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# The MSG Model of the Canadian Economy

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The findings of this paper are the sole responsibility of the author. This document will not be translated.

# Contents

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## Abstract

This paper presents the specification and simulation properties of the MSG model of the Canadian economy. The model is embedded into the MSG multi-country model, and a number of policy changes and shocks are considered. The paper considers the impact of changes in Canadian monetary and fiscal policies and draws a distinction between the short-run and long-run effects of these policies. A distinction is also made between temporary, permanent, anticipated, and unanticipated policy changes. In addition, the paper considers the impact on Canada of a fiscal expansion and a monetary expansion in the United States, as well as the effects on Canada of a permanent fall in the world supply of oil and a rise in productivity in Canada. The latter shock could be interpreted as one aspect of the free-trade agreement with the United States.

Finally, a baseline projection of the model is presented which replicates the 1987 database and then projects from 1988 to 2066 under explicit assumptions about the stance of monetary and fiscal policies in Canada and the other major economies. The simulation results are then used with the baseline to evaluate the performance of the model in understanding the Canadian experience since 1987.

## Introduction

This paper presents the structure and simulation properties of the MSG model of the Canadian economy.

The key features of this model are:

- Both the demand and supply side of the Canadian economy are explicitly modelled.

- Demand equations are based on a combination of intertemporal optimizing behaviour and liquidity constrained behaviour.

- The supply side takes explicit account of imported intermediate goods, especially the role of imported capital goods in the Canadian economy.

- Major flows such as physical investment, fiscal deficits, and current account imbalances cumulate into stocks of capital, government debt, and net external debt, which in turn change the composition and level of national wealth over time.

- Wealth adjustment determines stock equilibrium in the long run but also feeds back into short-run economic conditions through forward-looking share markets, bond markets, and foreign exchange markets.

- The Canadian asset markets are linked globally through the high international mobility of capital.

Section 2 (p. 2) gives an overview of the modelling strategy followed in building the Canadian model, while section 3 (p. 3) presents its basic structure. A detailed listing of model equations and parameters is found in *The MSG Multi-Country Model: Canadian Version; A Users Manual.* Section 4 (p. 16) presents a number of simulation results. The paper considers the impact of changes in Canadian monetary and fiscal policies, distinguishing between the short- and long-run effects of these policies. A distinction is also made between temporary, permanent, anticipated, and unanticipated policy changes. In addition, the paper considers the impact on Canada of a fiscal and a monetary contraction in the United States. Finally, the paper considers a permanent fall in the world supply of oil and a rise in productivity in Canada. The latter shock could be considered as one important aspect of the free-trade agreement with the United States. In section 5 (p. 35), the model is used to generate a baseline for the Canadian economy from 1987 to 2066. This baseline and the simulation results are used to interpret the main features of Canadian macroeconomic experience since 1987 as a means of evaluating the relevance of the model for Canada. A conclusion and suggestions for future research are presented in section 6 (p. 45).

## An Overview of the Modelling Approach

The Canadian version of the model follows the model developed in McKibbin and Sachs [1991]. The reader is referred to this publication for greater detail on the approach followed in this paper as well as an overview of the history of the model. It also contains an analysis of the properties of earlier versions of other country models built into the multi-country framework.

The model developed here is based more firmly on micro-foundations than the standard macroeconometric model. The approach starts with the assumption that economic agents maximize intertemporal objective functions. This idea is very similar to the class of models known as Computable General Equilibrium (CGE) models[1] except that the concepts of time and dynamics are of fundamental importance in the MSG2 model. The various rigidities that are apparent in macroeconomic data are taken into account by allowing for deviations from the fully optimizing behaviour. As with any modelling project that purports to describe reality, some trade-offs between theoretical rigour and empirical regularities are inevitable. The deviations from the intertemporal optimizing behaviour take the form of *rules of thumb* which are consistent with an optimizing agent that does not update predictions based on new information about future events. These *rules of thumb* are chosen to generate an equivalent steady state to the optimizing behaviour. Actual behaviour is assumed to be a weighted average of the optimizing and rule of thumb assumption. For example, aggregate consumption is a weighted average of consumption based on wealth and consumption, which in turn is based on current disposable income.

The MSG2 model can be described as a dynamic general equilibrium model of a multi-region world economy. In this paper, the regions modelled consist of the United States, Japan, Germany, the Rest of the EMS (REMS),[2] Canada, the Rest of the OECD (ROECD),[3] non-oil developing countries (LDCs),[4] oil exporting countries (OPEC),[5] and Eastern European economies, including the Commonwealth of Independent States.[6] The model is of moderate size (about three dozen behavioural equations per industrial region). It is distinctive relative to most other global models in that it solves for a full intertemporal equilibrium in which agents have rational expectations of future variables. Fiscal and monetary policies are examined in an intertemporal perfect-foresight environment, with considerable attention given to intertemporal optimization and intertemporal budget constraints. The model has a mix of Keynesian and classical properties by virtue of a maintained assumption of slow adjustment of nominal wages in the labour markets of the United States, Germany, the REMS, and the ROECD (Japan is treated somewhat differently, as described later). Both the German and REMS regions are also assumed to experience long periods of "hysteresis" when unemployment emerges.

The model is solved in a linearized form, to facilitate policy optimization exercises with the model, and especially to use linear-quadratic dynamic game theory and dynamic programming solution techniques.[7] The global stability of the linearized model can be readily confirmed by an analysis of the model's eigenvalues.

In fitting the model to macroeconomic data, we adopt a mix of standard CGE calibration techniques and econometric time-series estimates. In CGE models, the parameters of production and consumption decisions are determined by assuming a particular functional form for utility functions and production functions, and by assuming that *ex post* data from an expenditure share matrix or an input-output table represent an equilibrium of the model. For example, if utility is assumed to be a Cobb-Douglas nesting of the consumption of different goods, then the parameters of the utility function – and therefore the demand functions for different goods – are given by the expenditure shares found in actual historical data. The demand function for each good in the system will have price and income elasticities of unity. In most cases the data will determine the parameters of the model, although in some cases additional econometric analysis is required. Issues involved in calibrating the model will be discussed later.

The complete equation listing for the MSG2 model is presented in Appendix A of the User Manual. In this section the theoretical basis of these equations is outlined.

Each of the regions in the model produces a good which is an imperfect substitute in the production and spending decisions of the other regions. Each industrialized region is assumed to produce one final good which is used for investment and consumption purposes in that region and in all of the other regions. The LDC and OPEC regions each produce one good which is a primary input in the production processes of the industrial regions. Demands for the outputs of the LDC and OPEC regions are therefore derived demands for the production inputs.

In the version of MSG into which the Canadian model has been included for this paper, only the six industrial country regions are fully modelled with an internal macroeconomic structure. In the LDC and OPEC regions, only the foreign trade and external financial aspects are modelled. Note that in referring to variables of the various regions, the following notation is used: United States (*U*); Japan (*J*); Germany (*G*); Canada (*C*); Rest of the EMS (*E*); Rest of the OECD (*R*); OPEC (*O*); LDC (*L*); and Eastern Europe and Commonwealth of Independent States (*B*).

## The Structure of the Model

Consider the Canadian model in detail. Within Canada, the decisions of households, firms, and governments are modelled.

***Households***

Households are assumed to consume a basket of goods in every period where the basket is made up of domestic goods (both public and private) and imported goods from each of the industrialized regions. They receive income to purchase the goods through providing labour services for production and receiving a return from holding financial assets.

Aggregate consumption ($C$) is nested in the following way:

$$C = C\{C^d, C^m\}$$

$$C^m = C^m\{C^C{}_U, C^C{}_J, C^C{}_G, C^C{}_E, C^C{}_R\},$$

where $C^d$ is consumption of the domestic good, $C^m$ is consumption of the imported bundle, and $C^U{}_i$ is consumption by Canada of goods produced in country $i$ ($i = U, J, G, E, R$).

The decision on how consumption expenditure is allocated between the various goods across time is based on a representative consumer who maximizes an intertemporal utility function[8] of the form:

$$\int_t^\infty [U(C_s) + V(G_s)]\, e^{-(\theta - n)(s-t)}\, ds$$

subject to the wealth constraint:

$$dF/ds = (r_s - n)(F_s - M_s/P_s) + W_sL_s(1 - \tau_1)/P_s - P^c{}_sC_s/P_s\,. \tag{3.1}$$

$$F_s = M_s/P_s + B_s + q_sK_s + A_s + VOIL_s + VPE_s. \tag{3.2}$$

Utility in any period is written as an additively separable function of consumption of the private good ($C$) and the public good ($G$). In discounting the future stream of per-capita consumption, the rate of time preference ($\theta$) adjusted by the real growth rate ($n$) is used. The wealth accumulation equation given in equation 3.1 assumes that the change in real financial asset holdings ($dF/ds$) consists of a flow return on initial assets ($(r - n)F$), plus real after-tax labour income less real expenditure on consumption. Financial assets are defined as real money balances ($M/P$), government bonds in the hands of the public ($B$), equity wealth ($qK$), and net foreign asset holdings ($A$). We also include in the definition of financial wealth, the value of claims to domestic oil reserves ($VOIL$)[9] and the present value of net profit arising from the pricing behaviour of domestic firms in foreign markets ($VPE$).[10] Note that $P$ is the price of the domestic good, and $P^c$ is the price of the consumption good bundle ($p^c = P^c/P$). Note also that bonds are included as part of financial wealth, but this does not imply that they are part of total wealth, as the solution given below will show.

