general-equilibrium models. The Bank of Canada's new projection and policy-analysis model, the Terms-of-Trade Economic Model, or ToTEM, is such a model.*
- *ToTEM contains four distinct finished-product sectors as well as a commodity-producing sector. The move to a multiple-goods structure means that ToTEM can inform the judgment of Bank staff on a much wider variety of shocks, including relative price shocks.*
- *ToTEM's parameters have been chosen to reflect more recent data in which the volatility and persistence of inflation have declined significantly. One implication of this change is that, in response to typical shocks, inflation returns to the 2 per cent target somewhat faster in ToTEM than in QPM, about six quarters, on average.*

In December 2005, the Terms-of-Trade Economic Model, or ToTEM, replaced the Quarterly Projection Model (QPM) as the Bank of Canada's principal projection and policy-analysis model for the Canadian economy.[1] When it was introduced in September 1993, the aspirations for QPM were decidedly ambitious.[2] It was intended to serve both as the main tool for producing the staff economic projection, which is a key input into the monetary policy decision process (see Macklem 2002), and as a research tool for analyzing significant changes in economic structure or macroeconomic policies that require a deeper understanding of the longer-term equilibrating forces at work in the economy. And by any metric, QPM was highly successful. It helped the staff to interpret the shocks that have hit the Canadian economy since its implementation and to understand many of the key Canadian macroeconomic issues of the 1990s.[3] QPM also had a major impact on the modelling efforts of other inflation-targeting central banks throughout the world.[4]

ToTEM continues the key design philosophy and view of the economy underlying QPM but benefits from the

1. Earlier, two parallel or "shadow" projections were conducted with the model, in conjunction with QPM. For a complete description of ToTEM, see Murchison and Rennison (2006).

2. For a description of the steady-state version of QPM, SSQPM, see Black et al. (1994). For the dynamic model, see Coletti et al. (1996).

3. For a discussion of the important role played by economic models at the Bank of Canada, see Coletti and Murchison (2002) and Duguay and Longworth (1998).

4. In particular, the Reserve Bank of New Zealand and the Swedish Riksbank employ variations of the QPM. More recently the QPM has significantly influenced modelling efforts at the Bank of Japan. Reference to QPM's influence on other central bank models is also made in the 15 July edition of *The Economist* (see Special Report on Economic Models: "Big Questions and Big Numbers").

leaps in technological progress in economics and computing power of the past decade to enhance the fundamental strengths of the earlier model. ToTEM has a stronger theoretical foundation and better explains the dynamics of the Canadian economy.

ToTEM continues the key design philosophy and view of the economy underlying QPM but benefits from the leaps in technological progress in economics and computing power of the past decade to enhance the fundamental strengths of the earlier model.

The purpose of this article is to explain the motivation behind the development of ToTEM, to provide an overview of the model and its calibration, and to describe some simple simulations that illustrate a few of its key properties. A concluding section provides some indication of how the model is expected to evolve.

The Motivation for Developing ToTEM

Since QPM was first used by Bank of Canada staff in 1993, significant advances have been made in the field of applied macroeconomic modelling. Foremost is a more structural approach to modelling economic dynamics that views the economy as a set of rational agents, with each trying to explicitly maximize its well-being, subject to a set of constraints. The model's behaviour, both in and out of steady state, can thus be traced to a set of fundamental assumptions about the structure of the economy.[5] This increased reliance on economic theory in the dynamic model, in turn, results in model simulations that are easier to understand and to explain.

In addition, improved techniques for introducing multiple products into models and greater computing power have facilitated the use of richer, more realistic models that require fewer simplifying assumptions. These advances allow new models like ToTEM to maintain a more detailed structure than was possible with QPM. In particular, ToTEM is better able to capture international linkages in Canada. The core structure of QPM was designed around a one-good model; as a result, QPM had difficulty capturing, for instance, the relationship between commodity prices, the real exchange rate, and real gross domestic product (GDP). Staff therefore had to frequently introduce judgment, based on atheoretical add-on equations or other models (such as Macklem 1993) when analyzing terms-of-trade shocks (e.g., changes in commodity prices).

It is now possible to build models that accommodate multiple goods and optimizing agents where rational expectations are assumed throughout. Such models can be used to examine a broad range of questions of interest to a central bank, e.g., the determinants of exchange rate fluctuations, the implications of relative price movements (including commodity prices), and the aggregate implications of sector-specific shocks. With respect to the latter, it is reasonable to think that the impact of a movement in aggregate demand on core consumer price index (CPI) inflation[6] will differ, depending on whether it is the result of an increase in consumption or in investment demand.[7] Furthermore, in a multiple-goods structure with optimizing agents, a richer set of questions can be considered; e.g., from a welfare perspective, should a central bank target a price index that includes both domestically produced and imported goods, or should it focus solely on the former?

As well, by adopting a model whose core is that of an open economy dynamic stochastic general-equilibrium (DSGE) model, recent PhD graduates hired by the Bank will already be familiar with the basic structure of ToTEM, and therefore, less training will be required. In addition, the underlying optimizing-agent structure used in the model is very flexible. Additional features developed in the academic literature or at other central banks can be introduced (or turned off) in ToTEM in a much more straightforward manner than was the case with QPM. Finally, the use of linearization and new solution techniques allow the staff to simulate ToTEM in a fraction of the time required with QPM.

5. This approach was employed, for the most part, for the steady-state version of the model (SSQPM), but not for the dynamic model. The term steady state refers to the long-run equilibrium predicted by the model, after the effects of all shocks have fully dissipated.

6. The core measure of inflation excludes eight of the most volatile components of the CPI and adjusts the remaining components to remove the effect of changes in indirect taxes. The eight components removed are fruit, vegetables, gasoline, fuel oil, natural gas, intercity transportation, tobacco, and mortgage-interest costs.

7. In a one-good framework, a one per cent increase in aggregate demand will have a similar initial impact on prices whether it is the result of an increase in investment or in consumption demand.

To summarize, the objectives in developing ToTEM were threefold. First, the model needed to be more deeply grounded in economic theory than QPM, in order to provide, in particular, more coherent explanations of the model's business cycle dynamics. Second, the model would be better able to analyze the array of shocks that regularly hit the Canadian economy, especially terms-of-trade shocks, without introducing significant judgment when producing the quarterly projection. Finally, the model would be easier to work with, maintain, and change in line with advances in macroeconomic modelling. Having said this, the goal of ToTEM is not so much to implement a fundamentally new view of how the economy works as to provide a richer representation of the current view.

An Overview of ToTEM

ToTEM is an open economy DSGE model with four distinct finished-product sectors as well as a commodity-producing sector.[8] The behaviour of all key variables in ToTEM can be traced to a set of fundamental assumptions about the underlying structure of the Canadian economy, which greatly improves the model's ability to tell coherent, internally consistent stories about how the Canadian economy is—or will be—evolving. The multiple-products approach also allows ToTEM to inform the staff's judgment on a much wider variety of shocks, including relative price shocks, which was quite difficult with one-good models like QPM that included no role for relative prices.

The behaviour of all key variables in ToTEM can be traced to a set of fundamental assumptions about the underlying structure of the Canadian economy.

In ToTEM, there are four sets of agents: households, firms, the central bank, and a representative fiscal authority, or government. The first three are modelled as explicitly maximizing an objective, subject to a set of well-defined constraints. For example, firms in the model wish to maximize their profits, but are faced with constraints such as their production technology and the frequency with which they can change their prices. Consumers wish to maximize their well-being or "utility," subject to a budget constraint that limits the rate at which they can accumulate debt. Finally, the central bank in ToTEM wishes to maximize the well-being of consumers by minimizing deviations of inflation from the target and output from potential, as well as the variability of interest rates, while recognizing that the structure of the economy constrains its simultaneous achievement of these joint objectives (Cayen, Corbett, and Perrier, forthcoming).

Fiscal policy is modelled somewhat more traditionally in ToTEM. The government levies direct and indirect taxes and then spends or transfers to consumers the proceeds of these taxes according to a set of rules that are consistent with achieving a pre-specified ratio of debt to GDP over the medium term. The short-run responses of the rules are calibrated to mimic the historical behaviour of fiscal policy in Canada.

Turning to the details and starting with the role played by consumers (or households), ToTEM assumes the existence of two types of consumers, who differ only in their access to asset and credit markets. The first type, labelled "lifetime-income" consumers, face a lifetime budget constraint but can freely borrow or save so as to reallocate consumption across time. These agents base their consumption decisions on their total expected lifetime income and will choose a very smooth consumption path through time when the real interest rate is constant. Higher (lower) real interest rates will cause lifetime consumers to temporarily increase (reduce) their savings, in order to fully exploit the interest rate change. These agents are also assumed to own the domestic companies and are therefore the recipients of any profits.

"Current-income" consumers, in contrast, face a period-by-period budget constraint that equates their current consumption with their disposable income, including government transfers. In addition to not being able to save or dissave, current-income consumers do not own shares in companies and therefore do not receive dividends. The presence of current-income consumers in ToTEM reflects the simple fact that not all households in the economy enjoy unlimited access to credit markets, as is typically assumed in DSGE models. In terms of model behaviour, the main implication of introducing current-income consumers is that changes to taxes and government transfers have larger consumption effects.

8. For an intuitive discussion of dynamic general-equilibrium (DGE) models, see Moran (2000).

Both types of household sell labour to domestic producers and receive the same hourly wage, which they negotiate with the firm. Here it is important to note that workers are assumed to possess skills that are partially specific to the individual, thereby implying imperfect substitutability across workers. This assumption about the structure of labour markets is important because it means that workers have some market power in determining their wage. We also assume that workers and firms renegotiate the nominal wage about once every six quarters, on average, rather than every period. Furthermore, contract renewals are staggered over time, so a constant proportion are renewed each period. The introduction of "sticky" nominal wages will play a crucial role in creating business cycles in ToTEM while at the same time allowing monetary policy to influence real variables, such as GDP, in the short run (monetary non-neutrality).

In determining households' desired real wage, the assumption that both consumption and leisure are valued by households implies that they will consider *both* their current consumption level and the number of hours they are working when negotiating their wage. All else being equal, higher consumption or higher labour input will cause households to demand a higher real wage. The former effect occurs because a high consumption level makes leisure relatively more valuable. Thus, the only way to persuade the household to continue working the same number of hours is to offer a higher real wage.

Turning to the set of firms in the model, ToTEM contains producers of four distinct types of finished products: consumption goods and services, investment goods, government goods, and export goods. Each type of firm combines capital services, labour, commodities, and imports to produce a finished good. In the current version of ToTEM, only the relative import concentration distinguishes these goods; future versions, however, will allow for differences in the relative intensities of all factor inputs. The production technology for finished goods is characterized by constant elasticity of substitution. Increased capital utilization is possible, but at a cost. In other words, if a firm chooses to use its capital more intensively (by, say, adding an extra shift), the capital stock will effectively age faster, which in turn will reduce its productivity.

In addition to choosing the optimal mix of inputs, firms set a price for their product with an eye to maximizing their expected profits. Under the assumption that the elasticity of demand for any particular firm's product is constant, profit maximization corresponds to choosing a price that is a constant markup over marginal cost.[9] However, as with nominal wages, we assume that prices are costly for the firm to adjust, and therefore it will do so infrequently, and in a staggered fashion.[10] It will therefore not be possible for the firm to maintain a constant markup, except in steady state. Rather, knowing that any price it chooses will likely be in effect for several periods, the firm will set its nominal price so as to maintain a particular average markup over the duration of the period. Subsequent shocks will then cause variations in the firm's relative price, leading to variations in its sales, with low-price firms capturing greater market share.

Imports are treated as inputs to production, rather than as separate final goods. An importing firm buys goods from the foreign economy according to the law of one price and sells them to producers of finished goods at a price that is also adjusted only periodically. Thus, movements in exchange rates or foreign prices are not fully reflected immediately in the price paid by domestic producers. Furthermore, since the prices of both imported inputs and finished products are sticky, the model includes an element of vertical or supply-chain price staggering, which is crucial in allowing the model to generate realistic exchange rate pass-through to the CPI.

ToTEM also contains a separate commodity-producing sector. This is important for Canada, not only because the production of raw commodities accounts for roughly 13 per cent of GDP in Canada, but also because the finished-products and raw-materials sectors are characterized by different technologies and competitive structure. Much of the production of raw materials is highly price inelastic in the short run. At the same time, it is difficult to differentiate a commodity produced in Canada from one produced abroad. Finally, for most commodities, Canada can be viewed as a price-taker: it is too small a supplier to have any influence on world commodity prices. To properly understand the effects of commodity-price shocks, it is therefore necessary for a model to contain an explicit distinction between the commodity-producing and manufacturing sectors, as well as their respective

9. As in the labour market, the goods market is assumed to be characterized by imperfect competition, which implies that firms have some power to choose a price different than that of their competitors and still remain in business. Marginal cost refers to the cost to the firm of producing one additional unit of output.

10. The frequency of price readjustment has been calibrated in ToTEM to about twice per year, broadly consistent with the survey evidence presented in Amirault, Kwan, and Wilkinson (2006).

markets. In ToTEM, commodities are either exported, consumed directly by households, or used in the production of finished products.

Given their importance to the conduct of monetary policy, it is worth highlighting two particular aspects of ToTEM: the inflation process and the monetary policy transmission mechanism. These two aspects also illustrate some interesting conceptual differences between ToTEM and QPM.

The inflation process

ToTEM and QPM differ somewhat in terms of a theory of price determination. The underlying "story" for why, for example, inflation tends to rise when demand exceeds long-run supply, differs across the two models. In ToTEM, price increases are driven by marginal cost increases; in QPM, the output gap is the critical determinant of inflation in the short run. These conceptual differences do not, however, imply important differences in the behaviour of inflation across the two models since, for the most part, movements in costs tend to coincide with movements in the output gap. Rather, quantitative differences in the behaviour of inflation across the two models reflect the historical sample used to calibrate ToTEM (see "Model Calibration," below) not differences in assumed market structure.

In ToTEM, price increases are driven by marginal cost increases; in QPM, the output gap is the critical determinant of inflation in the short run.

As is now the convention in the literature on DSGE models, firms in ToTEM seek to maximize profits in an environment where the elasticity of demand for their goods is assumed to be constant and prices are sticky. A natural implication of these assumptions is that inflation is driven exclusively by current and expected future movements in marginal cost. Marginal cost, in turn, is increasing in firm-level output and, therefore, the firm-level short-run supply curve is upward sloping. For instance, higher production will tend to be associated with higher capital investment and more intensive utilization of existing capital. Both factors reduce productivity at the firm level, given that the installation of new capital causes production disruptions and that higher rates of utilization cause the existing capital stock to depreciate faster.

The monetary policy transmission mechanism

In Canada's current policy framework, the instrument of monetary policy is the target overnight interest rate.[11] In ToTEM, the Bank of Canada influences the nominal rate for 90-day commercial paper through its influence on the overnight rate. The level of the nominal short-term rate does not, however, directly affect real spending. Instead, consumption and investment decisions are based on the entire expected future path of short-term real interest rates; i.e., the demand side of the economy can be viewed as being influenced by a long-term real interest rate. Furthermore, changes in nominal short-term interest rates only influence this long-term real rate because prices and wages are not fully flexible in the short run. Similarly, monetary policy only affects the trade balance to the extent that nominal interest rate changes affect the real exchange rate, which, again, hinges on the assumption of nominal rigidity. In a world with fully flexible prices and wages, monetary policy would influence prices, but not real activity. In a world with considerable nominal rigidity, monetary policy influences inflation primarily through its influence on real activity.