Setting up the Hamiltonian for this problem, assuming $U(C) = \log C$ and solving, gives the familiar first order conditions:

$$p_t^c \mu_t = 1 / C_t. \tag{3.3}$$

$$d\mu_t / dt = (\theta - r_t)\mu_t, \tag{3.4}$$

where $\mu$ is the shadow value of consumption.

Solving these conditions gives:

$$dp^c C/dt = (r_t - \theta)p^c{}_t C_t. \tag{3.5}$$

This implies that if $r = \theta$, per-capita real consumption is constant in the steady state.

The budget constraint given in equation 3.1 can be integrated and written as:

$$\int_t^\infty p_s^c C_s \, e^{-(R_s - n)(s-t)} \, ds = H_t + F_t, \tag{3.6}$$

where $H_t$ is real human wealth in period $t$ and is defined:

$$\int_t^\infty W_s L_s (1 - \tau_1) / P_s \, e^{-(R_s - n)(s-t)} \, ds = H_t. \tag{3.7}$$

Real human wealth is the present discounted value of the entire future stream of real, after-tax labour income, where:

$$R_s = \frac{1}{(s-t)} \int_t^s r_v \, dv$$

and $r_i$ is the period $i$ short-term real interest rate.

From the first order condition given in equation 3.5, we find[11]:

$$\int_0^\infty p_t^c C_t \, e^{-(R_t - n)s} \, dt = p_0^c C_0 / (\theta - n). \tag{3.8}$$

This can be substituted into equation 3.6 to give:

$$C_t = (\theta - n)\{F_t + H_t\} / p_t^c, \tag{3.9}$$

and rewriting the human wealth condition gives:

$$dH_t / dt = (r_t - n)H_t - (1 - \tau_1)W_t L_t / P_t. \qquad (3.10)$$

This solution for aggregate consumption is a familiar life-cycle model where, by the assumption of log utility, we find that aggregate consumption is a linear function of real wealth which is comprised of financial and human wealth.

By assuming that aggregate consumption is a CES nesting of domestic and foreign goods, we find equations for expenditure on each good as a function of aggregate expenditure:

$$C^d = [\beta_3^{\sigma_1} (P^c/P)^{\sigma_1}]\, C. \qquad (3.11)$$

$$C^m = [(1 - \beta_3)^{\sigma_1} (P^c/P^m)^{\sigma_1}]\, C, \qquad (3.12)$$

where

$$P^c C = P^m C^m + P C^d$$

and

$$P^{c(1-\sigma_1)} = \beta_3^{\sigma_1} P^{(1-\sigma_1)} + (1 - \beta_3)^{\sigma_1} P^{m(1-\sigma_1)}.$$

$\sigma_1$ is the elasticity of substitution between domestic and imported goods in the consumption bundle. Similarly, if the lower level nesting of imported goods is assumed to be a CES function, we find further similar demand functions for each imported good.

There is a large body of empirical evidence that suggests that aggregate consumption is partly determined along life-cycle lines, with considerable intertemporal consumption smoothing, and partly along simpler Keynesian lines (perhaps because of liquidity constrained households).[12] Thus we specify that consumption spending is a fixed proportion of current net-of-tax labour income – with no consumption smoothing of the labour income flow – as in standard Keynesian models, and a fixed proportion of wealth, as in standard life-cycle models with infinite-lived individuals. Thus the aggregate consumption equation takes the form:

$$C = \beta_4(\theta - n)(F + H)P/P^c + (1 - \beta_4)(Y - T) \text{ (note } \theta = \beta_1\text{)}. \qquad (3.13)$$

We also introduce an additional term into the equation for human wealth. This is a risk premium that drives a wedge between the rate at which private individuals can borrow in the capital markets and the rate at which governments borrow.

These modifications to capture empirical regularities in aggregate consumption are assumed not to change the lower level demand functions. Note that in this model we assume $r > n$ which introduces another source of saddle-point stability into the model. This assumption is necessary if human wealth is to be positive in the steady state.[13]

### *Firms*

The cornerstone of aggregate supply in the model is a representative firm which maximizes its value by producing a single output $Q$ at price $P$, subject to a two-input production function. All variables are written in terms of per-efficiency labour units. Potential long-run growth in the model is assumed to be 3 per cent and unchanged over time. Thus aggregate production is given as:

$$Q = Q(V, N). \tag{3.14}$$

Gross output $Q$ is produced with value added $V$, and intermediate inputs $N$. In turn, $V$ is produced with capital $K$ and labour $L$, while $N$ is produced with imports from the LDCs ($N_L$) and energy, which consists of imports from OPEC ($N_O$) and domestic oil production ($N_P$):

$$V = V(K, L). \tag{3.15}$$

$$N = N(N_O, N_L, N_P). \tag{3.16}$$

We assume that domestic oil resources and imports of OPEC oil are perfect substitutes. Total oil demand, as an intermediate input, is assumed to be divided between the two sources, based on historical shares. As already noted above, we also assume that households hold claims over domestic oil resources.

The capital stock changes according to the rate of fixed capital formation $J$ and the rate of geometric depreciation $\delta$:

$$dK/dt = J_t - (\delta + n) K_t. \tag{3.17}$$

Note that $n$ appears in equation 3.17 because $K$ is in per-efficiency labour units rather than in levels. $J$ is itself a composite good, produced with a Cobb-Douglas technology that has as inputs the domestic goods from Canada and the final goods of the United States, Germany, the REMS, Japan, and the ROECD. The price of $J$ is simply a weighted sum of the prices of the home goods $P$ ($P^C$ for Canada) and the dollar import prices ($E^iP^i, i = U, J, G, E, R$) of goods from the other OECD regions:

$$J = \Pi_i (Q^i)^{\beta_{18i}} \qquad i = \{C, U, J, G, E, R\}, \quad \Sigma_i \beta_{18i} = 1. \tag{3.18}$$

$$P^J = \Pi_i (E^i P^i)^{\beta_{18i}} \qquad i = \{U, J, G, E, R\}. \tag{3.19}$$

Following the cost-of-adjustment models of Lucas [1967] and Treadway [1969], it is assumed that the investment process is subject to rising marginal costs of installation, with total real investment expenditures $I$ equal to the value of direct purchases of investment $P^J{*}J/P$, plus the per-unit costs of installation. These per-unit costs, in turn, are assumed to be a linear function of the rate of investment $J/K$, so that adjustment costs are $P^J{*}J\ [(\phi_o/2)(J/K)]/P$. Total investment expenditure is therefore:

$$I = [P^J + P^J (\phi_o/2)\ (J/K)]\ J/P. \tag{3.20}$$

The goal of the firm is to choose inputs of $L$, $N$, and $J$ to maximize intertemporal net-of-tax profits. In fact, the firm faces a stochastic problem, a point which is ignored in the derivation of the firm's behaviour (in other words, the firm is assumed to believe its estimates of future variables with subjective certainty). The firm's deterministic problem, formally stated, is:

maximize

$$\int_t^\infty \left[(1-\tau_2)(Q_s - (W_s / P_s)L_s - (P_s^N / P_s)N_s) - (P_s^J / P_s)I_s\right] e^{-(R_s - n)s} ds$$

subject to equations 3.14 through 3.20. Solving the firm's problem, we find a set of conditions found in equations 3.21 to 3.24:

$$Q_L = w, \qquad (w = W/P). \tag{3.21}$$

$$Q_N = p^n, \qquad (p^n = P^n/P). \tag{3.22}$$

$$\lambda = p^J(1 + \phi_o J/K), \qquad (p^J = P^J/P). \tag{3.23}$$

$$d\lambda_s/ds = (r + \delta)\lambda_s - (1 - \tau_2)\ Q_K - .5p^J\phi_o(J/K)^2 \tag{3.24}$$

where $\lambda$ is the shadow value of investment.

There are three key points from these solutions. First, inputs of $L$ and $N$ are hired to the point where the marginal productivity of these factors equals their factor prices. This gives equations for the derived demand for $L$ and $N$ given in equations 3.21 and 3.22.

The second point is seen by interpreting equation 3.24. This equation can be integrated to find:

$$\lambda_t = \int_t^{\infty} \left[(1-\tau_2)Q_{K_s} + \Phi_K\right] e^{-(R_s+\delta)s} ds. \tag{3.25}$$

Here $Q_K$ is the marginal product of capital in the production function, and $\phi_K (= 0.5 p_s^I \phi_o [J_s / K_s]^2)$ is the marginal product of capital in reducing adjustment costs in investment. Therefore, $\lambda$ is the increment to the value of the firm from a unit increase in investment. It has a similar interpretation to Tobin's $q$. If we assume that $q = P\lambda/P^I$, we can rewrite equation 3.23 as:

$$J = [(q-1)/\phi_o]\, K. \tag{3.26}$$

The third point is that gross fixed capital formation can be written in terms of Tobin's "marginal" $q$ as in equation 3.26.