In QPM, the adjusted yield spread,[12] by assumption, fulfilled dual roles as the instrument of monetary policy and as the relevant variable in households' consumption and savings decisions. In other words, there was a direct link between the actions of the central bank and consumption, and thus no way to explore the link between the influence of monetary policy and the degree of nominal rigidity.[13]

Model Calibration

As with any economic model, ToTEM contains several parameters for which economic theory does not assign specific values; rather, it provides only a sensible range of values. Typically, parameters are chosen so that

11. The overnight rate is the interest rate at which major financial institutions borrow and lend one-day (or "overnight") funds among themselves; the Bank sets a target level for that rate.

12. The adjusted yield spread is defined as the difference between the 90-day commercial paper rate and a 10-year government bond yield, adjusted for a measure of the term premium.

13. At the time, the use of the yield spread was justified on the grounds that it reflected the stance of policy better than short-term rates did and provided "a parsimonious way to capture the effects of the full term structure on aggregate spending" (Coletti et al. 1996).

the model's behaviour mimics as closely as possible the behaviour of the economy over some historical sample period. Specifically, the values for many of ToTEM's parameters were chosen such that the model's steady state exactly replicates key means in the data for the period 1980 to 2004. The values of the remaining parameters were chosen from estimates available in the existing literature or based on the model's ability to reproduce key properties of historical business cycles. Particular attention has been given to the model's ability to replicate certain temporal cross-correlations that appear to be robust in the historical data, and also to the model's theoretical impulse-response functions.

The time-series properties of certain key macro variables, most notably inflation, have changed markedly since the beginning of the 1990s (see Longworth 2002 for an extensive review). While exact dates are somewhat uncertain, both the volatility and persistence of inflation have declined markedly in the 1990s and 2000s relative to previous decades. In addition, the slope of the empirical Phillips curve has decreased, as has the extent to which exchange rate movements get passed through to the CPI. In other words, inflation is now less sensitive to excess demand and supply pressures as well as to movements in relative prices such as the exchange rate.

These changes in the properties of inflation are reflected in the behaviour of ToTEM. With respect to inflation persistence, for example, it takes seven quarters, on average, for inflation to return to the target following a shock in ToTEM when faced with the typical macroeconomic shocks observed over the 1980 to 2004 period, compared with about 10 quarters in QPM.[14] Moreover, when the shocks are drawn from the less-volatile 1991 to 2005 period, the average time declines to six quarters (Cayen, Corbett, and Perrier, forthcoming).[15]

An important consequence of a reduction in the persistence of structural inflation is that monetary policy need not look as far into the future when setting policy since, all else being equal, the maximum impact on inflation of monetary policy actions arrives sooner. This implication is also reflected in the calibration of ToTEM's optimized monetary policy rule: when specified in terms of year-over-year inflation, the policy feedback horizon is one year, which is again, about half of the six to eight quarters assumed in QPM.

Exchange rate pass-through, defined as the per cent change in the core consumer price level at a particular time horizon stemming from an initial one per cent exchange rate movement of average persistence, is markedly lower in ToTEM than in QPM after two years and beyond. At a one-year horizon, both QPM and ToTEM predict pass-through of about 0.05 per cent. After two years, however, QPM predicts that this number should rise to 0.18 per cent, about double that predicted by ToTEM, and the difference continues to grow with the time horizon.

A qualitatively similar result obtains for differences in the influence of excess demand (or supply) on inflation across the two models. In general, a shock to domestic demand causes inflation to rise by less, and the peak response occurs sooner and diminishes faster in ToTEM than in QPM.

Model Properties: A Few Illustrative Shocks

In this section, the implications of three exogenous shocks are analyzed using ToTEM to demonstrate the model's most important properties. The shocks selected are: (1) a temporary shock to households' desired level of consumption, (2) a temporary country risk premium or exchange rate shock, and (3) a temporary shock to the world price of commodities. Collectively, these shocks illustrate the main channels or propagation mechanisms in the model. In addition, they represent shocks frequently faced by the staff during the quarterly projection exercise. For the sake of brevity, we provide a description of the aggregate implications only for the consumption and exchange rate shocks, while providing somewhat more detail at the sectoral level for the commodity-price shock.

Consumption shock

This first shock shows the effects in ToTEM of an exogenously driven increase in domestic demand, in this case a temporary reduction in households' desired savings that causes consumption to increase by about 1.25 per cent at the end of the first year of the shock.

14. For a recent discussion of the appropriate inflation-target horizon in Canada, see Coletti, Selody, and Wilkins (2006).

15. It is important to note here that in measuring the time it takes for inflation to return to target over the 1991 to 2005 sample, we use an absolute criterion (inflation within 0.05 percentage points of the target, or between 1.95 and 2.05 per cent). As a result, the reduction in the time taken for inflation to return to the target, as defined here, reflects the reduction in the volatility, as well as the persistence, of inflation noted in the text above.

The responses of the key macroeconomic variables of interest are presented in Chart 1.[16] Two high-level features of the results are worth noting at the outset. First, there are no steady-state real effects on either stocks or flows from the shock because it is assumed to be temporary. Second, inflation responds very little to the shock and quickly returns to the baseline path.

Turning to some of the details of the simulation results and beginning with the composition of domestic demand, we first note that ToTEM's multiple-products structure affects the results. Real interest rates rise immediately following the increase in consumption, leading to a real appreciation of the currency and a decline in the relative price of investment, given that investment goods have a high import concentration in Canada. The relative price of investment declines sufficiently to generate a small increase in demand for capital goods. A peak increase of just over 0.1 per cent occurs in the middle of the second year of the simulation.[17]

The initial impact of the temporary consumption shock is an increase in real GDP of almost 0.5 per cent by the end of the first year, after which output gradually returns to control. The combination of stronger demand for consumption goods, which requires imports as factor inputs, and a 0.6 per cent real appreciation of the currency generates a 0.7 per cent increase in import demand, while exports fall by about 0.5 per cent. Thus, while GDP increases following a shock to domestic demand, the trade balance also worsens, suggesting that some of the extra consumption is borrowed from abroad.

It is also instructive to examine the supply response in the model in more detail. In ToTEM, firms meet an unexpected increase in demand for consumption goods in the short run through an increase in the use of variable inputs: labour, capital services, commodities, and imports. While the firm chooses the input combination so as to minimize its costs, no combination exists that will allow it to increase production without increasing its marginal cost, even if the prices of factor inputs remain unchanged. As a result of higher costs, all firms supplying more output would like to charge a higher price in order to maintain their profit margins. Only a subset, however, can change their price when the shock hits, so in aggregate, prices will rise by less than marginal cost and the average markup in the consumption-goods sector declines.

ToTEM predicts that a 0.4 per cent increase in real marginal cost will cause year-over-year core CPI inflation to rise 0.17 percentage points above target at the end of year one. So how does monetary policy ensure a quick return of inflation to the target in ToTEM? First, note that the increase in expected inflation causes a modest tightening (12 basis points at its peak) by the monetary authority. The tightening phase lasts about 2.5 years, however, and in ToTEM, the duration of the interest rate increase is as important as the size. Thus, monetary policy commits to a sustained, albeit modest, period of tighter policy that causes the expected future real interest rate to rise. Higher real interest rates reduce consumers' incentive to indulge in present consumption and firms' incentive to invest. At the same time, higher rates cause a real appreciation of the currency that facilitates a substitution away from domestic factor inputs towards imported inputs. The exchange rate appreciation also increases the price of Canadian exports abroad, thereby reducing export activity and further reducing excess demand pressures. All of these effects combine to help restore aggregate demand at its long-run, sustainable level, while at the same time returning inflation to its targeted level.

In ToTEM, the duration of the interest rate increase is as important as the size.

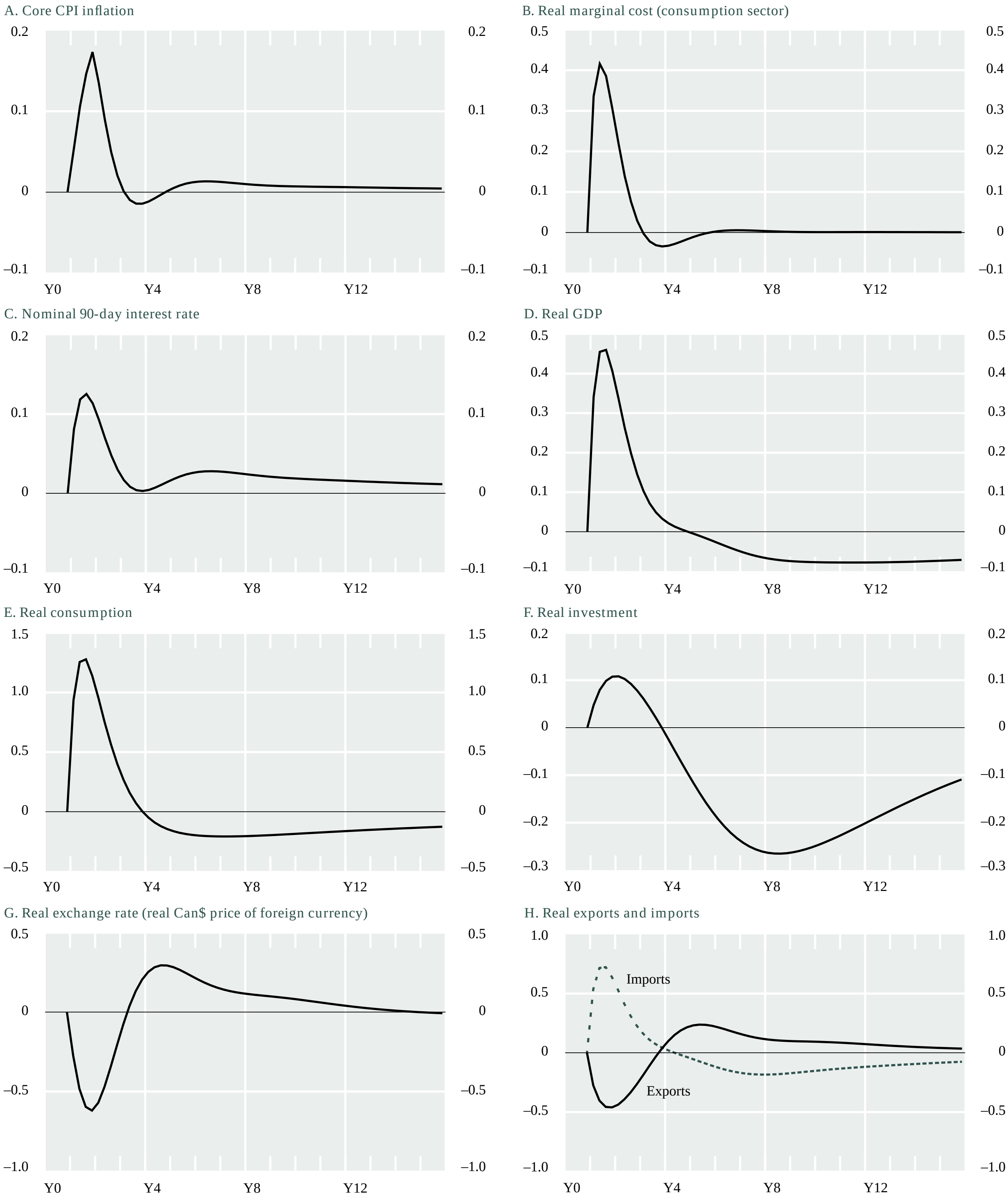
As with any model that accounts for stocks, in ToTEM, there is a price to be paid by consumers for their temporary spending binge. In this case, the increase in consumption is partially financed through a deterioration of the net foreign asset (NFA) position. However, because of the assumption that the desired NFA level remains unchanged in the shock, a period of dissavings must be matched by a period of increased savings which, in ToTEM, is reflected by a sustained period of consumption that is slightly below steady state (starting in year four).

16. The charts show the per cent deviations (relative to a baseline simulation with no shock) for all variables except interest rates and inflation rates, which are expressed in percentage points. Owing to the fact that simulations are done with a linearized version of ToTEM, the starting point (or baseline) does not affect the simulation results. Furthermore, the response of the model is linear in the magnitude of the shock.

17. This contrasts with the typical result found with one-good DSGE models, i.e., that consumption and investment move in opposite directions.

Chart 1

Consumption Shock



Exchange rate shock

This second shock shows the effects in ToTEM of an exogenous shock to the country-specific risk premium, which has the effect of depreciating the currency by about 6 per cent by the end of the first year. In Bank of Canada parlance, this may be regarded as a Type Two exchange rate movement, in that it does not reflect the endogenous adjustment of the exchange rate to another shock or economic development that has direct implications itself for the demand for Canadian goods and services, but considers the exchange rate depreciation itself the shock.[18]

The responses of the key macroeconomic variables of interest are presented in Chart 2. The solid lines capture the response of the baseline calibration of ToTEM, which assumes a net steady-state markup of prices over marginal cost of 5 per cent. The broken lines illustrate the model's response to the same shock, assuming a markup of 2 per cent, which corresponds to a higher level of competition in the goods market (goods become more substitutable). For the moment, we will focus on the behaviour of the baseline model calibration.

Again, some high-level results are worth noting at the outset. As with the temporary consumption shock, there are no steady-state real effects on either stocks or flows from the shock because it is temporary. However, the effects of this shock on inflation are somewhat longer-lived than in the first shock, given that, in ToTEM, a depreciation of the exchange rate feeds into import prices and marginal cost only gradually, whereas a shock to demand affects marginal cost immediately.

Specifically, a depreciation of the exchange rate in ToTEM causes an increase in the Canadian-dollar price of imported intermediate goods, investment goods, and commodities—all inputs to the production of finished products. A depreciation of the exchange rate therefore triggers an inward shift of the supply curve in the goods market.

Exporters of manufactured goods are affected by both the supply and demand dimensions of the shock. The price of their inputs increases, but demand for the output also increases. On net, the depreciation causes manufactured and commodity exports to rise by a combined 2 per cent, while consumption declines by as much as 0.35 per cent.

18. See Ragan (2005) for a discussion of Type One versus Type Two exchange rate movements.

Unlike in QPM, imports also increase in ToTEM (by about 0.5 per cent) immediately following a depreciation of the exchange rate. This difference emerges because, in ToTEM, the negative substitution effect (due to higher prices paid for imported intermediate inputs) is weaker than the income effect (higher demand for all inputs as aggregate demand increases). On net, real GDP increases by almost 0.4 per cent towards the end of the second year of the simulation, and returns to its control level after about four years.

Higher prices for import, investment, and commodity inputs to production eventually cause core CPI inflation to rise (peaking at 0.3 percentage points in year two of the shock) as producers of consumer products partially pass on their cost increases in the form of higher retail prices, which triggers the monetary authority to tighten policy by almost 50 basis points in the second year.

The experimental modification of the assumed degree of competition in the finished-products sector is interesting in that it demonstrates the breadth of analysis that can be carried out with more structural models such as ToTEM, whose parameters all have explicit economic interpretations.