In the specific application in the MSG2 model, the gross output production function is taken to be a two-level Cobb-Douglas function in $V$ and $N$, with $V$ a Cobb-Douglas function of $L$ and $K$, and $N$ a Cobb-Douglas function of oil and non-oil primary inputs. Oil is then a Cobb-Douglas function of domestic production and imports from OPEC. Following the results in Hayashi, the investment function derived in equation 3.26 is also modified, for empirical realism, by writing $J$ as a function not only of $q$, but also of the level of flow capital income at time $t$. One argument for the inclusion of current profits is that it captures the existence of firms that are unable to borrow and lend as assumed by the theoretical derivation and, therefore, invest out of retained earnings. The modified investment equation is of the form:

$$J_t = \beta_{18}\, [(q-1)/\phi_o]\, K + (1-\beta_{18})[Q - (W/P)L - (P^N/P)N]. \tag{3.26'}$$

The supply side of the Canadian block of the model is completed with the wage equation, which makes the nominal wage change a function of past consumer price changes $\left(\pi_{t-1}^c\right)$, rationally expected future price changes $\left(\pi_t^c\right)$, and the level of unemployment in the economy (labour demand, $L$, relative to full employment, $L^f$), according to a standard Phillips' curve mechanism:

$$d\log W/dt = \beta_{25}\, \pi_t^c + (1-\beta_{25})\, \pi_{t-1}^c + .25 * \log(L/L^f). \tag{3.27}$$

where $L^f$ represents the inelastically supplied full-employment stock of labour. In setting wages, the parameter $\beta_{25}$ in equation 3.27 determines how much weight is given to past inflation versus a rational expectations projection of future inflation.

As already noted, we allow for differences in the wage dynamics of the different regions. Behaviour in Canada, the United States, and the ROECD is characterized by equation 3.27. In Japan and Germany see McKibbin and Sachs [1991].

*Governments*

The government in each country is assumed to divide spending $G$ among final goods in the same proportion as does the private sector, so that:

$$G_i^c / G^c \quad = C_i^c / C^c \tag{3.28}$$

for $i \quad = C, U, J, G, E, R.$

The government finances this spending through company taxes and personal income taxes, and by issuing government debt. The government budget constraint can be written[14]:

$$dB/dt = DEF = G - T + (r - n)\,B. \tag{3.29}$$

Assuming a transversality condition that debt has value, i.e.,

$$\lim_{s \to \infty} B_s\, e^{-(Rs-n)s} = 0,$$

equation 3.29 can be integrated and written as:

$$B_t = \int_t^{\infty} (T_s - G_s)\, e^{-(Rs-n)(s-t)}\, ds.$$

The current level of debt to GDP is the present value of future primary budget surpluses. With an outstanding stock of debt, if a government runs a budget deficit today, it must run a budget surplus as some point in the future: otherwise the debt will have no value.

In simulating fiscal policy, several assumptions are made. The government can either choose policy exogenously or it can choose it based on dynamic optimization of some objective function. In the case of an exogenous change in fiscal policy, it is important that tax and spending policies be consistent with the intertemporal budget constraint of the public sector. In particular, as already mentioned, starting from any initial stock of public debt, the discounted value of current and future taxes must equal the discounted value of government spending plus the initial value of outstanding public debt.

If the tax schedule were not subsequently altered, the stock of public debt would eventually rise without bound, at an explosive geometric rate. To prevent this, it is assumed that labour income taxes are increased each year by enough to cover the increasing interest costs on the rising stock of public debt. Letting $B_0$ be the pre-expansion stock of debt, the tax rule is therefore:

$$T_t = T_o + \tau_1(W/P\, L) + \tau_2\,[Q - (W/P)\,L - (P_N/P)N] + T_s\,. \tag{3.30}$$

Here, $\tau_1$ is the average tax rate on labour income, and $\tau_2$ is the average tax rate (corporate and personal) on capital income. $T_s$ is a shift term in the tax schedule that rises along with the increase in interest payments on the public debt, $r_tB_t - r_0B_0$. It is assumed that $T_s$ falls entirely on labour income (this assumption is made for convenience only and will be modified in a later version of the model). $T_o$ is an exogenous tax shift parameter.

### *Financial Markets*

Explaining why agents desire to hold money balances is a common dilemma in general equilibrium models. A demand for money can only be derived if: money gives direct utility; money is a factor of production; or through a constraint that money must be used in transactions. Money is given a role in the MSG2 model by assuming it is a factor of production. It is a factor of production not because firms require money balances in day-to-day operations, but because the final produced good cannot be consumed by agents until it is purchased with money. Using this interpretation, the producer's decision is modified by adding a first order condition similar to that for the other variable factors; the derived demand for money will be a function of output and the relative price of money. By specifying a CES technology in purchasing goods, a unitary income elasticity is imposed but an interest elasticity proportional to the elasticity of substitution between money and the final good. The empirical money demand literature can be used to determine the interest elasticity and therefore an implied elasticity of substitution.

Asset markets are assumed to be perfectly integrated across the OECD regions. In the model calibrated on 1987 data, it is assumed that capital controls in the REMS are not effective. Expected returns on loans denominated in the currencies of the various regions are equalized period to period, according to the following interest arbitrage relations:

$$i_t^i = i_t^j + ({}_tE_{jt+1}^i - E_{jt}^i)\,/\,E_{jt}^i, \tag{3.31}$$

where

$E_{jt}^i$ is the exchange rate between currencies of countries $i$ and $j$.

Thus, there is no allowance for risk premia on the assets of alternative currencies. Perfect capital mobility and zero risk premia are assumed in light of the failure of the empirical exchange rate literature to demonstrate the existence of stable risk premia across international currencies. In the simulations of the model, the results are also consistent with assuming that even if a risk premia exists, it is independent of the shocks or other variables in the model.

### *Balance of Payments and the LDC and OPEC Blocs*

Any trade imbalances are financed by flows of assets between countries. To determine net asset positions, we make several simplifying assumptions. All new OPEC loans to each region are assumed to be in historical proportions. Similarly new loans to the LDCs are also fixed in historical proportions. To be consistent, all other net capital flows are restricted by imposing the constraint that current account and trade account balances sum to zero for the world as a whole. For Canada, the United States, Japan, Germany, the ROECD, and OPEC, the current account is determined under the assumption that domestic agents have free unrationed access to international borrowing and lending at the international interest rate. It is assumed for simplicity that all international borrowing and lending takes place in dollar denominated assets. For the LDCs, in distinction, the scale of borrowing is set exogenously, under the assumption that the amount of loans available to the LDCs is rationed by country risk considerations. Note that the rate of interest on these loans does not have a risk premium built into it. For example, loans from the United States and OPEC are made in U.S. dollars at the interest rate on U.S. government debt.

### *The Effect of Exchange Rates on Import Prices*

To capture the effect of slow pass through of exchange rate changes into import price, a lag of the following form is assumed in the exchange rate effect on import prices:

$$e_t^{i*} = e_{t-1}^{i*} + \beta_{23}(e_t^i - e_{t-1}^i) + (1-\beta_{23})(e_{t-1}^{*i} - e_{t-2}^{*i}) + .05(e_{t-1}^i - e_{t-1}^{*i}), \qquad (3.32)$$

where $e_t^{i*}$ is log of the exchange rate that enters the pricing and demand equations in each country.

This assumes that each foreign firm prices the same way in a particular country, but possibly differently in different countries. For example, this assumes that both Canadian and German firms selling goods in the U.S. market allow the same proportional flow-on of exchange rate changes in pricing in the U.S. market. Equivalently, German and American firms selling goods in the Canadian market also allow the same flow-on of exchange rate changes into prices but not necessarily the same as the firms selling in the U.S. market. This behaviour is consistent with a variety of arguments involving imperfect competition in international trade (see Dornbusch [1987] or Krugman [1986]). The profits and losses of the firms involved in exporting are translated into the valuation of the firm in the original economies and therefore also into the wealth calculations for each economy.

### *Model Closure*

The model is completed by assuming market clearing conditions. Prices in Canada (and the other OECD regions) are fully flexible within each period, so that demand for Canadian output (domestic demand plus export demand) equals output supply. Short-term nominal interest rates adjust to clear the money market.

### *Calibration*

There are two issues which need to be dealt with in calibrating this model for use in empirical simulations. The first is to choose specific empirical values for the behavioural parameters. The second is to choose a cross-section of data at some point in time, around which to linearize the model for game theoretic applications. The data and parameters must be internally consistent with the model specification. In finding parameters for the model, we use a mix of techniques from the CGE literature as well as time-series evidence.

In most CGE models, both the data and the model parameters are manipulated to replicate an equilibrium of the model. In a dynamic model such as the MSG model, a corresponding procedure would be to choose a steady state of the model around which to calibrate. In principle this is reasonable for a theoretical model, because it can be assumed that we start at a steady state since we are not concerned with recreating any actual year of data. To replicate an actual data set is more problematic since we are trying to keep within the bounds consistent with this data set.[15] For example, a positive stock of outstanding debt for a country in the steady state should be associated with a trade balance surplus, because the stock of debt needs to be serviced in the steady state. Yet, during a period of adjustment away from the steady state, positive debt is usually associated with a trade-account deficit during the early stages of debt accumulation. It is important to ensure the data replicates the trade position as well as the initial debt position: this is not always possible by assuming steady relationships.

Our technique is to choose a set of behavioural parameters which fall within the range found in the many empirical studies of time-series relations (e.g., factor shares and elasticities of substitution). Given this set of parameters and data for macro aggregates (e.g., output, consumption expenditure) which are based on data for 1987, we can use steady-state relations in the model to generate other data (e.g., human wealth). A summary of the key features of this procedure can be found in McKibbin and Sachs [1991]. The base date of 1987 is an arbitrary period, but it corresponds to the latest base period for the full MSG model.