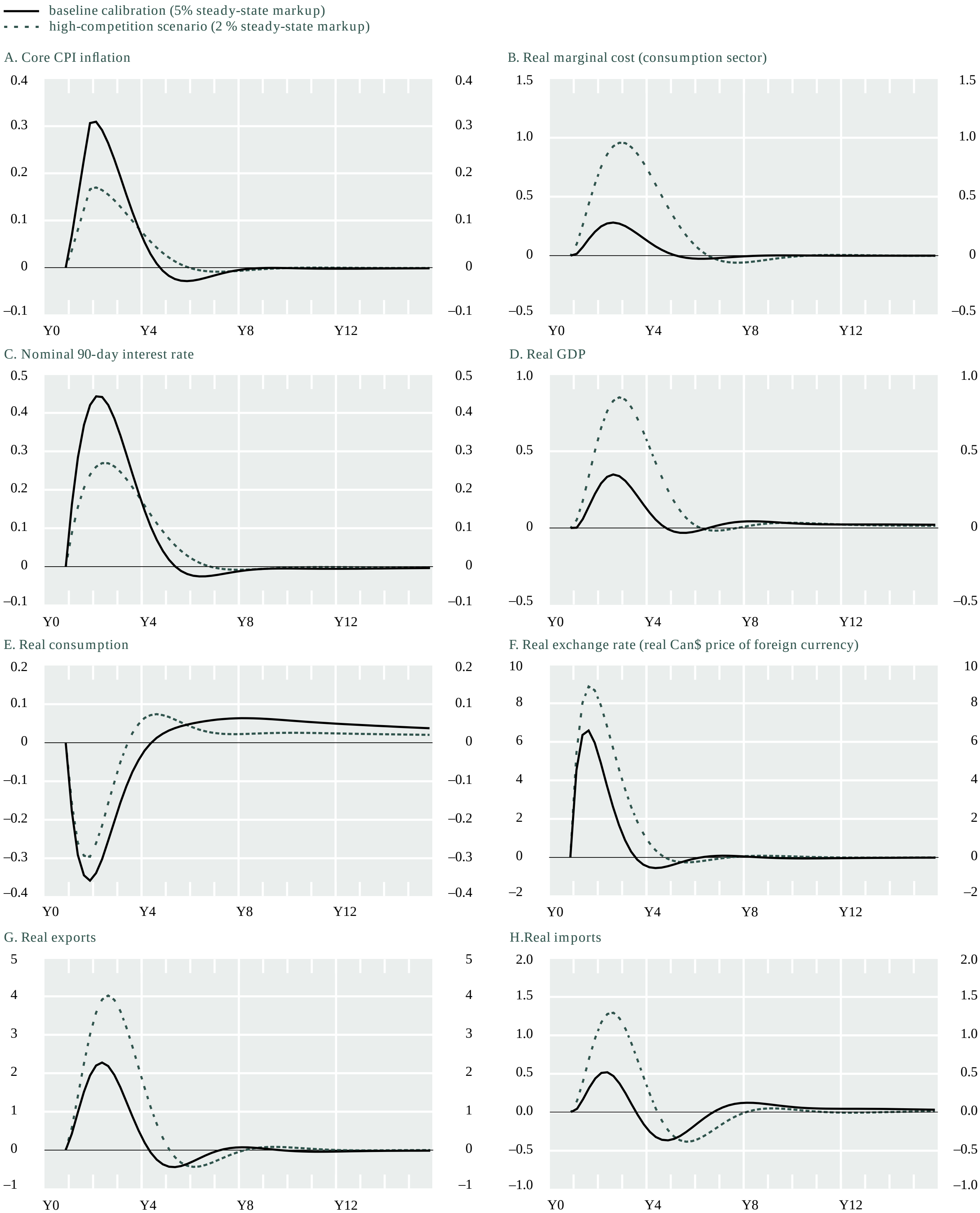
All else being equal, when markets are very competitive, demand, and therefore marginal cost, will be very sensitive to a firm's relative price in ToTEM. This means that high competition should cause less relative-price variation and therefore, at the aggregate level, inflation should be less sensitive to movements in economy-wide real marginal cost. The same nominal exchange rate shock now causes core CPI inflation to peak at about 0.17 percentage points above control, about half of its baseline-calibration response (broken line, Chart 2A). As a result of the weaker inflation response, monetary policy is not required to tighten by as much and, thus, output peaks at just over 0.8 per cent above control, more than double its baseline response.

Commodity-price shock

The third shock shows the effects in ToTEM of a temporary 10 per cent increase in the world price of commodities stemming from a supply disruption that arises in other commodity-producing countries but leaves Canada's commodity supply unchanged. It is assumed that the shock affects the price of all commodities—energy and non-energy—the same. We also assume that this negative supply shock temporarily lowers rest-of-world GDP, which reduces the demand for Canadian manufactured exports.

Chart 2

Exchange Rate Shock



Perhaps the most striking feature of the results is just how important commodity prices are for the Canadian economy and how long lasting the effects of even a temporary change in commodity prices (roughly three years) can be (Chart 3). One of the most noteworthy effects of the increase in commodity prices is the sustained increase in consumption (about 0.4 per cent for the first five years), which lasts about 20 years. This effect captures the response of households to the increase in their wealth, which is evidenced by an immediate increase in their net foreign asset (NFA) holdings. Furthermore, since we assume an unchanged desired NFA position, even stronger consumption is required to gradually restore the former NFA level.

Also noteworthy is the 2.5 per cent appreciation of the real exchange rate that builds over the first year and then persists for several years to come.[19] This real appreciation is generated endogenously by the model in order to encourage higher imports, which are needed first to stabilize the NFA position and ultimately to restore it to its pre-shock level. The appreciation eventually leads to a fall in the price of import-intensive investment, thereby boosting investment spending by as much as 0.7 per cent in year five.

On the trade side, commodity exports essentially form the residual between commodity production and demand for commodities in Canada. For a temporary shock such as this, the positive supply response by commodity producers is quite small.[20] Owing to the price increase, however, there is some substitution away from commodities by firms and consumers, and so commodity exports rise about 1.4 per cent. Manufactured exports, in contrast, fall by 1.2 per cent at the end of year two in response to the appreciation of the exchange rate and the reduction in demand in the rest of the world. Finally, imports flourish (0.5 per cent in year five), owing to both an immediate and strong income effect and a strong substitution effect that builds gradually as lower import prices at the border are passed through to manufacturing firms.

In the labour market, higher overall demand in the economy causes firms to increase their demand for labour input, measured in ToTEM as hours worked. This increase in hours, combined with stronger consumption spending, leads households to raise their desired real wage. However, since only a small subset of households can actually renegotiate their wage at the outset of the shock (recall that wage contracts are staggered and last about six quarters, on average, in ToTEM), the aggregate real consumer wage initially falls by as much as 0.2 per cent, which, from the representative firm's point of view, helps to stem the rise in real marginal cost.[21] Only after about three years does the real wage rise above control.

Turning to the nominal side of the economy, core CPI inflation initially rises by as much as 0.1 per cent (0.2 per cent for CPI inflation) and then falls below control in year three. The behaviour of inflation can be explained by the impact of commodity and import prices on real marginal cost in the consumption sector. Initially, the large increase in commodity prices, combined with an overall reduction in productivity, causes marginal cost to rise. However, as commodity prices return to control and the appreciation of the exchange rate begins to show up in the price paid by manufacturing firms for imports, real marginal cost falls below control.

Over the medium term, real GDP remains above control while inflation has returned to target. This arises from the increase in capital stock from higher investment activity in preceding years. Thus, a persistent rise in the terms of trade in ToTEM generates a small, but sustained, increase in potential output. Were the commodity-price shock permanent, potential output would rise permanently by about 0.5 per cent.

Conclusion

The decision to develop a new model was intended to return the staff's projection and policy-analysis model to its state-of-the-art status. The goal was to build a model in the spirit of QPM, but one that is more structural, with multiple goods that will handle a wider array of shocks, with less need for judgmental intervention.

While ToTEM is a significant accomplishment, it should be stressed that all economic models are simplified representations of a complex reality. How good a representation they are depends on the state of knowledge and technology in the economics discipline at the time they are built. Indeed, our intended approach is to make continuous improvements to

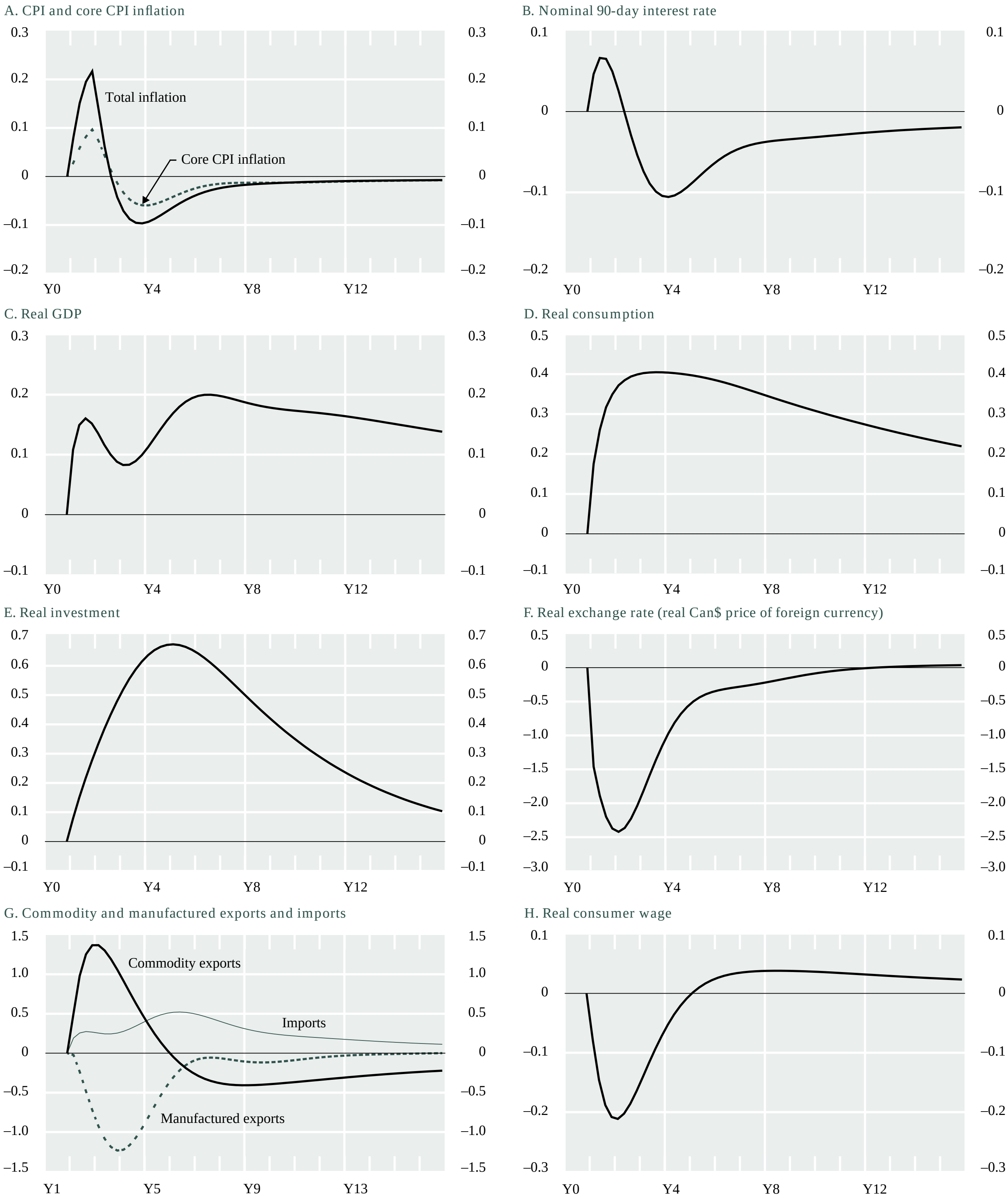
19. If the increase in commodity prices were permanent, the real exchange rate appreciation would be more than twice as large, consistent with the cointegration evidence for Canada (see Amano and van Norden 1995).

20. The supply response by commodity producers depends critically on the persistence of the commodity-price increase. A permanent increase would generate a significantly larger positive supply response.

21. In a world with flexible wages, the real wage would immediately rise, putting more upward pressure on real marginal cost and reducing the overall GDP expansion. Thus, in a model like ToTEM, the elasticity of real activity with respect to commodity prices is closely linked to the degree of nominal flexibility in the labour market.

Chart 3

Commodity-Price Shock



ToTEM as new technologies and knowledge become available. In the near term, we intend to concentrate our efforts on improving two aspects of the model: its empirical properties and its supply side, particularly in the commodities sector.

Our intended approach is to make continuous improvements to ToTEM as new technologies and knowledge become available.

With respect to the empirical properties, our plan is to formally estimate the model parameters directly, although it may be necessary for a time to use calibration techniques for some parameters. In general, the benefits of estimation over informal calibration techniques are twofold. First, estimation should help the model make more accurate forecasts. Second, it would yield a measure of the uncertainty associated with the parameter estimates that could be used to assess risks to the projection, to construct confidence intervals, and to aid in the design of more robust monetary policy rules.

With respect to the supply side of the model, each type of firm currently combines capital services, labour, commodities, and imports to produce a finished good. In the current version of ToTEM, only the relative import content distinguishes these goods; future versions, however, will allow for differences in the relative intensities of all factor inputs to reflect that capital goods and commodities are more capital intensive than consumer products and that government spending may be more labour intensive. Work is also planned to better capture adjustment costs in the production process and to make an explicit distinction between energy and non-energy commodities.

Finally, in the medium term, the staff plans to revisit the manner in which expectations are formed in ToTEM. While appropriate in most cases, purely rational expectations can be unrealistic under certain circumstances, particularly when unusual shocks that are not well understood by private agents hit the economy. Future versions of ToTEM will offer greater flexibility in the treatment of expectations. In addition, work is currently underway at the Bank to introduce a financial sector into a small DSGE model (see the article, "Modelling Financial Channels for Monetary Policy Analysis," in this issue). Once completed, the staff plans to examine carefully the potential benefits of introducing such a sector in ToTEM.

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MUSE: The Bank of Canada's New Projection Model of the U.S. Economy

Marc-André Gosselin, René Lalonde, and Nicolas Parent, International Department

- *Canada has a very open economy which is broadly integrated into the global economy. Accordingly, the Bank of Canada has developed several models to analyze and forecast economic developments in the rest of the world.*
- *Given the importance of Canada's economic relationship with the United States, the Bank of Canada places considerable importance on generating internal forecasts of U.S. economic activity as an input to the Canadian projection.*
- *Over the past couple of years, Bank of Canada staff have been using a new macroeconometric model, MUSE, to analyze and forecast developments in the U.S. economy. The model is a system of equations that describe the interactions among the principal U.S. macroeconomic variables, including gross domestic product, inflation, interest rates, and the exchange rate. At the same time, a smaller forecasting model for Europe, NEUQ (New European Union Quarterly Model) has been introduced.*
- *Although the main goal of MUSE and NEUQ is to provide forecasts of foreign economic variables as inputs to the Canadian projection, these models can also be used independently to address other issues, such as understanding the responses of foreign economies to different shocks. It is hoped that these models will result in a better-informed perspective on current and future external economic developments.*

The analysis and forecasting of economic developments in the rest of the world plays a critical role in the formulation of Canadian monetary policy. In particular, the Bank of Canada places considerable importance on generating internal forecasts of U.S. economic activity as an input to the Canadian projection (Macklem 2002). This focus stems from the close real and financial linkages between the Canadian and U.S. economies. Although different generations of Canadian economic models used at the Bank have undergone significant changes in terms of theoretical underpinnings or macroeconomic structure, they have always relied on other models or sources of information for estimates of external economic activity.

Over the past couple of years, Bank staff have been using a new macroeconometric model, MUSE (Model of the U.S. Economy), to analyze and forecast developments in the U.S. economy.[1] The model is a system of equations that describe the interactions among the principal U.S. macroeconomic variables, such as gross domestic product (GDP), inflation, interest rates, and the exchange rate. MUSE contains more than 30 behavioural equations, most of which are estimated. At the same time, a smaller forecasting model for Europe, NEUQ (New European Union Quarterly Model) has been introduced. In addition, to improve our understanding of global economic issues and to complement other Bank models, the staff are currently developing BoC-GEM (Bank of Canada Global Economy Model), an adaptation of GEM, the multi-country dynamic stochastic general-equilibrium model built at the International Monetary Fund. While this article mainly focuses on MUSE, brief descriptions

1. MUSE has been developed at the Bank. A detailed discussion of the specification of the model can be found in Gosselin and Lalonde (2005).

of the specifications and purpose of NEUQ (Box 1) and BoC-GEM (Box 2) are also included.

Importance of International Projections

There is a conceptual difference between the Bank staff's projection for Canada and those for the rest of the world. The Canadian projection is the staff's assessment of the most likely path for the economy. It includes a recommendation to the Bank's Governing Council on the optimal profile for the overnight interest rate that will return inflation to the 2 per cent midpoint of the inflation-control target range. In contrast, the primary role of the international projection is not to provide specific recommendations for monetary policy, but to forecast external economic activity and inflation, together with the probable interest rate response by foreign monetary authorities. The models involved in this process are therefore not as oriented towards policy analysis as is the Canadian model.

Although the main goal of MUSE and NEUQ is to provide forecasts of foreign economic variables as inputs to the Canadian projection, these models can also be used independently to address other issues of interest, including understanding the responses of foreign economies to different shocks.

Although the main goal of MUSE and NEUQ is to provide forecasts of foreign economic variables as inputs to the Canadian projection, these models can also be used independently to address other issues of interest, including understanding the responses of foreign economies to different shocks (e.g., oil-price shocks, productivity shocks, and fiscal policy shocks). Such analysis can also be useful for comparison with the Canadian economy.

Basic Structure of MUSE

Long-term planning and the presence of costs in adjusting economic activities both play a key role in MUSE. Thus, the specification of most behavioural equations relies on the polynomial adjustment-cost (PAC) approach, which is widely used in the Federal Reserve Board's FRB / US model (Brayton et al. 1997). In PAC models, households and firms make informed decisions based on expectations about future circumstances, and these decisions rest on forecasts of desired goals that would be selected in the absence of adjustment costs. While firms and households modelled under the PAC approach behave optimally, planning lags, contractual requirements, and other frictions prevent them from moving immediately towards the desired level. Decisions subject to higher adjustment costs require longer planning horizons.

PAC models stand halfway between general-equilibrium models, in which the dynamics are entirely explained by theory, and reduced-form models, which are based solely on data.

The PAC specification is akin to an error-correction model. It contains two equations: one for the desired level (often based on a cointegrating relationship) and one for the dynamic path of the variable under consideration (in growth rates). The dynamic behaviour of the variable of interest is determined by the lagged gap between the actual and desired values of the variable, the lagged values of the dependent variable, and expected future changes in the desired level of the variable.[2] By using a very general description of adjustment costs, these models are able to closely match the persistence in the historical time-series data. As a result, they stand halfway between general-equilibrium models, in which the dynamics are entirely explained by theory, and reduced-form models, which are based solely on data.

The stock-flow equilibrium is fully described in MUSE. In steady state, the model defines specific equilibrium values for all stocks. For instance, the equilibrium ratio of business capital to output is determined by firms' financing costs and asset-specific depreciation rates and relative prices. The tax rate adjusts to meet a target

2. The number of lags of the dependent variable depends on a very general description of the order of adjustment costs. In PAC models, it can be costly to adjust the variable of interest in terms of level, change, rate of acceleration, and so on (Tinsley 1993).

level of government debt in the steady state. The model also converges to a constant ratio of net foreign assets to GDP. Finally, households' human wealth in equilibrium is influenced by personal income, taxes, and government transfers.

Nominal dynamics in MUSE are determined by a short-run Phillips curve that describes the positive relation between inflation and the output gap. Thus, the difference between actual and potential output is a key driver of inflation in the model. In addition, inflation is determined in the context of forward-looking rational expectations, and the persistence in the inflation process is explained by adjustment costs. Monetary policy is modelled according to a simple forward-looking rule. The central bank reacts with the objective of closing both the current output gap and the expected gap between actual inflation and an implicit inflation target. The other key adjustment mechanism in the model is the real exchange rate, which reacts to interest rate differentials and the current account balance so as to restore the target position for net foreign assets.

Box 1: The NEUQ Model*

The euro area and the United Kingdom (U.K.) combined account for approximately 5 per cent of Canadian exports and 11 per cent of Canadian imports and represent Canada's second most important trading partner after the United States. Although total Canadian trade and financial linkages with the two economies are smaller than those with the United States (U.S.), they are magnified by the indirect effect that the euro area and the United Kingdom have on the U.S. economy and on world commodity prices.[1] To account for these direct and indirect effects on the Canadian economy, projections of key macroeconomic variables for the euro area and the United Kingdom are used as inputs into MUSE, ToTEM, and the Bank of Canada internal projection for commodity prices.

In March 2005, the Bank of Canada incorporated NEUQ, its New European Union Quarterly projection model, into the projection process (see Piretti and St-Arnaud 2006 for details). NEUQ is a small estimated reduced-form model built using the same "conventional"—or Phillips curve—paradigm as MUSE, but at a higher level of aggregation. NEUQ is primarily designed as a tool to project the future path of real output, inflation, and the policy rate for the euro area and U.K. economies.

The NEUQ model consists of two country blocs (one for the euro area and one for the United Kingdom), which are endogenous to each other via the foreign demand channel. Each country bloc features three behavioural equations. Aggregate demand, the first equation, relates real output to the interest rate, the real effective exchange rate, and foreign activity (U.K., U.S. and Asian demand for the euro area, and euro area, U.S. and Asian demand for the United Kingdom). Aggregate supply, the second equation, is modelled using a forward-looking Phillips curve where inflation is determined by the output gap, the real effective exchange rate, and the real price of oil. As in MUSE, inflation dynamics are modelled using the PAC (polynomial adjustment-cost) approach to account for expected inflation and some persistence in the adjustment process of inflation.[2] The model is closed by a third endogenous equation, an estimated forward-looking interest rate rule for monetary policy. It relates the nominal short-term interest rate to the deviation of forecast inflation from the monetary authority's inflation target, and to the deviation of real output from potential output. As in MUSE, each dynamic equation has a steady state to which the model converges in the long run.

The NEUQ model delivers reasonably accurate projections of key U.K. and euro area macro variables at a variety of horizons and also provides a useful tool for policy analysis. An interesting feature of the model is that the simulation results suggest that output and inflation exhibit a greater degree of persistence to shocks in the euro area than in the United Kingdom.

* This box was written by Denise Côté.

1. The euro area and the United Kingdom account for around 20 per cent of U.S. exports and 17 per cent of U.S. imports, and represent the second-largest U.S. trading partner after Canada (International Monetary Fund 2006).

2. As part of the aggregate supply side, potential outputs for the U.K. and euro area economies are estimated by means of a Hodrick-Prescott filter, conditioned by an equilibrium path generated by a structural vector autoregression (St-Arnaud 2004).

Real GDP

In MUSE, U.S. real GDP is decomposed into household spending, business investment, government spending, and international trade. Hence, MUSE can be used to analyze the impact of a wide variety of shocks on the U.S. economy.

In MUSE, U.S. real GDP is decomposed into household spending, business investment, government spending, and international trade.

Household spending

Household spending is modelled in MUSE as the sum of total consumption and residential investment. According to the permanent-income hypothesis, a household's consumption in any given period depends on its permanent income, defined as the current value of household wealth (human and non-human). In this context, consumption changes when agents modify their expectations of future income, or when agents make expectational errors. Most economists, however, reject the pure permanent-income hypothesis, arguing that the existence of credit-constrained households limits its applicability and that households could also choose to save for precautionary reasons. In both cases, consumption may be more closely related to current than to permanent income.

On this basis, the desired level of household purchases in MUSE is consistent with the permanent-income hypothesis, but deviations from the hypothesis are allowed along the dynamic path (Gosselin and Lalonde 2003). The desired level of household spending is a function of real interest rates, expected future disposable labour income (human wealth), and stocks of real estate and financial wealth.[3] In addition to the standard determinants from the dynamic PAC specification, short-run movements in household spending are influenced by current disposable income. The percentage of households that are credit constrained is 27 per cent; 73 per cent are forward looking, and their behaviour is represented by the permanent-income hypothesis. Consequently, the spending patterns of households adjust relatively sluggishly to differences between actual expenditures and their desired level. To account for credit-constrained consumers, a negative effect of higher oil prices is also included to proxy the impact of this variable on disposable income.

3. Real estate wealth is a function of the stock of residential capital and of house prices. The main determinant of residential investment flows and house prices is the real mortgage rate. Financial wealth is anchored on businesses' capital stock, government debt, and net foreign assets.

Business investment

In MUSE, firms can invest in three types of capital goods: non-residential structures, high-tech equipment, and other equipment excluding high-tech. Modelling business investment using these different categories of expenditure allows for substitution and complementarity effects among the three types of capital. The user cost of capital and the level of output are the key determinants of long-run movements in desired capital stocks.[4] Desired investment flows are derived from the desired capital stocks. As can be imagined, reaching the desired investment levels entails significant adjustment costs, which can derive from such diverse sources as information gathering, plant or product design, testing, and regulatory approval. The dynamic path of investment is specified in terms of the PAC structure. In some cases, output growth is also included in order to capture cash-flow effects for some subset of financially constrained firms. In all cases, investment exhibits substantial inertia to movements in output or user costs.

The trend of labour input and total factor productivity, which are based on exogenous assumptions, combined with the forecasted capital stock, feed into a Cobb-Douglas production function to generate a projection for potential output.[5]

Government spending

Several channels through which the government sector affects the economy are modelled in MUSE. Aside from government consumption and investment, which feed directly into GDP, taxes and transfers partly determine personal disposable income. Government debt influences consumption through its effect on

4. The user cost of capital depends on the relative prices of investment goods, interest rates, and depreciation rates.

5. Over the historical period, potential output is measured using the eclectic approach, which consists of Hodrick-Prescott filters to which an equilibrium path generated by a structural vector autoregression is added as information conditioning the filters. We use this approach to estimate the two components of potential GDP: the full-employment labour input and trend labour productivity. The full-employment labour input is a function of the population, the equilibrium participation rate, the equilibrium unemployment rate, and the equilibrium hours worked (Gosselin and Lalonde 2006).

household financial wealth. It also influences the risk premium on Treasury bonds, which affects the cost of capital for businesses and mortgage rates. Total government expenditures (including transfers) are a function of the output gap, which reflects the operation of automatic stabilizers. The greater the recession or degree of excess supply, the higher are government expenditures in the form of transfers to the household sector.

There is a fiscal policy rule in MUSE: the government adjusts revenues to achieve an exogenous debt target in the long run. Political constraints, budget deliberations, and implementation lags prevent the government from adjusting the tax rate to its desired level in the near term. Thus, the aggregate tax rate adjusts slowly to its target level.

International trade

MUSE is a one-good model: it does not differentiate between traded and non-traded goods. Desired export and import volumes are modelled similarly: both react to relative prices, and they react to foreign and domestic income, respectively. Adjustment costs can be important in the tradable goods sector. These costs reflect costs of changing suppliers or markets, such as costs owing to a lack of familiarity with the commercial practices of foreign markets, commercial policies (e.g., taxes and tariffs), or other border effects. Given such costs, profit-maximizing firms must be forward looking in their behaviour, anticipating domestic and foreign growth in order to reduce the costs of sudden shifts in demand (Gagnon 1989). Such frictions justify using the PAC approach to model dynamic movements in trade volumes and relative prices.

In MUSE, the desired level of real imports is a function of private domestic demand, openness to global trade, and the relative price of imports.[6] The desired level of real exports is also determined by the standard paradigm of income and relative prices, augmented by a proxy for globalization. In the dynamic PAC specification of imports, the change in the output gap is added to account for the fact that the short-run income elasticity of imports is much higher than its long-run value (Hooper, Johnson, and Marquez 2000). For the same reason, the foreign output gap is included in the

6. Openness to trade is proxied by the volume of trade between the countries that belong to the Organisation for Economic Co-operation and Development. For more details, see Gosselin and Lalonde (2004).

Box 2: BoC-GEM

Economists at the Bank of Canada are currently adapting GEM (the Global Economy Model), developed by the International Monetary Fund, to the Bank's needs.

In this version of GEM, the BoC-GEM, the global economy is divided into five countries or country groups: Canada, the United States, emerging Asian countries that import raw materials (primarily China and India), commodity-exporting countries (including members of the Organization of Petroleum-Exporting Countries), and the rest of the world (notably Europe and Japan). Owing to the size of the natural resource sector in Canada, this version of GEM incorporates, in addition to the tradable and non-tradable goods sectors, the oil and gas sector, as well as other commodities.

BoC-GEM is a dynamic general-equilibrium (DGE) model. Its theoretical and microeconomic foundations are therefore highly developed and are modelled on the principles of supply and demand. The model's parameters were calibrated using data and microeconomic studies or by drawing on other DGE models. Overall, the properties of BoC-GEM are compatible with those of estimated or partially estimated models.

Because of its complexity and specific characteristics, BoC-GEM is complementary to the MUSE, NEUQ, and ToTEM models. It will be used primarily for studying issues that require a global perspective, such as global imbalances, causes and effects of the rise in oil prices observed in recent years, and the impact of open markets on competitiveness and price levels. The model will also be used in the context of the international projection to guide the staff's judgment on monetary policy issues that require an integrated global perspective. Finally, BoC-GEM can help Bank staff to ensure that economic forecasts generated using MUSE, NEUQ, and ToTEM form a consistent whole.

dynamic exports equation. The desired levels of the relative prices of imports and of exports are a function of the real exchange rate, the relative price of oil, and a downward deterministic trend that captures the higher productivity in the traded-goods sector relative to the non-traded-goods sector. Import prices play an important role in MUSE, since they help to determine import volumes and feed directly into the inflation process.

U.S.-Dollar Real Effective Exchange Rate

As mentioned earlier, in the steady state, MUSE reaches a target ratio of net foreign assets to GDP. This convergence is facilitated by the adjustment of the real effective exchange rate. Given the steady-state version of the model, there is a unique value of the exchange rate such that the ratio of net foreign assets to GDP converges to its target level. Therefore, the real exchange rate generates the movements in the trade balance that are required to attain the target ratio for net foreign assets.

A partly calibrated error-correction equation governs exchange rate fluctuations. The key short-run determinants are the gap between the actual and equilibrium exchange rates and real interest rate differentials between the United States and its major trading partners. There is a dichotomy between the short-run and long-run behaviour of the exchange rate. For instance, following an increase in domestic demand, the exchange rate appreciates in the short run because of positive interest rate differentials, but then depreciates in order to generate a trade surplus consistent with a restoration of the target for net foreign assets.