For any equation in which adjustment occurs according to some share formulation, we assume the shares are those prevailing in 1987. For example, the use of U.S. goods in Canadian investment is assumed to be equal to the 1987 ratio of imports of U.S. investment goods to total investment expenditure in Canada.

We also need data for trade flows and asset stocks around which to linearize the model. The 1987-based data that we use for the matrix of bilateral trade flows are given in Table 1. This trade matrix is further disaggregated in the model using the *OECD Trade and Production Compatible Database* (based on ISIC categories) to distinguish approximately between imports of consumption goods and imports of capital goods.

The assumptions on asset holdings are given in Table 2. Because of our assumption that assets are perfect substitutes, only net debt positions are required for asset holdings. The data on asset stocks by country are poor. We combine data from a number of sources and make approximating assumptions where required. Details of the procedures are contained in McKibbin and Sachs [1991], and recent data revisions are contained in the documentation for the MSG database.

We select the long-run potential growth rates ($n$) of each region at 3 per cent per year and the steady-state value for the real interest rate $r_0$ at 5 per

**Table 1**

**Trade as a percentage of importing country GDP, 1987**

| | Exporter | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | United States | Japan | Germany | Canada | REMS | ROECD | LDC | OPEC | EEB |
| Importer | | | | | | | | | |
| United States | -- | 1.865 | 0.616 | 1.577 | 1.193 | 0.369 | 2.604 | 0.442 | 0.050 |
| Japan | 1.111 | -- | 0.244 | 0.211 | 0.398 | 0.452 | 1.883 | 0.968 | 0.084 |
| Germany | 0.980 | 1.152 | -- | 0.108 | 10.124 | 3.021 | 1.952 | 0.485 | 1.128 |
| Canada | 14.240 | 1.350 | 0.638 | -- | 1.851 | 0.524 | 1.717 | 0.223 | 0.075 |
| REMS | 1.461 | 0.779 | 4.836 | 0.178 | -- | 2.214 | 1.983 | 0.890 | 0.676 |
| ROECD | 1.398 | 1.523 | 5.985 | 0.171 | 7.522 | -- | 1.742 | 0.407 | 1.270 |
| LDC | 1.550 | 1.594 | 0.605 | 0.147 | 1.485 | 0.526 | -- | 0.742 | 0.606 |
| OPEC | 0.223 | 0.255 | 0.182 | 0.026 | 0.577 | 0.135 | 0.377 | -- | 0.115 |
| EEB | 0.053 | 0.074 | 0.350 | 0.017 | 0.300 | 0.240 | 0.375 | 0.063 | -- |

Source United Nations Direction of Trade Statistics, 1989 revision.

**Table 2**

**Portfolio matrix, ratio of net asset holdings to U.S. GDP, 1987**

| | Claim held by: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | United States | Japan | Germany | Canada | REMS | ROECD | LDC | OPEC | EEB |
| Claim on: | | | | | | | | | |
| United States | -- | 1.882 | 1.993 | −1.196 | 4.473 | 0.244 | −5.049 | 6.156 | −0.111 |
| Japan | | -- | −0.421 | −2.215 | −0.620 | −1.594 | −1.329 | 0.687 | 0.000 |
| Germany | | | -- | −0.177 | −1.174 | −0.244 | −0.997 | 0.354 | −0.221 |
| Canada | | | | -- | 0.687 | 0.221 | −0.221 | −0.111 | −0.089 |
| REMS | | | | | -- | 0.997 | −1.528 | 1.240 | −0.421 |
| ROECD | | | | | | -- | −0.554 | −0.244 | −0.288 |
| LDC | | | | | | | -- | 0.886 | 0.000 |
| OPEC | | | | | | | | -- | 0.000 |
| EEB | | | | | | | | | -- |

SOURCE MSG Bilateral Asset Position Database.

cent. We also assume that the rate of time preference is equal to the real rate of interest. The choice of equal rates of time preference for the residents of each country is dictated by the problem that in infinite horizon multi-country models, one country would dominate the world eventually. All initial prices are normalized at 1 (= 0 in logs).

### *Model Solution*

Solving a model such as the MSG model, which assumes rational expectations in different markets, is not a straightforward exercise. Forward-looking variables, such as asset prices, consumption, and investment decisions, are conditioned on the entire future path of all variables in the model. We are presented with a two-point boundary value problem; values for inherited variables (state variables) are known, and the expected paths of exogenous variables are assumed to be known. But for forward-looking variables, we can only assume some terminal conditions.

Details on the solution technique followed here can be found in McKibbin and Sachs [1991, Appendix C]. It involves linearizing the model around the based period data set of 1987. The model is then solved numerically using an iterative technique that searches for the unique stable rule linking jumping variables to known information in each period, while ensuring that the terminal conditions are not violated.

## Properties of the Model

One of the advantages of the approach followed in building this model is that it is possible to explore both the long- and the short-run consequences of a given shock, explicitly incorporating the expectations of the nature of the shock. For the long-run response, we have an analytical solution to the model, and for the short-run properties, one can use the numerical simulation technique outlined above.

This section considers the effects on Canada of six types of shocks:

- temporary and permanent (anticipated and unanticipated) Canadian fiscal expansion;
- temporary and permanent (anticipated and unanticipated) Canadian monetary expansion;
- a permanent rise in productivity in Canada;
- a permanent expansion in fiscal policy in the United States;
- a permanent expansion in monetary policy in the United States; and
- an exogenous increase in the world price of oil.

In some of the results, the direct familiar effects from other macroeconometric models are offset or reversed by changes in market participants' expectations of the future path of the world economy. This is especially true in the cases of changes in policy that are announced in advance. It is important to note that the shocks examined here are implemented assuming that asset market participants fully understand the shock, forming rational expectations of future shocks and understanding the way in which the global economy works. This is obviously an extreme assumption, but it gives a benchmark against which to compare the results obtained from the traditional approach of assuming slowly changing expectations. The traditional approach used in many large-scale macroeconometric models leads to small movements in asset prices in response to changes in the economy, and is unable to account for the large changes in asset prices experienced during the 1980s. This paper's approach highlights the fact that an expectations formation is fundamental to determining many macroeconomic outcomes.

To aid in digesting the vast amount of material generated by the combination of a large range of variables and shocks, graphical results for a number of key variables are presented here.

### *Canadian Fiscal Policy*

The first set of shocks are fiscal expansions in Canada beginning in 1992. The shock in each case is a rise in government spending on goods and services equivalent to 1 per cent of the Canadian GDP. In implementing a change in fiscal policy, it is important that tax and spending policies be consistent with the intertemporal budget constraint facing the government. The first policy change is a permanent increase in the level of government expenditure, with taxes only rising due to endogenous changes in tax receipts resulting from changes in economic activity. Over time, taxes on labour income are also assumed to rise to cover the increasing interest burden of a rising stock of public debt. The overall fiscal deficit remains permanently higher, although the primary fiscal spending (defined as spending net of interest payments minus total taxes) eventually turns to a surplus to prevent the explosive growth of government debt.

The second change in fiscal policy is the same as the first, except that the policy is announced in 1992 to be undertaken in 1993. This will highlight the role of expectations.

The third fiscal change is a temporary, one period fiscal expansion that is known to only occur in 1992.

#### *Long Run*

For the permanent changes in fiscal policy, the long-run results will be qualitatively the same. Recall that the fiscal expansion is designed so that a permanent deficit emerges. The long-run level of government debt to GDP is equal to the long-run deficit to GDP divided by the gap between the real interest rate and the real growth rate. In the current example, with a permanent increase in the deficit by 1 per cent of the GDP – an initial real interest rate of 5 per cent and real growth rate of 3 per cent – this would imply a long-run increase in the ratio of debt to GDP of 50 per cent. However, the assumption that taxes adjust to cover interest servicing implies that the long-run ratio of debt to GDP only rises by 33.3 per cent (e.g., 1/.03).

Consumption in this model is affected by the path of taxes partly because of short-run liquidity constraints, but also because consumers in the model discount future income at a higher rate than the real interest rate. This implies that for a given rise in government spending, steady-state consumption will not fall by as much as the rise in government spending. In the long run, with excess demand real interest rates rise partly crowding out private spending. Lower investment expenditure results in a lower capital stock which is consistent with the higher marginal product of capital. Even though the lower capital stock implies a lower level of output, the real growth rate of output returns to 3 per cent.

Together, the assumption of perfect asset substitutability and the relatively small size of the Canadian economy imply that world interest rates will only rise slightly in response to the Canadian fiscal expansion. In the case of a permanent U.S. fiscal expansion, world interest rates rise about 100 basis points in the long run. In contrast, for the Canadian case, this is closer to 20 basis points for a 1-per-cent of own country GDP fiscal expansion. This implies that, in the long run, the transmission of the fiscal expansion will be negative to foreign output depending on the extent to which world interest rates rise.