Inflation

Inflation persistence due to sticky prices can be modelled in many ways, from menu costs to price-setting behaviour in the fashion of Calvo (1983) and Taylor (1980). More recent research focuses on New Keynesian Phillips curves or their variants. Hybrid specifications, such as that of Galí and Gertler (1999), can identify significant inflation persistence with the use of lagged values of inflation.

Instead of choosing one of these approaches, we do not take a rigid stance on the theory of inflation determination. Like Kozicki and Tinsley (2002), we use a more general PAC approach and let the data determine the persistence of inflation, rather than impose it by specification. This approach assumes rational economic agents that balance the cost of price adjustments against the costs of diverging from the desired price level. The costs associated with changing prices lead firms to smooth the inflation profile, generating persistence in the inflation process. In addition to the leads and lags of inflation that capture inflation expectations and adjustment costs, the inflation process in MUSE is driven by the current output gap and past movements in the relative price of imports.

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Monetary Policy

A number of interest rates are modelled in MUSE and, in turn, influence various elements of the model. They are all anchored, in one way or another, to the U.S. federal funds rate.[7] The nominal federal funds rate in MUSE follows a Taylor (1993) rule. This type of monetary rule is a good description of the Federal Reserve's actions and is consistent with the monetary authority's dual mandate of maintaining low and stable inflation while supporting maximum sustainable employment. Based on the work of English, Nelson, and Sack (2002), the rule is specified in terms of the neutral rate, the future gap between inflation and the implicit inflation target, the current output gap, and a smoothing coefficient. The neutral rate is fixed at its steady-state value. This value is endogenous in MUSE: it is equal to the unique value of the real interest rate that makes aggregate demand equal to aggregate supply in the steady state.

Shock Analysis

Several relevant shocks can be used to illustrate the dynamic behaviour of MUSE. We simulate the impact

7. The other interest rates modelled in MUSE are the 10-year government bond rate, the 30-year mortgage rate, the corporate bond rate, and the interest rate on net foreign assets. Long-term rates depend on the expected future short rates plus a term premium that is a function of the ratio of government debt to GDP.

of three temporary shocks: a shock to demand, a shock to the federal funds rate, and an inflation shock. We also look at a permanent shock to total factor productivity.[8]

A temporary shock to private domestic demand

In this scenario, an increase in private domestic demand generates a positive output gap that lasts about two years. The opening of the output gap yields a small but persistent increase in inflation. In reaction to these two developments, the monetary authority raises the federal funds rate and engineers a small degree of excess supply to bring inflation back to the target. This rate increase feeds through the term structure and raises longer-term rates, thereby pushing household spending and investment back to the control scenario.[9] Investment is the slowest to return to equilibrium, since adjustment costs are higher for this component. Since fiscal policy is countercyclical, government transfers decrease following the shock. Lower transfers reduce personal disposable income flows and human wealth, which depresses household spending.

Real imports rise in the short run because part of the increase in demand is for imported goods and services. Since this scenario assumes no response in foreign variables, real exports fall in response to a short-term appreciation in the real exchange rate that results from higher domestic interest rates. The deterioration in the trade balance leads to a temporary worsening of the net foreign assets position, thereby requiring a depreciation of the real exchange rate in the medium run in order to return net foreign assets to the target position (Chart 1, page 27).

A temporary shock to the federal funds rate

This shock illustrates the various channels of the U.S. monetary policy transmission mechanism that are modelled in MUSE. In this simulation, the Federal Reserve raises the nominal federal funds rate by 100 basis points in the first period and maintains it above control for about six quarters, which reflects a preference for interest rate smoothing. Through the term structure of interest rates, the change in short-term interest rates affects all other interest rates in the model. Higher interest rates reduce both consumption and investment in the early years of the simulation. Again, investment is slower to return to control. The impact on consumption would be greater absent the fiscal response, which generates an increase in government transfers, lending support to disposable income.

Positive interest rate differentials generate an appreciation of the dollar, leading to lower exports in the short run. Imports fall as well because the short-run effect from the reduction in private income dominates the relative price effect. Higher interest rates raise the interest costs associated with net foreign assets. To compensate, MUSE must generate a depreciation of the dollar in the longer run to improve the trade balance and return net foreign assets to its target. The excess supply combined with the higher U.S. dollar has a negative impact on inflation (Chart 2, page 28).

An inflation shock

In this simulation, we look at the effects of higher inflation on the U.S. economy. The shock is relatively persistent, since inflation remains above the implicit target for about three years. This reflects the extent of the adjustment costs inherent in the inflation process. The Federal Reserve reacts quickly, but tightens policy by a relatively small amount. Two reasons explain this behaviour. The first is that more than half of the inflation shock dissipates after one quarter. The second explanation pertains to the Fed’s dual mandate: the interest rate tightening is limited by the fact that it generates a negative output gap, which by itself would necessitate a monetary easing. Yet, the Fed creates the excess supply that is required to bring inflation back to the implicit target (Chart 3, page 29).

A permanent shock to total factor productivity

In this scenario, we simulate the effects of an unexpected permanent increase in the level of total factor productivity. This increase raises potential output immediately. The adjustment costs related to the components of demand are such that, initially, demand does not react as fast as supply. Therefore, the shock creates a short-lived but nevertheless significant excess supply, which leads to a temporarily lower inflation rate. The Fed responds by reducing interest rates, which speeds up the adjustment of demand. Household spending is positively affected by the permanent increase in human wealth, while investment flows rise in order to reach firms’ equilibrium ratio of capital to output.

8. In all simulations, we assume that foreign output and foreign interest rates do not respond to shocks in the United States.

9. The control scenario refers to the variables’ profile in the absence of shocks.

Owing to the negative output gap, government transfers increase significantly in the short run. Government expenditures rise by the same amount as output in the long run, which restores the steady-state size of the government sector. Imports rise permanently, in line with the permanent increase in private domestic demand. The increase in imports in the longer run deteriorates net foreign assets such that, in order to bring net foreign assets back to its target, a permanent depreciation of the exchange rate is needed. This depreciation raises real exports in the steady state and dampens the increase in real imports (Chart 4, page 30). MUSE generates a completely different response in the context of an expected productivity shock. For instance, an increase in total factor productivity that is expected to occur two years from now is inflationary, not deflationary, since it initially creates excess demand: agents anticipate the shock to future income and increase demand immediately. In this case, the Fed raises rates and creates excess supply, which eventually brings inflation back to target.

Conclusions

Through an extensive application of PAC models, we have developed in MUSE what we believe to be a good balance between theoretical structure and forecasting accuracy. Importantly, MUSE can also be used for policy simulations. It can, for example, be used to examine issues ranging from how the U.S. economy might react to inflationary pressures to the consequences of sustained productivity gains. As a result, it is hoped that this model will result in a more enlightened perspective on current and future economic developments in the United States.

The NEUQ model is a useful complement to MUSE in the context of the international economic projection. Furthermore, given the high and rising real and financial linkages within the global economy, the BoC-GEM model will be key to examining economic issues from an international perspective. Taken together, these three models are valuable tools in the formulation of Canadian monetary policy

Chart 1

Results of a Demand Shock

The second variable is indicated by the dashed line.

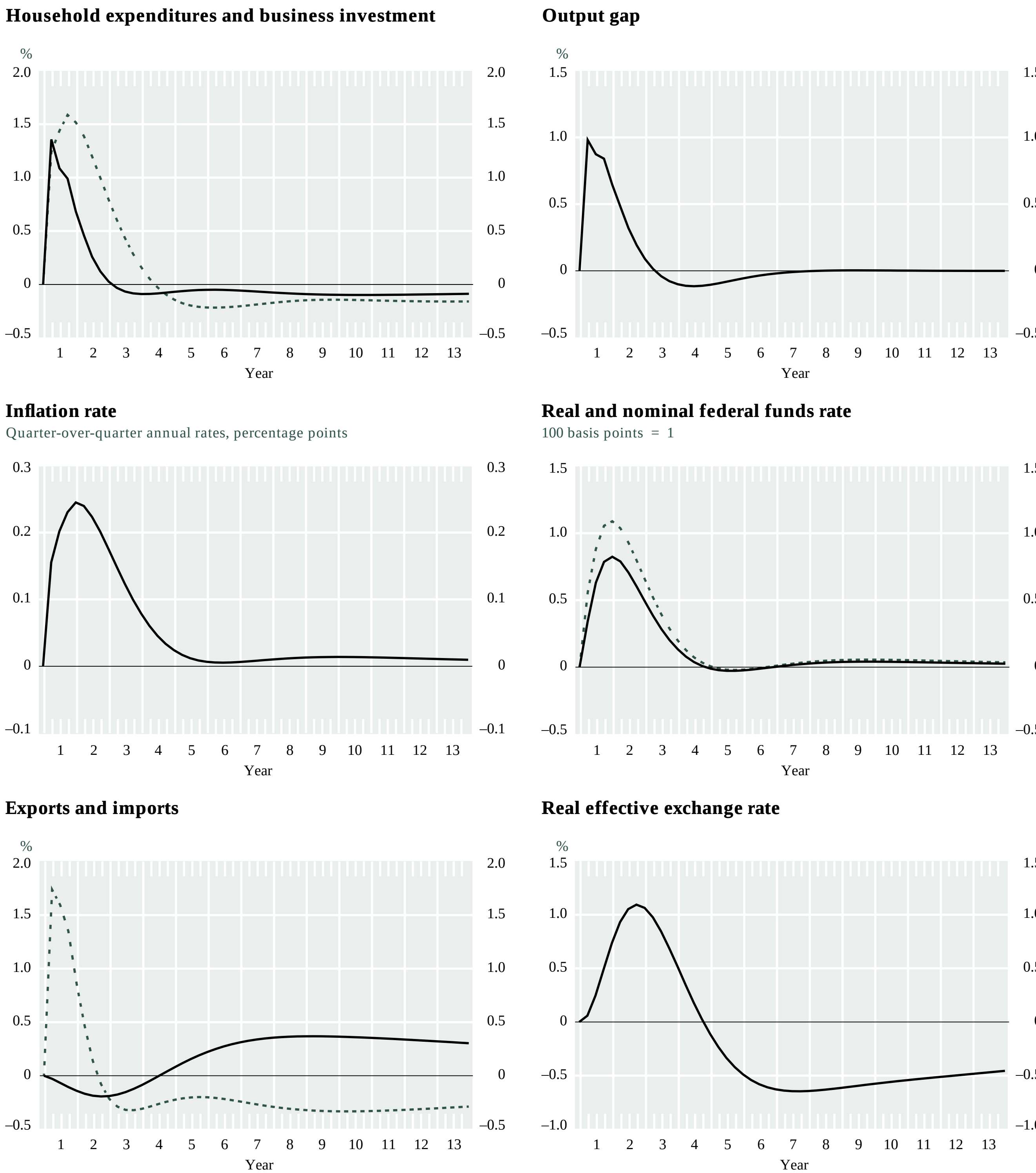


Chart 2

Results of a 100-Basis-Point Shock to the Federal Funds Rate

The second variable is indicated by the dashed line.

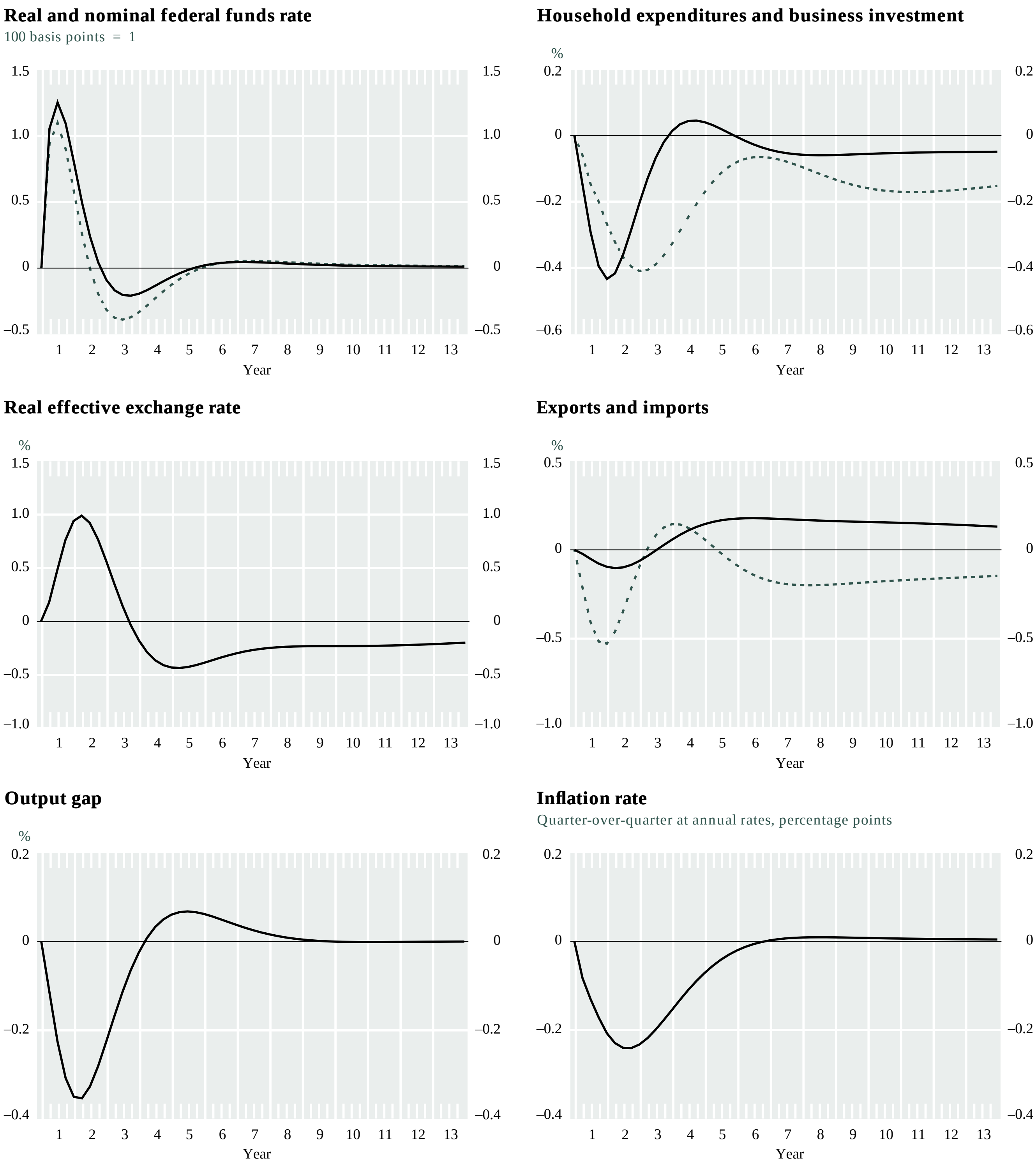


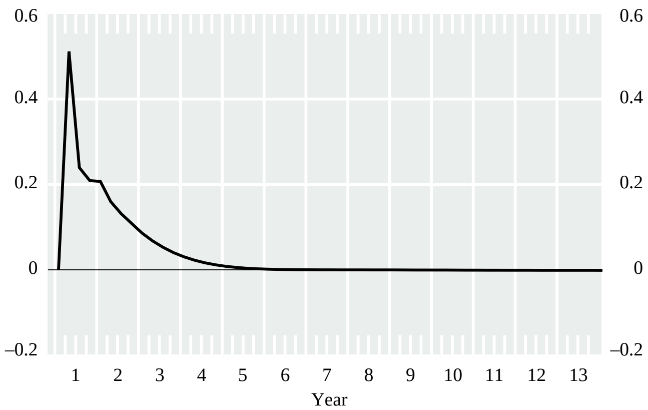
Chart 3

Results of an Inflation Shock

The second variable is indicated by the dashed line.