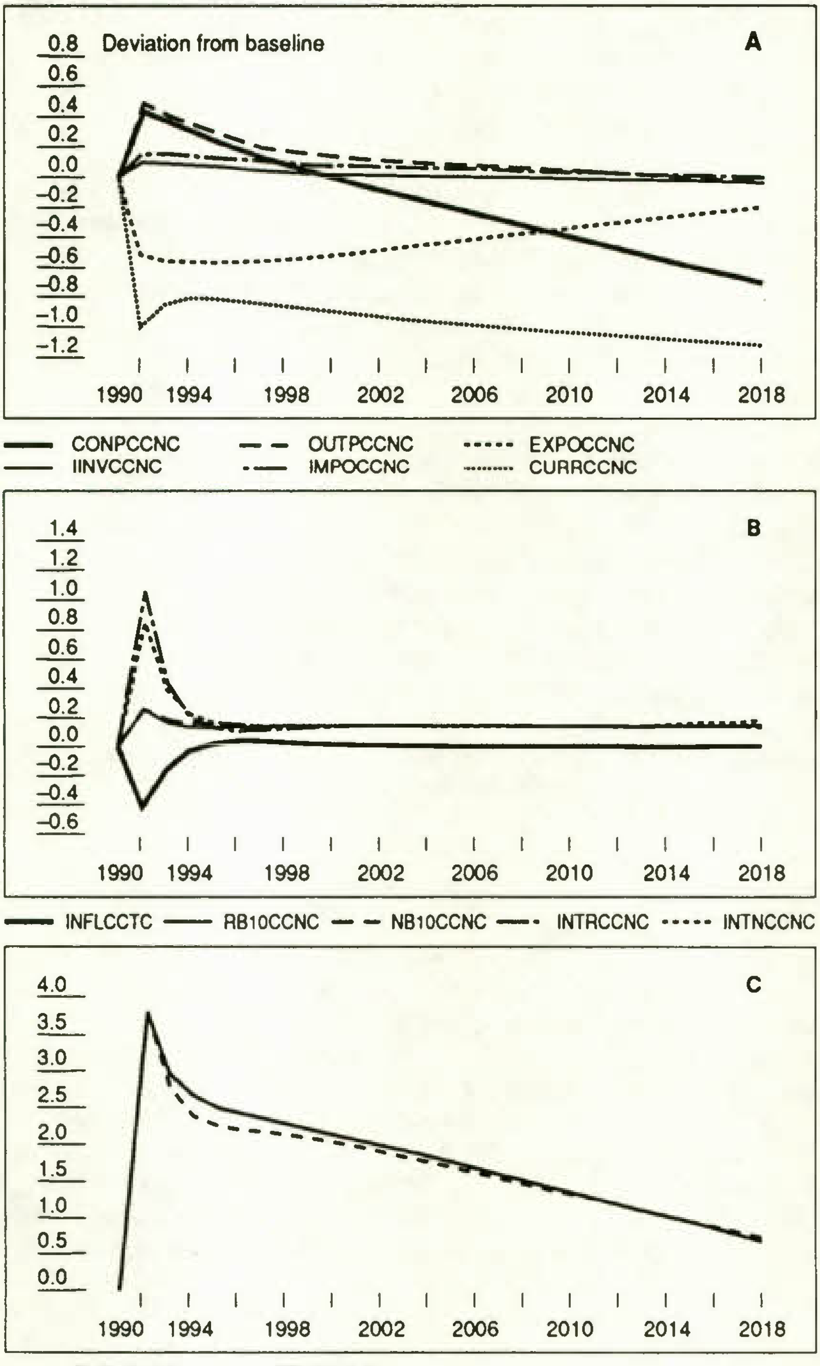
In addition to the build-up of domestic government debt, there will be an accumulation of foreign debt. To service this foreign debt, the long-run trade position must move towards surplus which implies a relatively depreciated Canadian real exchange rate.

*Short-Run Dynamics*

*Unanticipated Permanent Fiscal Expansion* — Consider the short-run simulation results for the Canadian fiscal expansion, defined as a rise in the level of government spending by 1 per cent of the GDP. The results are summarized in Figures 1a through 1c. In reading these figures, note that output, consumption, investment, exports, imports, and the current account are measured as deviations from a baseline expressed as a proportion of baseline, Canadian potential GDP. Inflation (defined in terms of the consumer price index) and interest rates (both one-year and ten-year bonds) are expressed as changes in percentage points: therefore, a rise in an interest rate of 1 percentage point is 100 basis points. Nominal and real exchange rates are measured as percentage deviation from base. Note that a positive change in the exchange rate is an appreciation of the Canadian dollar against the U.S. dollar.

What should we expect from theory? From the Mundell-Fleming model, we should expect that a bond-financed fiscal expansion in the presence of perfect substitutability of home and foreign financial assets will result in a rise in domestic income, and an appreciation of the Canadian dollar. The smaller the economy, the less of a rise in real output because capital inflow induced by higher interest rates will crowd out net exports through an appreciation of the exchange rate. Indeed, in the simulation, Canadian gross output rises by about 0.5 percentage point in the first year, while the Canadian dollar appreciates by 3.8 per cent vis-à-vis the U.S. dollar. The rise in output and the appreciation of the dollar produce a large trade deficit, equal to 1 per cent of GDP in the first year of the fiscal expansion. Over time, as prices

**Figure 1**
**Permanent Canadian fiscal expansion, 1990-2018**



rise, there is crowding out of private investment and private consumption. The theoretically expected effect on consumption is ambiguous, as the forward-looking component falls due to higher interest rates, while the proportion driven by current disposable income rises. The direction of the expected effect on investment is also theoretically ambiguous. The share market falls because the higher real interest rate dominates the effect of higher output on the valuation of future profitability.

Long-term Canadian interest rates rise by 20 basis points. They stay above U.S. interest rates because of the continual depreciation of the Canadian dollar. Note that the Canadian dollar initially appreciates but subsequently depreciates over time. In reading the figures, it is important to remember that any result above zero means that a variable is higher than the baseline, even though that variable may be falling over time.

*Anticipated Permanent Fiscal Expansion* — Figures 2a through 2c show the results for a similar fiscal expansion but announced one in 1992, to take place in 1993. Referring to Figure 2a, it is clear that output falls in 1992, rather than rises. This occurs because the announcement of the fiscal change leads to a rise in real long-term interest rates and an appreciation of the Canadian dollar. Both effects tend to lower output through crowding out of interest-sensitive investment expenditure and net exports, respectively. In the case of an announced future fiscal expansion, there is no change in government spending in 1992, therefore there is no positive demand stimulus until 1993. Output, consumption, investment, and exports fall in 1992. In 1993, when the change in government spending takes place, each item of aggregate demand rises, except exports which suffer from a further appreciation of the Canadian dollar.

*Temporary Fiscal Expansion* — Figures 3a through 3c show the results of a temporary Canadian fiscal expansion which is a rise in government spending in 1992 which is reversed in 1993. Figure 3a shows the results for the components of aggregate demand and trade. Output rises by more than 0.9 per cent in this case because there is very little change in long-term real interest rates or the real exchange rate. Hence there is less crowding out of the temporary increase in government spending. This is confirmed in Figures 3b and 3c. Note that short-term interest rates change by more under the temporary shock. This is because the conditions in the money market determine the short-term interest rate and under the assumption that the stock of money is fixed, a larger income rise implies a short-term rise in the demand for money. Equilibrium in the money market is achieved by a rise in interest rates.

Finally, a comparison between the three types of fiscal expansions is provided in Figure 3d, which compares the output responses under the temporary fiscal expansion and the anticipated and unanticipated fiscal

**Figure 2**
**Anticipated Canadian fiscal expansion, 1990-2018**

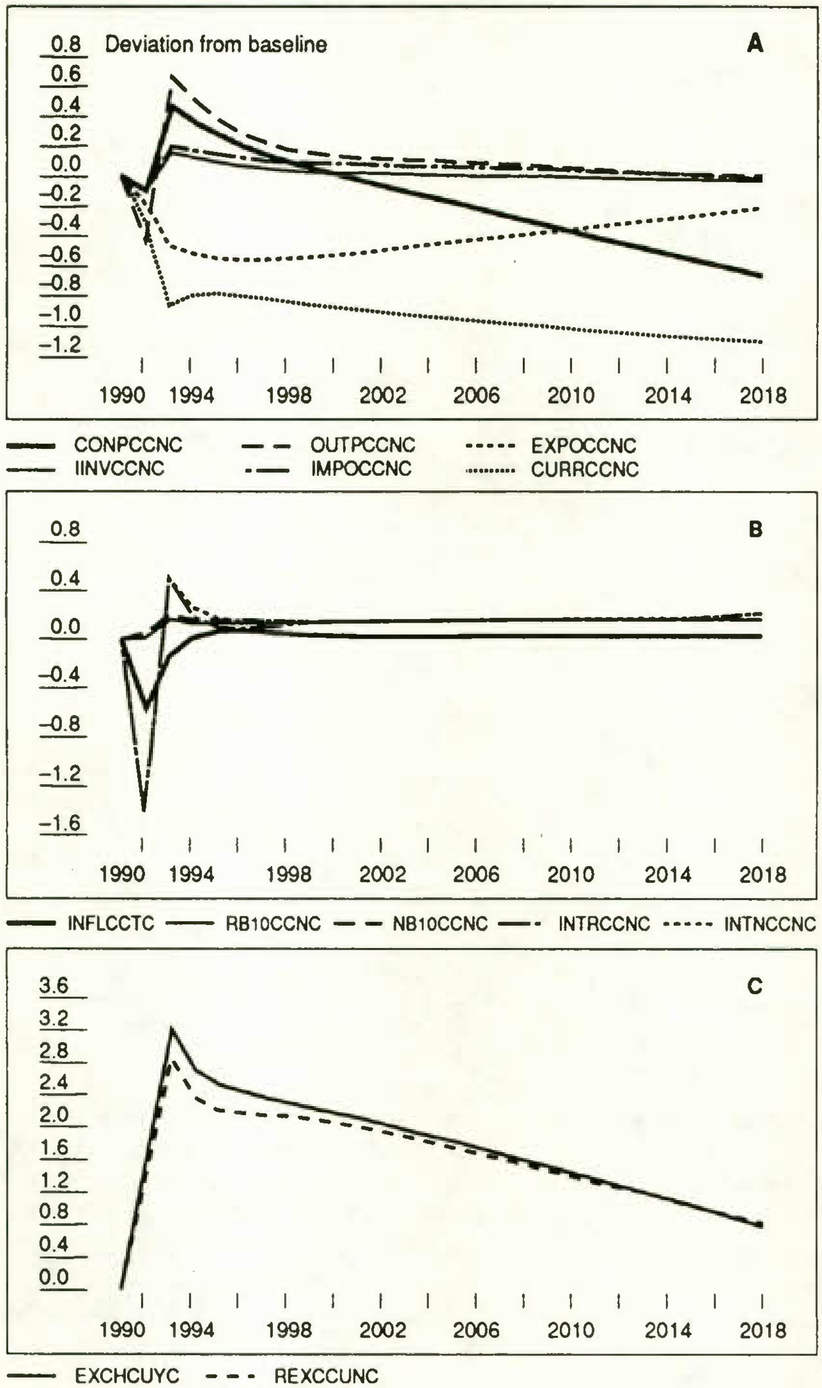
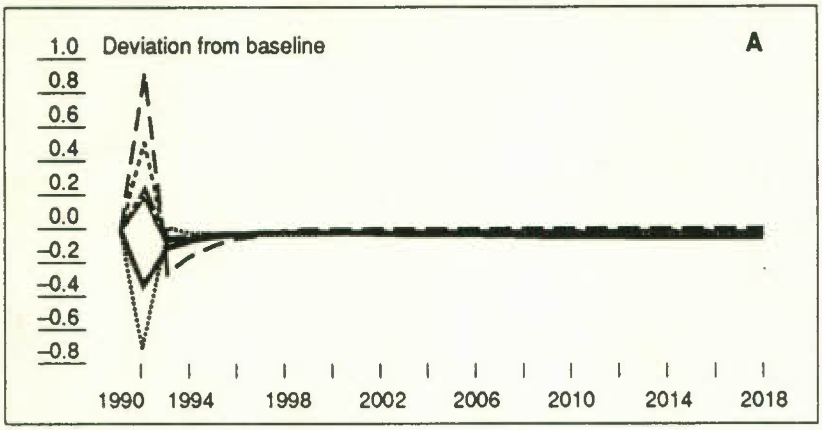
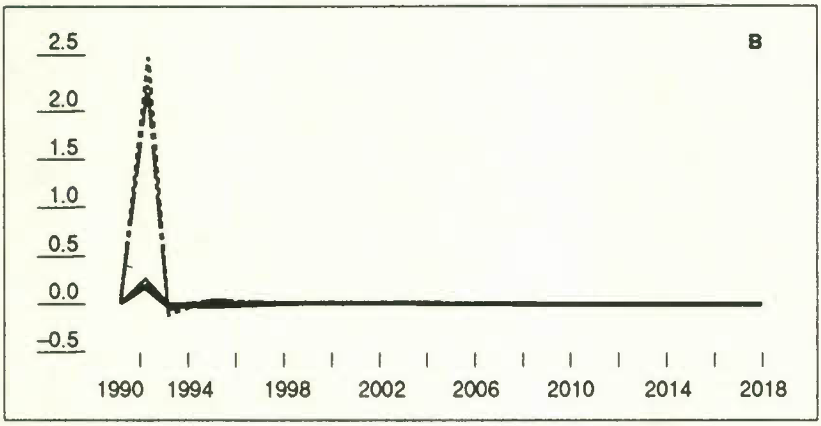


**Figure 3**
**Temporary Canadian fiscal expansion, 1990-2018**



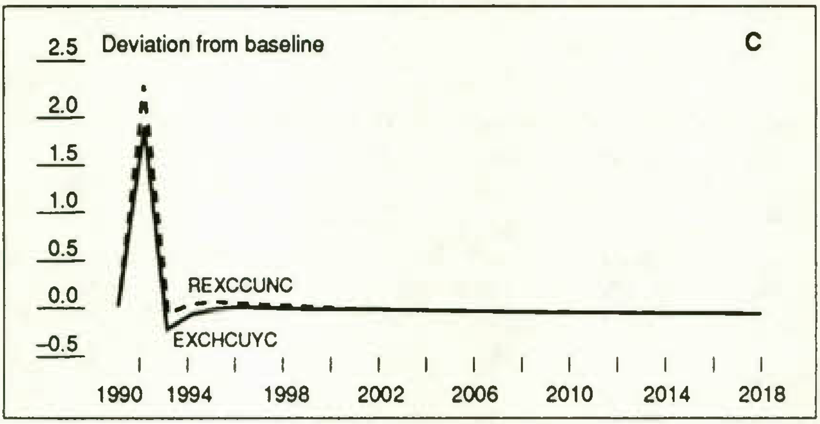

CONPCCNC — OUTPCCNC — EXPOCCNC
IINVCCNC — IMPOCCNC — CURRCCNC



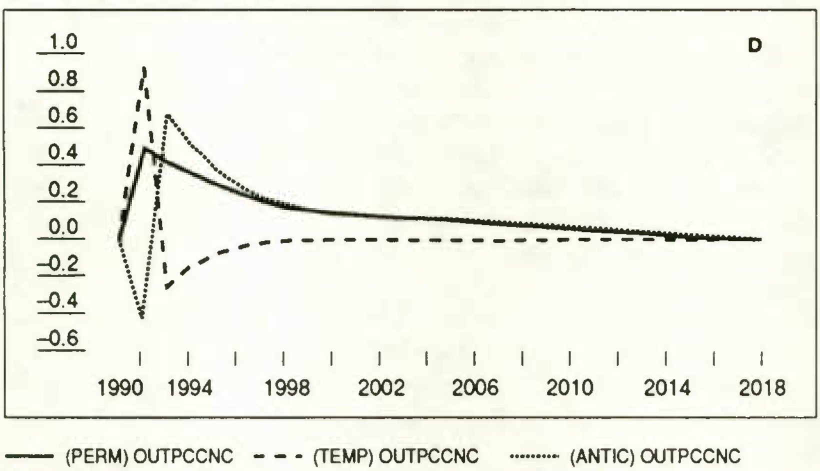

INFLCCTC — RB10CCNC — NB10CCNC — INTRCCNC — INTNCCNC

expansions. Note that output rises most for the temporary shock and even falls in 1992, when the shock is anticipated. As already discussed, this is because of the changes in forward-looking interest rates and exchange rates in the model. For the temporary shock, these asset prices change less and therefore the direct short-run demand effects dominate. For the anticipated shock, the short-run demand effects of greater fiscal spending are completely absent. One further point to note from Figure 3d is that, in the long run, output is permanently lower for the permanent fiscal expansions, whereas for the temporary shock, output returns to baseline. This reflects the effect of the

**Figure 3**
**Temporary Canadian fiscal expansion, 1990-2018**




**Permanent, temporary, and anticipated Canadian fiscal expansion, 1990-2018**




permanent shock of raising real interest rates, and therefore raising the marginal product of capital, which implies lower output even though Canada returns to the baseline growth rate.

### *Canadian Monetary Policy*

In this section, we examine the consequences of a sustained monetary expansion in Canada. Both a temporary increase in the rate of growth of money (i.e., a rise in the level of money balances) and a permanent increase in the anticipated rate of growth of money are examined.