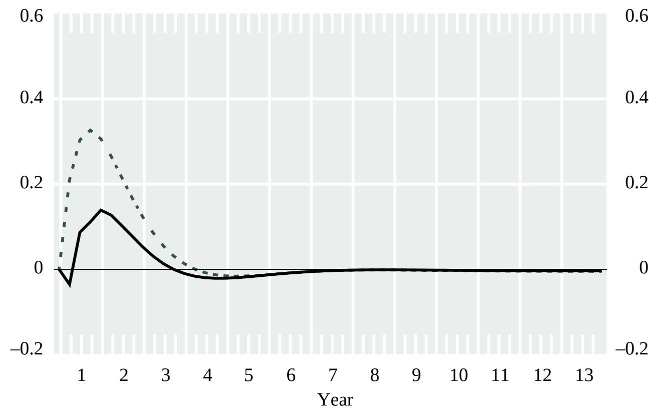
Inflation rate

Quarter-over-quarter at annual rates, percentage points

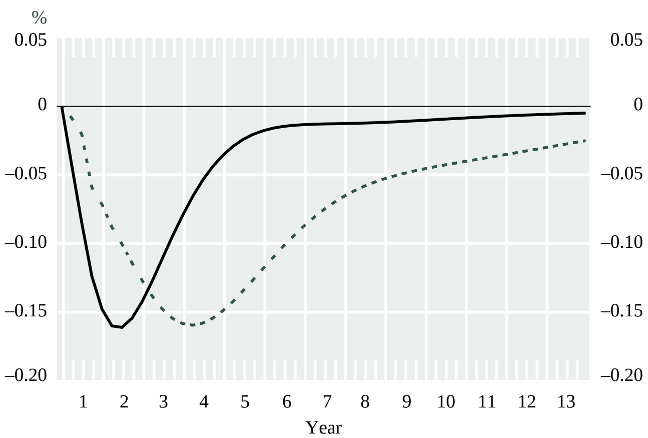


Real and nominal federal funds rate

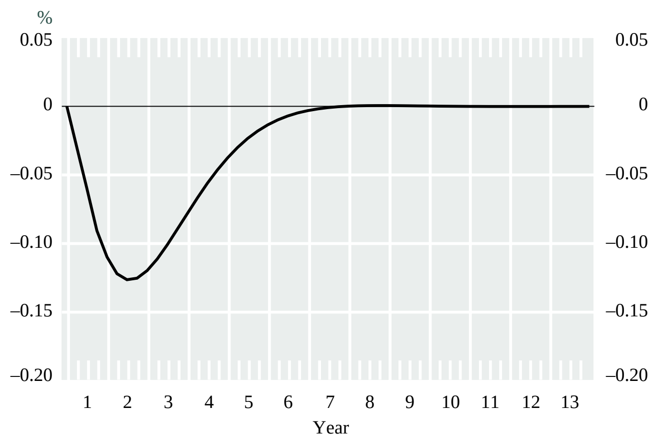
100 basis points = 1



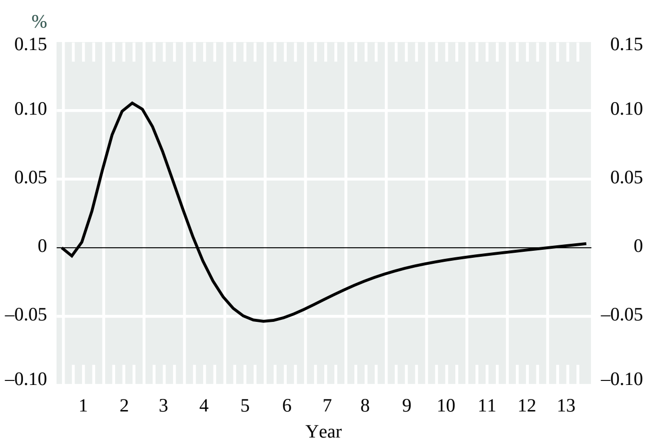
Household expenditures and business investment



Output gap



Real effective exchange rate



Exports and imports

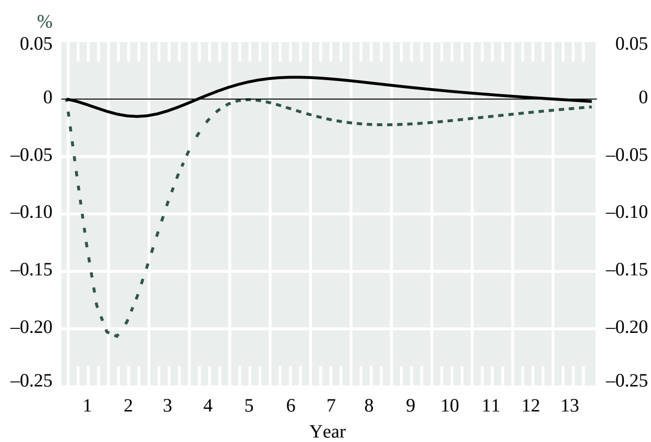
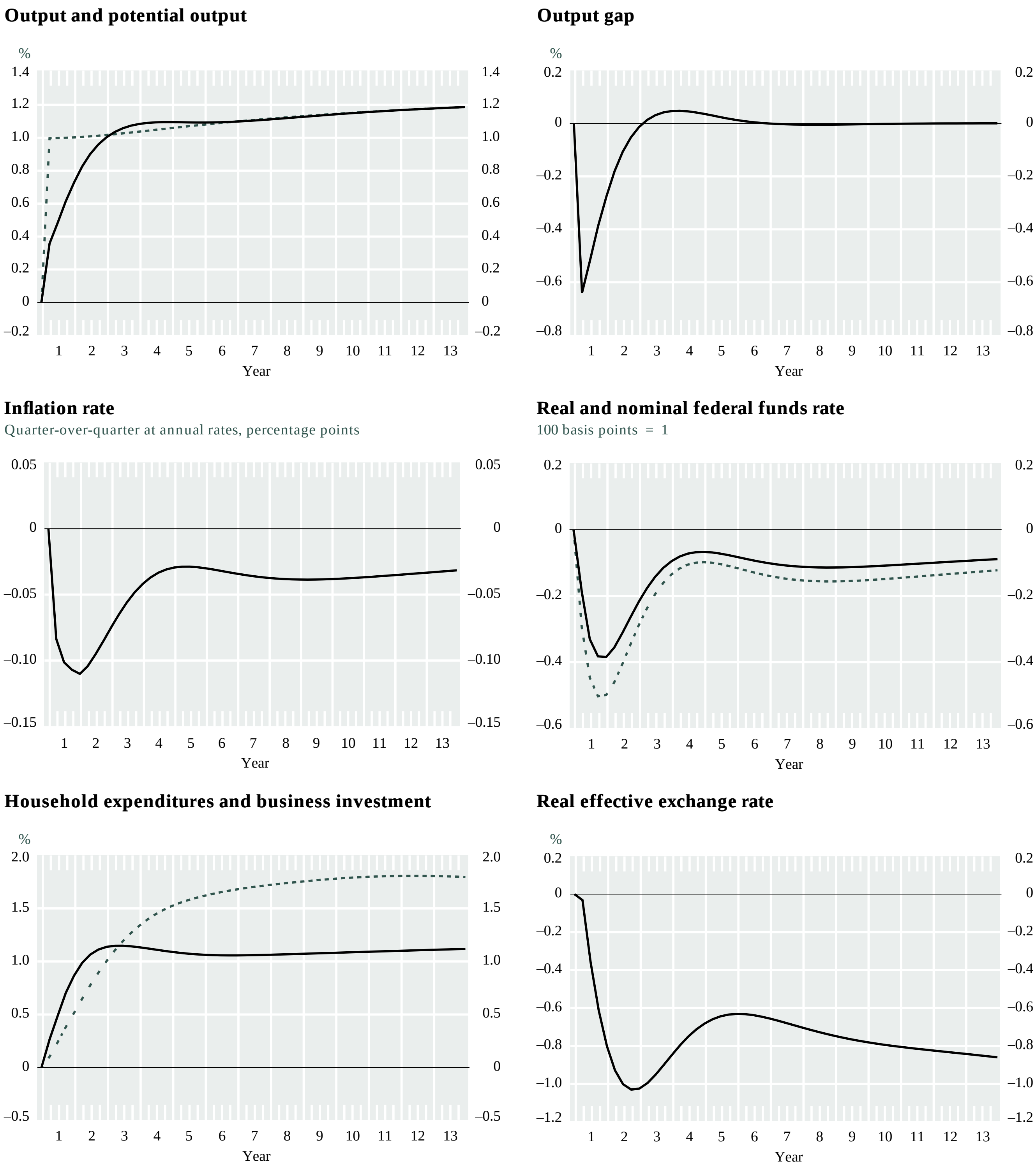


Chart 4

Results of a Permanent Shock to Total Factor Productivity

The second variable is indicated by the dashed line.



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Modelling Financial Channels for Monetary Policy Analysis

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- *The Bank of Canada's main projection model, like any other model, is a simplification of a complex reality and may not contain all the information that is relevant for policy-makers. While it may be desirable to keep the financial elements of the core projection model relatively simple, there is theoretical and empirical support for taking a broader range of financial variables into account. In the presence of financial frictions, financing costs will depend on the balance sheets of borrowers, resulting in a credit channel for the transmission of monetary policy.*
- *Models under development at the Bank include financial accelerators in which changes in borrowers' balance sheets play an important role in cyclical fluctuations by affecting borrowers' collateral and thus their ability to access external financing.*
- *These models are still at an early stage of development, but the results to date suggest that financial-accelerator mechanisms have the potential to improve policy advice and to help answer various policy questions.*

The Bank of Canada uses various strategies to deal with uncertainty regarding future developments in the Canadian economy. Most importantly, it considers a wide range of information and analysis before making a monetary policy decision and uses carefully articulated models to produce economic projections and to examine alternative scenarios (Jenkins and Longworth 2002). Central to the analysis presented to policy-makers at the Bank is the staff economic projection for Canada from the model ToTEM.[1] Although any model is a simplification of a complex reality and may not capture all the information that is relevant for policy-makers, the staff projection provides the reference point from which the implications of other sources of information are assessed. To analyze information not considered in ToTEM, staff at the Bank use other economic models to assess the implications of this projection for policy.[2]

This article describes an ongoing research agenda at the Bank to develop models in which financial variables play an active role in the transmission of monetary policy actions to economic activity. These models can help analyze information from the financial side of the economy and provide an overall view of the implications of financial developments for the current economic outlook. The article also explains how this research can help address other fundamental issues related to the objectives and conduct of monetary policy. One example is how asset-price movements should be taken into account in the monetary policy framework.

1. For a discussion of ToTEM, see Fenton and Murchison (2006) in this issue.
2. See Coletti and Murchison (2002).

Why Should We Be Interested in Financial Channels?

A primary purpose of the financial system is to allocate savings to the most productive investments. In many macroeconomic models, the financial system is represented by a single interest rate that equates saving and investment. While this abstraction is useful for some purposes, it is also restrictive. Borrowing and lending do not take place in perfect markets. Financial activities are complicated by *frictions* that arise from transactions costs, asymmetric information, and the limited enforceability of contracts. If information is asymmetric, information such as the quality and outcome of an investment project is known to the borrower, but lenders can obtain this information only by incurring a monitoring or verification cost. In addition, a financial contract requires considerable time and expense to enforce. In the event that a contract is broken, it is costly to reach a legal settlement. These frictions may make lenders more reluctant to lend. As a result, external funds may be more costly or less available than in a model without financial frictions.

Diverse financial arrangements have emerged to reduce the high costs of monitoring and enforcement faced by individual lenders and borrowers. To align the incentives of borrower and lender, these arrangements make the financial position of the borrower an important determinant of the cost of borrowing or the availability of funds.[3] As a result, balance-sheet effects play an important role in economic fluctuations, a role that is not present in more traditional macroeconomic models.

There is also empirical evidence that balance-sheet variables are important determinants of investment and consumption expenditures. For example, empirical studies using firm-level data have provided evidence that financial variables such as cash flow, leverage, and other balance-sheet factors influence investment spending (Fazzari, Hubbard, and Petersen 1988 and subsequent work).[4] As well, small firms, which are often believed to face greater financing constraints, account for a disproportionate share of the decline in manufacturing output and inventory demand after a change in monetary policy (Gertler and Gilchrist 1994).

In the presence of frictions in the financial system, financing costs will depend on the financial position of borrowers, giving rise to a credit channel for the transmission of monetary policy (Bernanke and Gertler 1995). This means that lower interest rates can increase real expenditures because they strengthen borrowers' balance sheets and lower their costs of borrowing. This feature of the economy is not captured by traditional models in which monetary policy affects aggregate demand and inflation only through the interest rate and exchange rate channels. Given the theoretical and empirical support for taking financial channels into account, policy-makers should be interested in models with more developed financial elements in order to better understand how their decisions will affect economic activity.

In the presence of frictions in the financial system, financing costs will depend on the financial position of borrowers, giving rise to a credit channel for the transmission of monetary policy.

In addition, the importance of these financial effects could be episodic and could depend on the state of the business cycle. Financial factors are particularly important in explaining some of the biggest economic downturns over the past 100 years. Bernanke (1983) argues that a breakdown in financial intermediation, i.e., the funnelling of savings to investment, turned the U.S. downturn of 1929–30 into the Great Depression. Fisher (1933) highlights how the falling price level drove up the real debt burden of borrowers during this period. As well, many commentators have blamed the protracted slump and deflation in Japan in the 1990s on the bursting of the real estate and stock market bubbles and the subsequent weakening of the financial position of the banking system. Moreover, the U.S. recession of the early 1990s generated much discussion about whether a credit crunch had been brought about by poorly capitalized banks. These problems may have been worsened in some regions by a sharp decline in commercial property prices. A better understanding of the financial factors at play in such episodes is important so that policy-makers can prevent their recurrence.

While policy-makers should be interested in financial channels, it may be a valid strategy to leave many of them out of the core projection model. For example,

3. For example, a lender may require collateral to back a loan to reduce the likelihood that the borrower will default.

4. See Ng and Schaller (1996); Chirinko and Schaller (2004); and Aivazian, Ge, and Qiu (2005) for studies that consider Canadian firms.

financial channels might play a bigger role in some periods than in others and may thus enter into monetary policy decisions on an irregular basis. If so, the gain from adding these channels may sometimes be outweighed by the cost of creating additional complexity in the model. Nonetheless, separate models with better-developed financial channels can complement the core model and reduce the risk of policy errors.

Contributing to Policy Analysis

Models with a richer financial sector can contribute significantly to the discussion on several policy issues that central banks currently face. One example is that, in recent years, housing prices have increased sharply in several countries while household spending has simultaneously been very strong. The higher housing values have made a large pool of home equity available to households, increasing their ability to borrow.[5] Tapping into this home equity through, for example, home-equity loans, has been an important channel of support to household spending in recent years. In Canada, the strong growth in home-equity lines of credit (HELOCs) has coincided with the increase in housing prices.[6] U.S. survey data suggest that about half of the home-financed borrowing was spent on goods and services, while Canadian household microdata indicate that between 20 per cent and 50 per cent of HELOCs are being used to finance current consumption.[7]Modelling a richer financial sector could help to quantify the contribution of these balance-sheet effects to household spending and housing-market activity.