*Long Run*

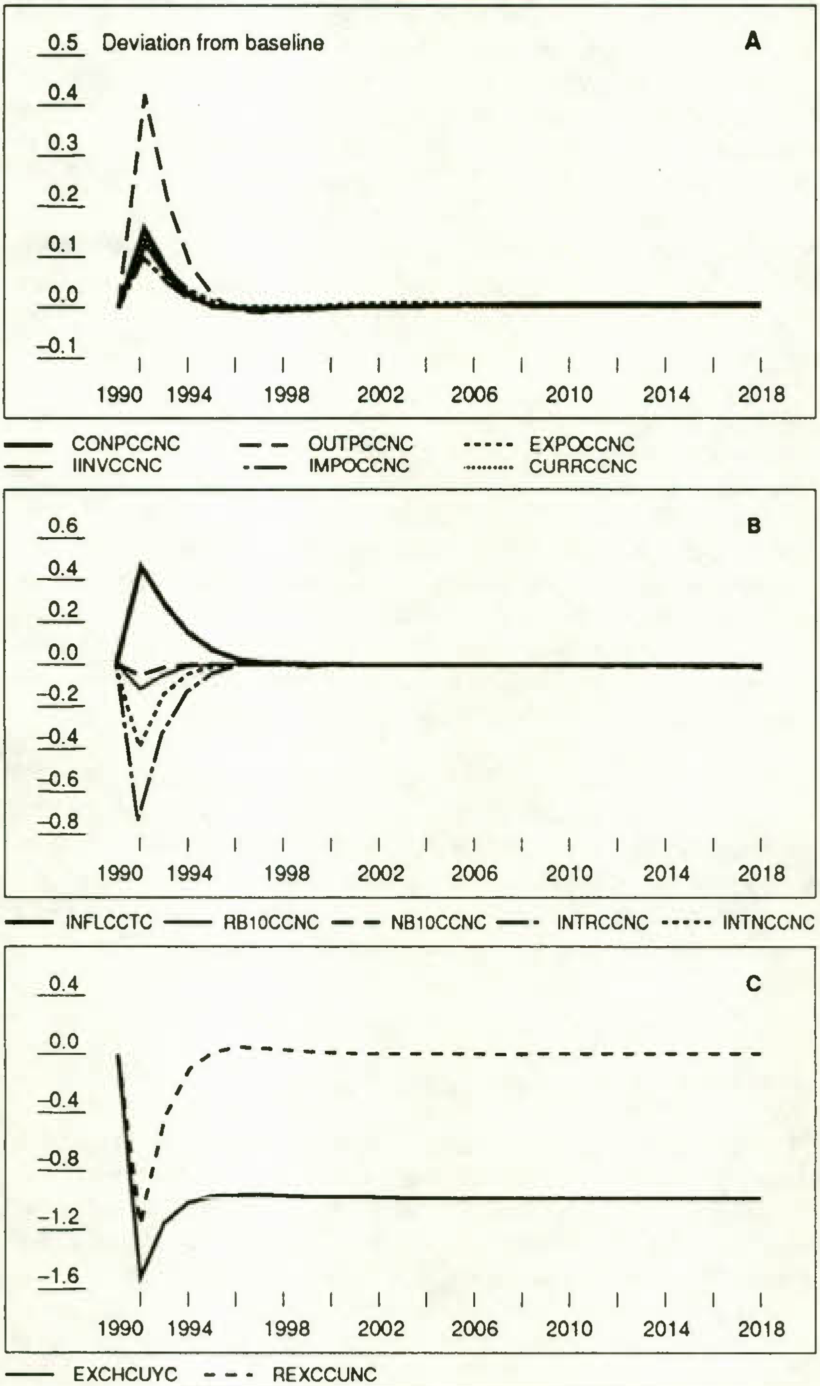
Money is neutral in the long run in this model. A rise in the level of money balances ultimately leads to a rise in all prices of the same magnitude and an equivalent depreciation of the home currency. A permanent rise in the rate of growth of money leads to an equivalent long-run rise in the rate of inflation. Money is not super-neutral as there are some small real effects of a permanent change in money growth and the permanent change in inflation, operating through changes in the real value of wealth.

*Short Run*

*Temporary Change in Canadian Monetary Growth Rate* — The results for a 1-per-cent rise in the level of money balances in Canada are shown in Figures 4a through 4c. A Canadian monetary expansion lowers real and nominal interest rates which raises aggregate demand by over 0.4 per cent. The reduction in interest rates leads to a capital outflow which depreciates the Canadian dollar. The depreciation of the Canadian dollar shifts the demand towards Canadian goods and improves the trade balance. The rise in aggregate demand in Canada tends to raise imports which worsens the trade balance. In this model, the relative price change dominates and, therefore, a monetary expansion improves the trade balance in the short run.

Note the magnitude of the effect of a monetary expansion on the nominal exchange rate shown in Figure 4c. It is well known from the Dornbusch [1976] model that the home currency will depreciate upon a permanent, once-and-for-all increase in the money supply, but that the size of the depreciation on impact may exceed ("overshoot") or fall below ("undershoot") the long-run change in the nominal rate, which just equals the proportionate change in the money stock. If the effect of the exchange rate on domestic demand is large (through the effect on the trade balance), and if the effect of domestic demand on money demand is large (through the income elasticity of demand for money), and if the home currency depreciation causes a rapid rise in domestic prices, then it can be shown that home nominal interest rates will tend to rise after the money expansion, and that the home exchange rate will tend to undershoot its long-run change. If, on the other hand, one or all of these three channels is weak, then domestic nominal interest rates will tend to fall after the money expansion, and the exchange rate will tend to overshoot its long-run change. In the current example, the Canadian dollar depreciates by 1.5 per cent, overshooting its long-run level of 1 per cent. Canadian

**Figure 4**
**Permanent Canadian monetary expansion, 1990-2018**



inflation (shown in Figure 4b) increases by nearly 0.5 per cent, which is far more inflation per unit of demand stimulus than for fiscal policy, because of the opposite direction of effect on the exchange rate.[16]

*Permanent Change in Canadian Monetary Growth* — In Figures 5a through 5c, the results for a permanent 1-per-cent increase in the rate of growth of money in Canada are presented. The assumption of sticky nominal wages and partially backward-looking behaviour by wage setters in Canada is illustrated here. Output remains high for a longer period than when the level of money balances is changed. Nominal interest rates rise rather than fall due to the expected inflation built into short (1 year) and long rates. The Canadian dollar depreciates by 3 per cent in the first year and settles down to a long-run depreciation of 1 per cent per year. This is consistent with the widening of the inflation differential between Canada and the rest of the world, by the same amount.

In Figure 6a, the results are presented for the same increase in expected monetary growth but, in this case, the policy is announced to begin in 1993. Comparing Figures 6a and 5a, it is clear that the anticipation of the change in monetary growth dampens the effect of the policy in the year in which it takes place. Output rises by less than 0.5 per cent in 1993 (when the money balances first change), compared to close to 0.8 per cent in 1992 when the initial change in money balances occurred in Figure 5a. This occurs because wage setters in 1992 select a higher wage for 1993 to account for the change in expected inflation. In 1993, when the monetary growth rate increases, the real wage falls by less than when the shock was a surprise.

Also note that in Figure 6b, short-term real interest rates rise rather than fall in 1992. Again this can be seen from the money market assumptions. Income rises in 1992 in anticipation of future spending increases which places upward pressure on short-term interest rates before the supply of money is increased. Finally, referring to Figure 6c, it is clear that the Canadian dollar begins to depreciate in 1992 in anticipation of the relaxation of monetary policy.

### *Rise in Canadian Productivity*

The results for a rise in total factor productivity are shown in Figures 7a through 7c. This shock is implemented as a shift out in the Canadian production function; a greater amount is produced for the same amount of factor inputs. In addition, this simulation assumes that the Canadian fiscal deficit is kept constant rather than falling as the GDP rises.[17] As expected, output rises but note that it rises by more than the 1-per-cent rise in productivity. This occurs because of the increase in the marginal product of capital- and labour-