Changes in the financial system may also have implications for the appropriate setting for the stance of monetary policy. Innovative financial instruments or lending practices may change the amount or type of debt on borrowers' balance sheets, with consequences for the transmission mechanism of monetary policy.[8] In this respect, financial factors are important for understanding how the economy is evolving and for assessing the likely impact of monetary policy actions.

In addition, richer links between financial and real developments are critical for analyzing some key questions related to the monetary policy framework. How a central bank should respond to asset prices depends on what role asset prices play in output and inflation fluctuations and how movements in these prices affect the functioning of the financial system (see the discussion below). Other important questions relate to the optimal level of inflation and the costs and benefits of inflation targeting versus price-level targeting. The prevalence of nominal debt contracts, both short and long term, together with bankruptcy laws that affect the costs of default, should be an important consideration in such analyses (see also Howitt 2005).

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Finally, models with well-articulated links between the financial sector and the real economy will not only be useful for monetary policy analysis, but also for analyzing questions related to financial stability, another topic of keen interest among central bankers. A good grasp of how the financial system works is crucial when considering the impact of a disruption to its normal functioning.

Modelling Financial Channels

The most popular models for capturing financial channels are referred to as *financial accelerators*. These are models in which there is an explicit link between the balance sheets of borrowers and their access to, or cost of, external financing.

One important strand of this research began with Bernanke and Gertler (1989). In this model, there are two key players: households, who are lenders, and business owners / entrepreneurs, who are borrowers. As well, there is asymmetric information between borrowers and lenders, since lenders can only observe the outcome of a borrower's investment project at a cost. Agency costs that arise from asymmetric infor-

5. Campbell and Cocco (2005) find evidence in U.K. microdata that is consistent with the argument that an increase in housing prices relaxes borrowing constraints.

6. Debt outstanding on personal lines of credit has grown at an average rate of 20 per cent per year since 1999, and about two-thirds of these credit lines are secured by home equity. Some of this growth likely reflects substitution for other forms of lending.

7. See Greenspan and Kennedy (2005) for U.S. circumstances.

8. Examples of such innovations include the use of credit scoring to make screening of loan applicants more efficient or the ability of financial institutions to securitize loans so that they can expand the sources of funds available to lenders. Innovations in the financial system tend to reduce frictions and could bring an economy closer to the one approximated in ToTEM.

mation can drive the price of uncollateralized funds above the cost of the firm's internally generated funds. In this setting, financial position is a key determinant of the credit conditions that a borrower faces. Specifically, the net worth of a firm affects the premium that must be paid for external sources of finance (funds that come from sources outside the firm). In aggregate, changes in the financial position of firms over the business cycle drive a countercyclical risk premium on debt that amplifies fluctuations in output and investment.

This chain of events is known as a financial-accelerator mechanism because there are feedback effects between the financial position of the borrowers and the terms of credit that can amplify business cycle fluctuations. For example, firm net worth deteriorates when a negative shock reduces cash flows and lowers the value of its capital assets. As a result of the deterioration in borrower balance sheets, the cost of finance rises, and this depresses investment. This leads to a further fall in the value of capital, which further reduces firm net worth, reinforcing the increase in financing costs and further depressing investment.

An alternative way of capturing the financial-accelerator mechanism is developed in the seminal work of Kiyotaki and Moore (1997). In this model, the financial friction is an enforcement problem; essentially borrowers can default and never repay. The financial contract that ensures repayment is one in which the quantity of loans available is restricted to some fraction of the value of the borrower's collateral. In this case, it is the quantity of external funds, rather than the cost, which is related to the state of borrower balance sheets.

Many studies argue that the financial-accelerator mechanism can amplify the effects of small shocks (Bernanke, Gertler, and Gilchrist 1999; Iacoviello 2005) or can make their effects on real variables more persistent (Carlstrom and Fuerst 1997). This suggests that financial accelerators could be important for developing more realistic business cycle dynamics in models for policy analysis.

A Starting Point for Model Development

Our strategy has been to start with the main building blocks of dynamic stochastic general-equilibrium (DSGE) models created for policy analysis at a number of central banks and develop financial elements within those models.

We introduce two financial accelerators, one that applies to households, and the other to firms, into a model that is otherwise fairly similar to ToTEM in terms of the real side of the model. For example, prices are sticky, allowing monetary policy to affect real variables in the short run. This strategy makes it possible to assess the implications of financial channels for risks to ToTEM's analysis.

Our strategy is to start with the main building blocks of DSGE models created for policy analysis . . . and to develop financial elements within those models.

Our work so far has followed that of Iacoviello (2005).[9] In the model there are households who lend funds to other households and to firm owners. The financial friction takes the form of a problem of enforcing repayment that leads lenders to require collateral. Households also buy and sell housing, giving rise to a housing market. Loan size is restricted to some fraction of the value of a borrower's real estate. This fraction can be interpreted as the loan-to-value ratio that features prominently in standard mortgages.

To illustrate some key features of the model, consider a shock to the economy that leads to a rise in housing prices. This increases the value of assets held by households and the amount they can post as collateral. Higher collateral values allow households to borrow more, and these resources can be used to purchase more housing and consumption. The accelerator effect is present here because these extra expenditures drive housing prices further up, reinforcing the rise in collateral values and access to debt. Firm owners also face a collateral constraint, but in their case, it also affects their ability to invest.

One interesting feature of this model is that balance sheets improve for all borrowers (households and firms) during an upswing in economic activity. This brings about widespread improvements in financing conditions that affect both households and firms at the same time, suggesting there will be a stronger impact

9. Our research is a work-in-progress, and here we provide some insights from the work we have done so far and from Iacoviello (2005).

on output, since both consumption and investment spending will be affected.[10]

Another interesting insight from this model is that the effects of the accelerator mechanisms on key macro variables depend on the nature of the shock. One key element of the model that generates these differential impacts is that debt contracts are written in nominal terms, as is the case in most real-world financing relationships. If inflation is unexpectedly low over the life of the loan, the debtor faces a cost of repayment that is higher in real terms than was anticipated.[11] Unexpected price declines reduce debtors' net worth and, as a result, their capacity to borrow. The higher real cost of debt repayment shifts funds from borrowers, who have a high marginal propensity to consume, to lenders (savers) who have a low propensity to consume. The result is a reduction in aggregate demand. The financial mechanisms in the model will therefore amplify demand shocks, but dampen supply shocks. A positive demand shock will raise output and inflation, and the increase in inflation (albeit temporary under inflation targeting) will reduce the real cost of debt service, reinforcing the borrower's ability to obtain financing beyond what is available through the standard accelerator mechanism. After a supply shock that raises output and lowers inflation, the real cost of debt repayment rises, reducing borrower net worth and dampening part of the rise in output.

In order to better understand these financial-accelerator mechanisms, two Bank of Canada working papers (Christensen and Dib 2006; Gammoudi and Mendes, forthcoming) consider the impact of the business and household accelerators in isolation. Christensen and Dib (2006) estimate a model very similar to that of Bernanke, Gertler, and Gilchrist (1999) in which firms must borrow to purchase capital and pay a premium on external funds. Their results suggest that this mechanism can help to capture the co-movement in output, inflation, and investment. They also show that the financial accelerator amplifies investment fluctuations, but may dampen consumption movements. This dampening may happen, for example, because households (the ultimate source of funds) will reduce consumption and save more to take advantage of temporarily higher investment returns and the lower risk associated with loans to firms. For some types of shocks this means that the financial-accelerator mechanism has had little impact on output or inflation—the variables of ultimate interest to policy-makers. Gammoudi and Mendes (forthcoming) develop a model with lending and borrowing households. Borrowing households in this model face a collateral constraint based on the work of Iacoviello (2005). One key finding is that the model is better able to capture the correlation between housing prices and consumption than a model without the borrowing constraint. In both of these studies, financial accelerators play an important role in capturing the co-movement in key variables of interest. Results from the integrated model under development suggest that including financial accelerators in both the business and household sectors can lead to a stronger impact on output, under certain types of shocks, than when financial accelerators are restricted to operating in only one sector, as in the two studies discussed here.

The impact of the financial-accelerator mechanisms . . . will depend on the nature of the shock, showing that such a model could provide a useful alternative interpretation of recent data.

Research to date suggests that financial-accelerator mechanisms have the potential to provide useful insights for policy deliberations. The impact of these mechanisms on key macroeconomic variables can be important and will depend on the nature of the shock hitting the economy. This suggests that these models may provide a better-informed view of what economic forces have been at play over history. In the policy arena, such a model could provide a useful alternative interpretation of recent data and could guide policy decisions about how economic events will unfold over the forecast horizon.

Towards a More Complete Analysis of Financial Channels

The quantitative importance of financial frictions is still the subject of much debate. Some have argued that the financial mechanisms in the models described

10. The net impact will depend on the behaviour of those who supply the savings in this model economy. For example, it is likely that a positive shock that is expected to be temporary will induce savers to lend more in the short term.

11. This is the mechanism highlighted in Fisher's (1933) famous paper on debt and deflation.

above are unlikely to play a significant role in business cycle fluctuations. Kocherlakota (2000) and Cordoba and Ripoll (2004), for example, find that the amplification of shocks produced by borrowing constraints may be important only under relatively restrictive assumptions. Chari, Kehoe, and McGrattan (2006) argue that how financial frictions are modelled is critical to a model's usefulness in explaining business cycle fluctuations. The issues these authors raise suggest that there is fertile ground for future research in this area, particularly in exploring the role these mechanisms play in different types of models and in assessing their ability to capture key features of macroeconomic data.

There is also a need to flesh out the mechanisms at play in financial-accelerator models to better reflect the characteristics of real world financial markets. In the work described above, there is no formal distinction between financial institutions and financial markets. This distinction could well be important, however, since bank balance-sheet conditions can influence the ability of borrowers to access credit. As well, the effects of the financial accelerator could be altered if firms are able to access alternative sources of financing, such as bonds and equity. Below, we discuss some areas for additional research.

Bank capital channel

The models discussed above abstract completely from the role of bank capital (i.e., bank net worth and bank equity) in the monetary policy transmission mechanism. This omission is particularly unfortunate given the strong empirical evidence in support of the role of banks' financial structure in lending decisions and their importance for macroeconomic stability (Peek and Rosengren 1995, 1997). Researchers at the Bank of Canada and elsewhere have studied the importance of bank capital for the amplification and propagation of shocks. This work presents another financial-accelerator mechanism where the endogenous evolution of bank capital and its interplay with entrepreneur net worth (and asset prices) propagate the effects of monetary policy to the real economy.

Meh and Moran (2004) and Sunirand (2002) develop dynamic general-equilibrium models that study the link between the evolution of bank capital and entrepreneur net worth on the one hand, and monetary policy and economic activity on the other. These models feature two sources of asymmetric information. The first comes from the relationship between banks and their borrowers (firms), where firms can choose to undertake riskier projects or not to report truthfully their production in order to enjoy unobservable private benefits. To mitigate this problem, banks require entrepreneurs to invest their own net worth in the projects. This channel, where the ability of firms to borrow depends on their financial position, has been emphasized by most financial-accelerator models, as discussed above (see Bernanke, Gertler, and Gilchrist 1999). The second source comes from the relationship between banks and their own source of funds (depositors or investors) where banks, to which depositors delegate the monitoring of firms, may not do an adequate job because monitoring is costly. In response, investors demand that banks invest their own net worth—bank capital—in the financing of projects. Thus, the available funds that banks can attract from investors to lend to firms are limited by the amount of bank capital.

Multiple sources of external finance

In all the models discussed so far, it is assumed, for simplicity, that only a single source of external funds—debt financing—is available to firms or banks. In practice, most firms raise external funds from multiple sources, such as marketable debt, bank loans, or equity.

Using data on U.S. firms from the Compustat data set, Covas and den Haan (forthcoming) find that debt and equity issuances are procyclical for most firms. They then construct a DSGE model where firms can have access to two sources of external financing for investment: debt financing and equity financing. In such a model, the net worth of the firm is not only increased through retained earnings (as assumed in the previous models) but also by issuing equity. Another important feature of the model is its heterogeneity in terms of firm size, where small firms are much more likely to rely on equity financing while large firms tend to use more debt financing. A calibrated version of their model shows that the presence of equity financing substantially contributes to the performance of financial-accelerator models. More specifically, after a positive productivity shock, output increases more in the model with debt and equity financing than in the model with only debt financing.

Similarly, Jermann and Quadrini (2006) consider a model in which firms finance production with both debt and equity. In addition, business cycle fluctuations are driven by asset-price shocks that are propagated to the real economy through financial frictions. They show that financial innovations that improve the ability to borrow and issue equity allow firms to adjust more easily to an asset-price shock. The greater flexibility in financing arrangements leads to greater volatility in the financial structure of firms, but also lowers the volatility of output in response to shocks to asset prices.

Determination of asset prices

An important characteristic in models with financial frictions (like the one described on pp. 34–35) is that movements in asset prices affect the ability of firms or households to borrow. So the model is a natural laboratory to address key policy questions, such as how monetary policy should react to asset-price shocks. To address such questions, it is important to have a model that links asset-price movements to the real economy and inflation.

Bank researchers Basant-Roi and Mendes (forthcoming) develop a model in which households face an external financing premium similar to that in Bernanke, Gertler, and Gilchrist (1999). The authors use this model to analyze how the financial accelerator interacts with a housing-price bubble (defined as a sustained and growing deviation of housing prices from their fundamental levels) to affect the optimal horizon over which monetary authorities should bring inflation back to target. They find that a housing-price bubble lengthens the optimal horizon appreciably.[12] In their work, and in many other models, bubbles are exogenous and are therefore unaffected by monetary policy actions. A challenge for future work is to develop quantitative models in which large changes in asset prices are endogenous to developments elsewhere in the economy. Researchers at the Bank of Canada and elsewhere have started such work (Caballero and Krishnamurthy 2006; Ríos-Rull and Sánchez-Marcos 2006; and Tomura, forthcoming).

12. For a summary of this and related work, see Coletti, Selody, and Wilkins (2006).

Conclusions

In this article, we present a research agenda on developing models of financial channels for monetary policy analysis at the Bank of Canada and discuss the progress we have made so far. This research is particularly relevant given recent financial developments and substantial fluctuations in asset prices. Current progress in DSGE modelling and research on financial frictions suggests that this line of research could lead to a better understanding of the role of credit and financial variables in the monetary policy transmission mechanism. Many challenges remain, however, in modelling the financial and real linkages, and various ways to improve the current research are being considered. The progress we have made to date suggests that these models should improve policy advice and are capable of helping to answer different policy questions. This is important for policy-makers, because “looking at the economy through a variety of lenses leads to more comprehensive rigorous analyses” (Macklem 2002).

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A New Effective Exchange Rate Index for the Canadian Dollar

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- *A new Canadian-dollar effective exchange rate index (CERI) has been created to replace the C–6 index that the Bank currently uses. The CERI uses multilateral trade weights published by the International Monetary Fund and includes the six currencies of countries or economic zones with the largest share of Canada's international trade.*
- *The multilateral trade weights used to calculate the CERI account for both direct and third-market competition, thus giving a more comprehensive picture of Canada's trade competitiveness than the bilateral weights used in the existing C–6 index.*
- *This new index better reflects the recent changes in Canada's trade profile, including the rise in the importance of China and Mexico and the relative decline in importance of Europe and Japan in Canada's international trade.*
- *Given the substantial weight assigned to the U.S. dollar in each index, the CERI and the existing C–6 track each other closely. However, the sub-indexes created when the U.S. dollar is excluded from both indexes show significantly different paths for the Canadian dollar.*

An effective exchange rate is a measure of the value of a country's currency vis-à-vis the currencies of its most important trading partners. It is calculated by taking a weighted average of the relevant bilateral exchange rates of the country in question. These weights typically represent the relative importance of a foreign country to the home country's international trade. An index of this effective exchange rate is used by the Bank of Canada to summarize exchange rate developments in order to assess current and future economic developments. The purpose of this article is to describe the Bank's new Canadian-dollar effective exchange rate index (CERI), which was created to replace its current trade-weighted index.

The Bank has been using the C–6 index and its predecessor, the G–10 index, since the early 1980s. The C–6 index tracks the foreign exchange value of the Canadian dollar against six major currencies (the U.S. dollar, the euro, the Japanese yen, the U.K. pound, the Swiss franc, and the Swedish krona).[1] The weightings used to calculate the values of the C–6 are based on Canadian merchandise trade flows over the 1994 to 1996 period. Apart from a revision to the currency basket to reflect the introduction of the euro in 1999, the currency composition and weights used in the computation of the C–6 index have not been reviewed since 1999.

1. For the period before 1999, the index includes the currencies of Belgium, France, Germany, Italy, and the Netherlands, which are now part of the euro zone.

Trade patterns worldwide and in Canada have changed appreciably over the past decade. According to a recent survey of global trade patterns by the International Monetary Fund (IMF), the United States, Mexico, and developing Asia (particularly China) have all seen their relative share of Canada's international trade increase, while the shares of both the euro zone and Japan have declined (Bayoumi, Lee, and Jayanthi 2005).

The C–6 will no longer be published on the Bank's website or in external publications after 31 December 2006.

To better reflect these changes in Canada's trade profile, the Bank of Canada has replaced the C–6 index with an effective exchange rate index composed of an updated group of currencies and associated weights based on the most recent IMF statistics. The C–6 will no longer be published on the Bank's website or in external publications after 31 December 2006.

The New Index

Designed to be a summary measure of the Canadian dollar's movements against the currencies of its important trading partners, the CERI updates the weights and composition of the currency basket based on IMF-calculated trade weights.[2] The weights used to calculate the index from 1996 to the present are based on trade data for 184 countries over the 1999–2001 period and encompass trade in non-energy commodities, manufactured goods, and services (e.g., tourism).[3] Before 1996, the weights are based on trade data over the 1989–91 period.

2. For more details on the IMF methodology to calculate the weights, see Bayoumi, Lee, and Jayanthi (2005).

3. See the Appendix for the formula used to calculate the index.

Inclusion in the new index is limited to the currencies of countries that have IMF-calculated trade weights of 2 per cent or higher.

The weights also account for the geographical distribution of trade (import, bilateral export, and third-market competition) in determining the significance of a particular country to Canada's international trade.[4] This is important because domestic firms compete with foreign firms in three locations: 1) at home, through imports; 2) in foreign markets with local firms; and 3) with other exporters in foreign markets. Ideally, all three locations of competition should be captured in the calculation of trade weights between a country and the rest of the world. Given the breadth and depth of the IMF's methodology, the IMF weights provide a more accurate ranking of the importance of different countries to Canada's international trade than do the weights in the C–6, which are calculated using simple bilateral merchandise-trade data.

Inclusion in the new index is limited to the currencies of countries that have IMF-calculated trade weights of 2 per cent or higher. Of the 184 countries surveyed by the IMF, five countries plus the euro zone satisfy this criterion.[5] The United States, with the highest weight, is Canada's most important trading partner by a very large margin. The euro zone and Japan rank second and third, respectively. China, Mexico, and the United Kingdom complete the six countries included in the index (Table 1).[6]

4. Third-market weights measure the intensity of competition between two countries (domestic and foreign) outside their respective local markets by multiplying the foreign country's share of total supply in each third market by the relative importance of the third markets as destinations for the domestic country's exports. For details on how the weights are computed, see Bayoumi, Lee, and Jayanthi (2005).

5. The IMF treated the euro zone as a single entity with a single exchange rate.

6. With a trade weight of around 1 per cent, China did not make the cut-off of 2 per cent for the 1989-91 period. During that time, Canada traded (or competed) more with South Korea than with the People's Republic of China.

Table 1

CERI and C–6 Currency Weightings

Currencies[a]	CERI		C–6 index
	Weights used 1996–present[b]	Weights used 1981–95[b]	Weights used 1980–present
U.S. dollar	0.7618	0.5886	0.8584
Euro	0.0931	0.1943	0.0594
Japanese yen	0.0527	0.1279	0.0527
Chinese yuan	0.0329	–	–
Mexican peso	0.0324	0.0217	–
British pound	0.0271	0.0368	0.0217
South Korean won	–	0.0307	–
Swiss franc	–	–	0.0043
Swedish krona	–	–	0.0035

a) We used the Bank of England proxy for the euro for the period before January 1999. Some of the exchange rates were from Bloomberg.
b) The IMF weights were rescaled to sum to unity.

The composition of the index captures a significant share (86 per cent) of Canada's international trade volume and better reflects Canada's trade profile than the C–6, which excludes Mexico and China (South Korea in the earlier period), and should therefore provide a better indication of the current and future impact of exchange rate movements on the real economy. As newer IMF trade weights are published, the index weights and currency composition will be adjusted as required. Historically, the IMF has updated the index weights every 10 years.

The composition of the index captures a significant share (86 per cent) of Canada's international trade volume.

The CERI and the C–6 Compared

The CERI offers several advantages over the current C–6 index, particularly the use of multilateral trade weights, the inclusion of trade in services, and the use of more recent trade data. These improvements provide a more accurate reflection of the nature of Canada's international trade patterns. Table 2 summarizes the key differences between the two indexes.

Table 2

Summary Comparison of the CERI and the C–6

Points of comparison	CERI	C–6 index
Currency-weight calculations	Multilateral	Bilateral
Dates used for reference and for updating	1989–91 weights used for the period 1981–95; 1999–2001 weights used for 1996 to the present	1994–96 weights used for the entire period; updated every 10 years
Percentage of Canada's international trade captured*	86%	81%
Trade included	Goods, services, non-energy commodities	Merchandise trade

* Based on average total trade over the 1999–2001 period

Because both indexes place a very high weight on the U.S. dollar, the CERI and the C–6 have tracked each other relatively closely over time.

Because both indexes place a very high weight on the U.S. dollar, the CERI and the C–6 have tracked each other relatively closely over time (Chart 1).[7] There is, however, a noticeable discrepancy between them over the period 1981 to 1986. During that time, the C–6 depreciated by 13 per cent, while the CERI first appreciated by almost 10 per cent before depreciating sharply, for an overall fall of about 7 per cent.

Some of the discrepancy experienced between 1981 and 1986 can be attributed to the Canadian dollar's significant appreciation (3,000 per cent) against the Mexican peso and, to a lesser degree, the South Korean won (10 per cent), which offset in part the Canadian dollar's 13 per cent depreciation against the U.S. dollar. For the same period, the Canadian dollar also fell by 10 per cent against the euro and 36 per cent against the Japanese yen. The result of the deprecia-

7. An increase in the indexes represents an effective appreciation of the Canadian dollar against the currencies in the basket.

tion against these currencies can be seen mostly in the C–6, which does not include the Mexican peso and the South Korean won to counter the effect.

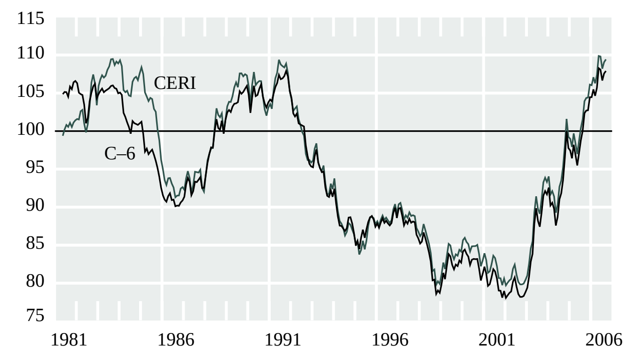
From 1987 onward, the CERI and the C–6 have tracked each other very tightly. The two indexes appreciated by around 18 per cent from 1987 to August 2006 (Chart 1). One reason for the very close relationship is the increase in the weight of the U.S. dollar in the CERI. Beginning in 1996, this weight increased from 0.5886 to 0.7618, which is much closer to the weight in the C–6 of 0.8584. Because of the high weight on the U.S. dollar in both indexes in the recent period, both series are essentially reflecting the Canadian dollar's appreciation against the U.S. dollar for that period.

Chart 1

The CERI and the C–6

Monthly

1992 = 100



If the indexes are expressed in real terms, using the consumer price indexes (CPI) of the various countries, from 1981 to 1986 both the CERI and the C–6 were down by only 3.5 per cent (Chart 2).[8] From 1986 to 1988, the real C–6 rose by 15 per cent, while the real CERI was up by 6 per cent. Since then, the two indexes have tracked each other quite closely.

If the U.S. dollar is removed from the indexes, the difference between them becomes more noticeable (Chart 3). The CERI excluding the U.S. dollar appreciated by 10.5 per cent from 1981 to 1986. However, the C–5 (i.e., the C–6 excluding the U.S. dollar) showed a depreciation of 15 per cent over the same period. The CERI excluding the U.S. dollar increased in value by about 22 per cent from 1987 onward, while the C–5 has returned to about its January 1987 level. The reason for the latter difference is that the CERI captures the significant appreciation of the Canadian dollar against both the Mexican peso and the Chinese yuan for the later period, while the C–5 did not. The C–5 reflects the sideways movement of the Canadian dollar against the yen and the euro.

Chart 2

The Real CERI and the Real C–6

Monthly

1992 = 100

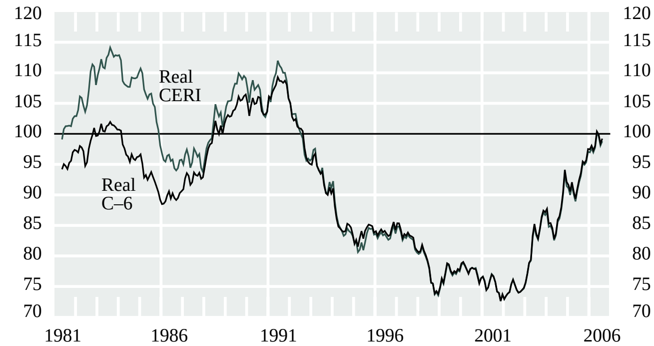
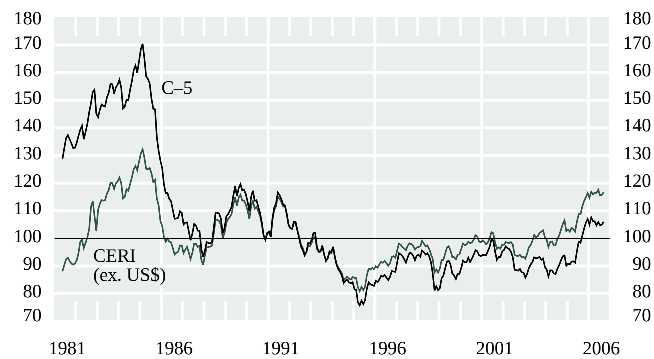


Chart 3

The CERI (excluding US$) and the C–5

Monthly

1992 = 100



8. The data end in June 2006 because there is a lag in computing the real effective exchange rate, based on when some of the countries report their CPI.

From 1981 to 1986, however, the real CERI excluding the U.S. dollar declined by only 3 per cent, while the C–5 depreciated by 8 per cent (Chart 4). Over that period, for the real CERI excluding the U.S. dollar, the Canadian dollar's real appreciation against the Mexican peso and the South Korean won partially offset its real depreciation against the yen and the euro.

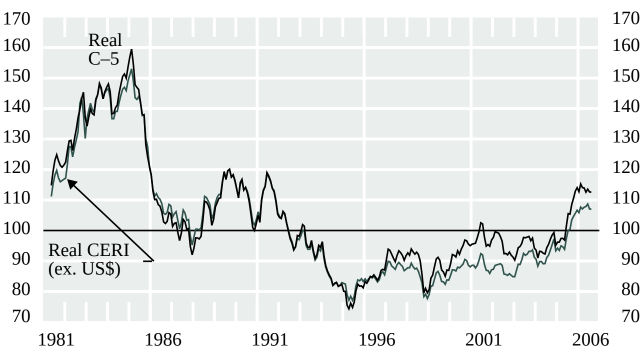
When the U.S. dollar is removed, the real CERI excluding the U. S. dollar is up by only 2.5 per cent since 1987, while the real C–5 is up 11 per cent (Chart 4). This is partly owing to the Canadian dollar's 30 per cent real depreciation against the Mexican peso from 1987 to 2006, and the 33 per cent real depreciation against the South Korean won from 1987 to 1995. As well, the CERI excludes the Canadian dollar's 30 per cent real appreciation against the Swedish krona and the 10 per cent real appreciation against the Swiss franc from 1987.

Chart 4

The Real CERI (excluding US$) and the Real C–5

Monthly

1992 = 100



Conclusion

The Bank of Canada has created the CERI, an updated index reflecting recent changes in Canada's trade profile, to replace the C–6. The weights for the new index were derived using more recent trade data and a more comprehensive methodology than the one used in calculating the weights for the C–6. The IMF weights factor in both direct and third-market competition, while the C–6 used only bilateral trade data and uses 1999–2001 trade data compared with the 1994–1996 trade data used in the C–6.

Although the changes in the methodology translate into only small changes in the profile of the Canadian-dollar trade-weighted index when the United States is included, the profile is quite different when the United States is excluded, given its large weight in both indexes. The difference in the nominal indexes occurs primarily over the 1981 to 1986 period and is largely owing to divergences in the inflation patterns across countries.

The Bank will continue to refine its trade-weighted index as necessary. Specifically, it will periodically examine the methodology used in computing weights for the CERI. As well, corresponding real effective exchange rates using monthly unit labour costs may be constructed as data for China become available.[9]

9. China does not report unit labour costs.

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Appendix

The formula for the CERI is

$$I_t = I_{t-1} \times \prod_{j=1}^{N(t)} (e_{j,t}/e_{j,t-1})^{w_{j,t}}$$

where I_{t-1} is the index in the previous period and $e_{j,t}$ and $e_{j,t-1}$ are the prices of foreign currency j per Canadian dollar at times t and $t-1$. $N(t)$ is the number of foreign currencies in the index at time t, $w_{j,t}$ is the weight of currency j in the index at time t, and $\Sigma_j w_{j,t} = 1$. This is the same formula used by the Federal Reserve Bank to construct their U.S. dollar trade-weighted index (Leahy 1998).

A real CERI can be constructed by changing the nominal exchange rate to a real rate, using the formula $e_{j,t} \times P_t / P_{j,t}$, where P_t is the price deflator for Canada and $P_{j,t}$ is the price deflator for country j. The real CERI presented in this article is constructed using the CPI as the price deflator for Canada and the other countries in the basket.[1]

1. Based on a study by Lafrance, Osakwe, and St-Amant (1998), unit labour costs (ULC) explain movements in Canadian net exports and real output significantly better than those based on consumer price indexes. However, since there are limitations with respect to the availability and quality of ULC measures for emerging markets, the CPI can be used as a proxy because it appears to be highly correlated to ULC.

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