**Figure 5**
**Increase in Canadian monetary growth, 1990-2018**

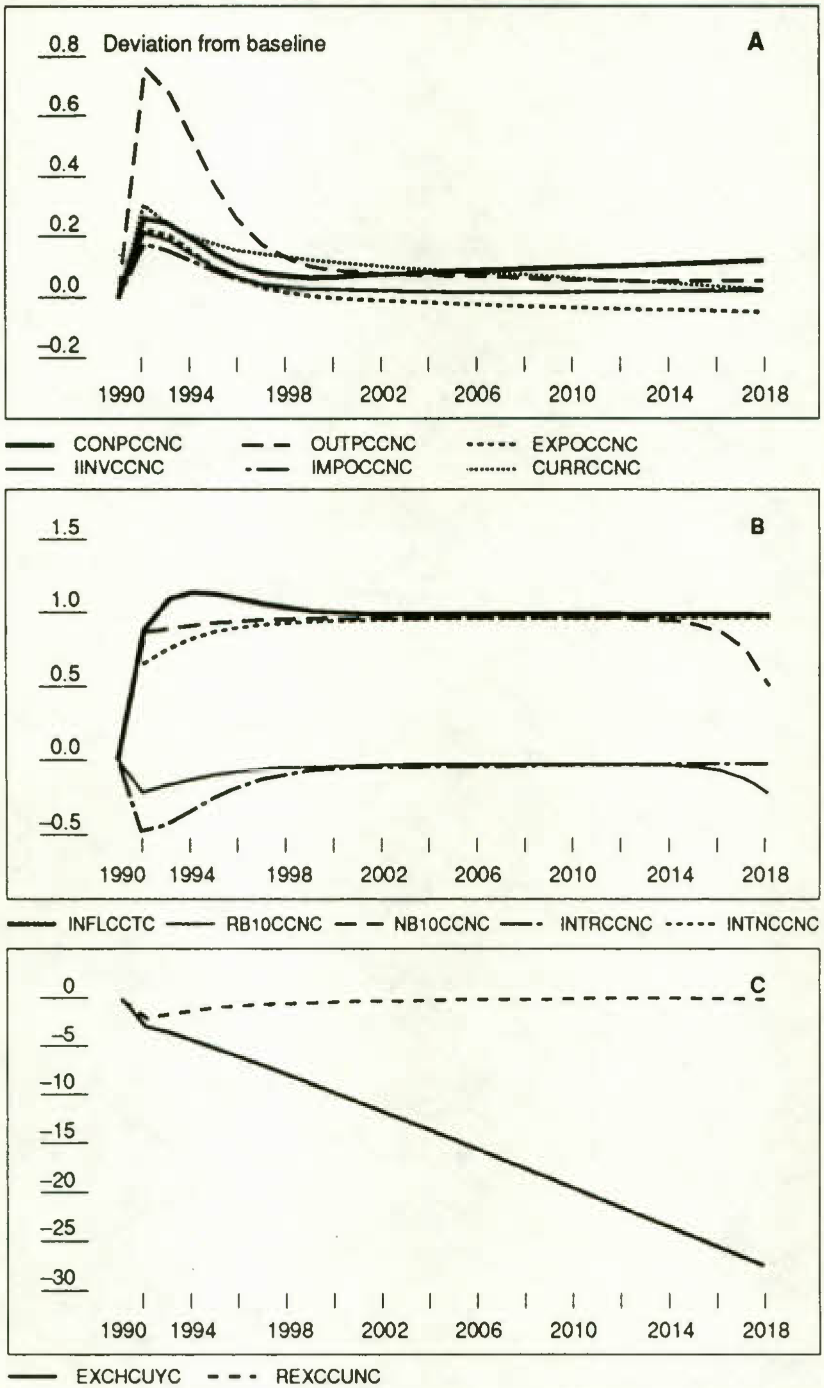


**Figure 6**
**Anticipated rise in Canada money growth, 1990-2018**

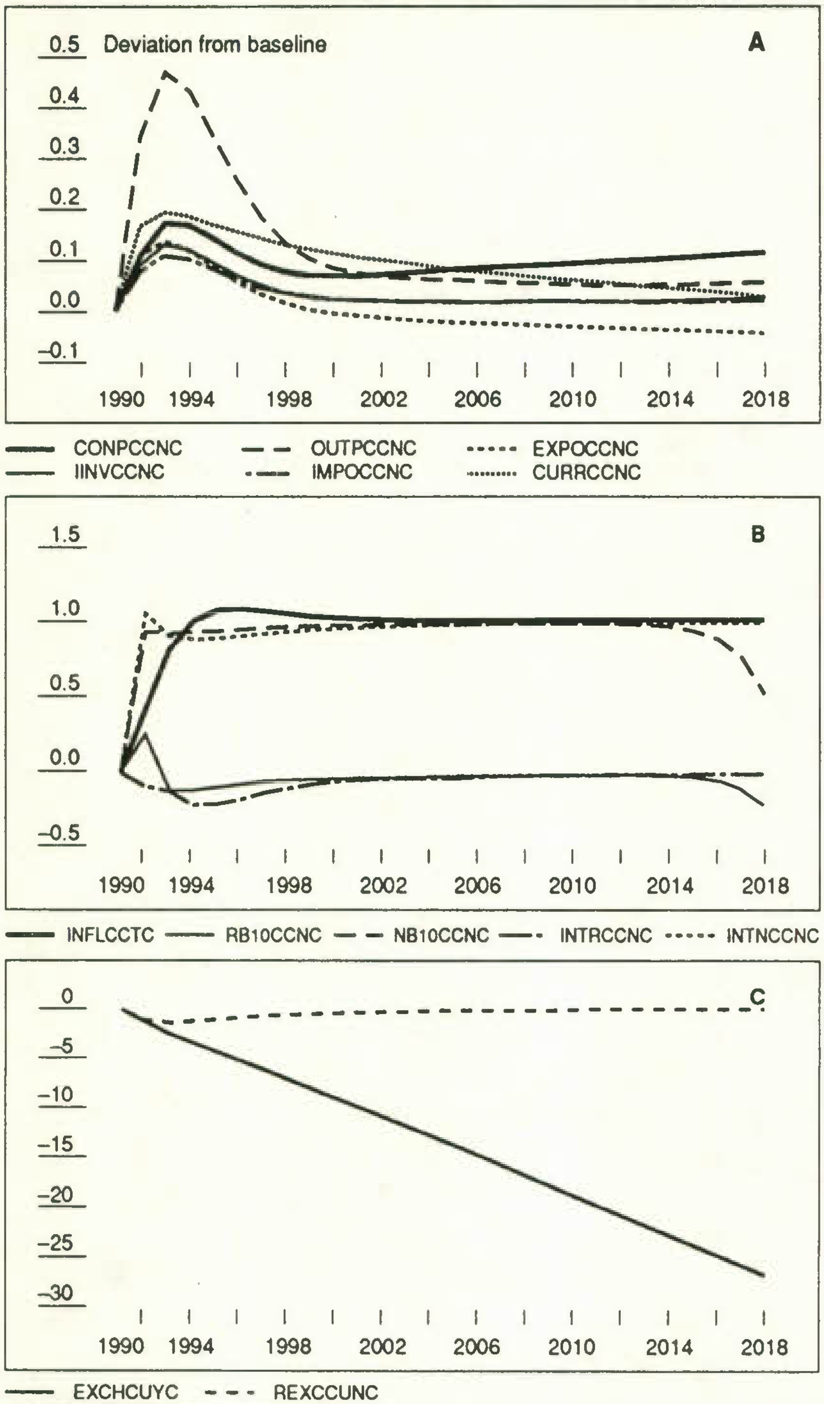
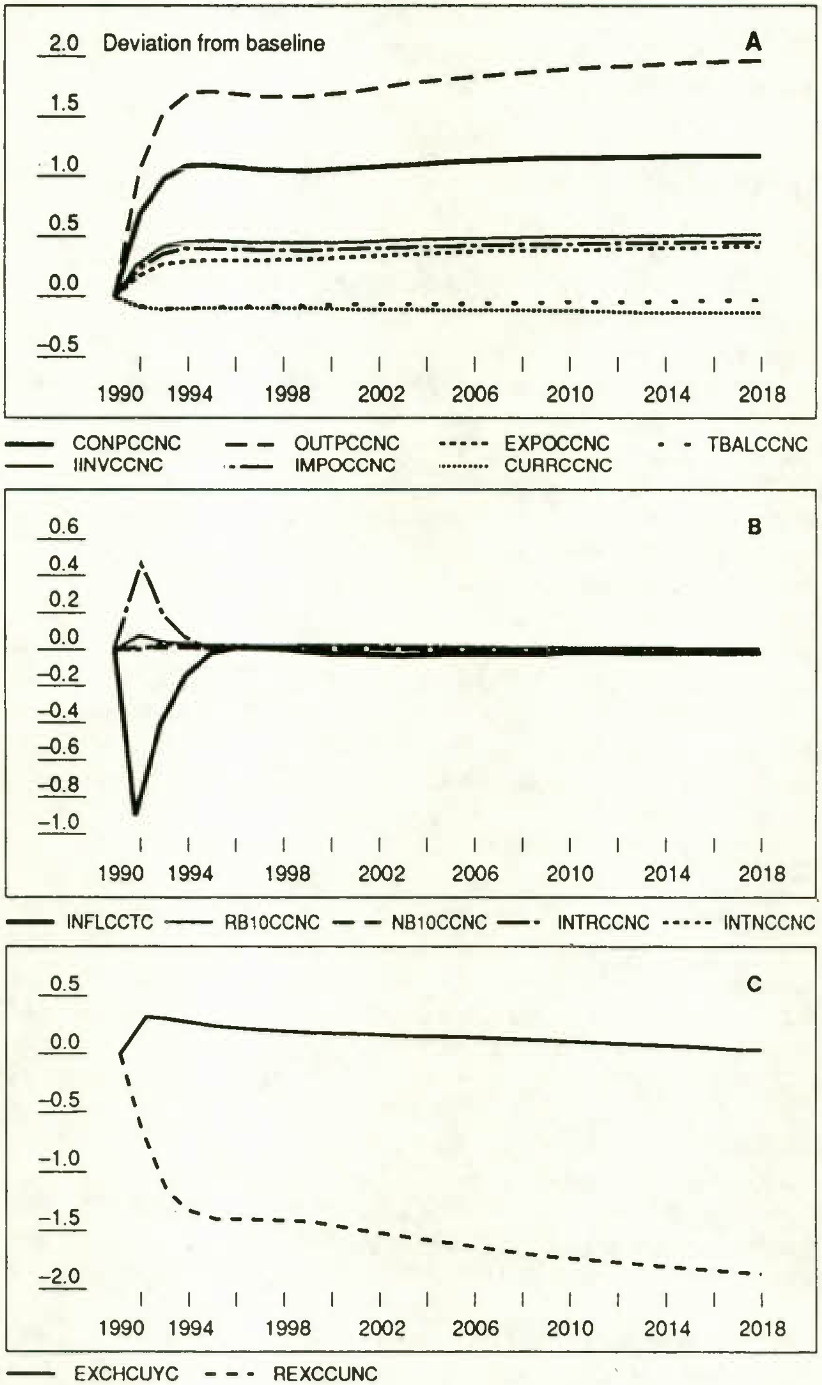


**Figure 7**
**Rise in Canadian productivity, 1990-2018**



induced firms to employ more labour and increase investment to raise the capital stock. Foreign capital flows into Canada as part of this process and in so doing, worsens the current account by appreciating the Canadian dollar. Given the assumption of fixed money stock, the rise in the level of output implies a fall in the price level over time. This raises the real wage which partly dampens the rise in employment.

### *U.S. Fiscal Expansion*

The consequences for the Canadian economy of a permanent rise in the U.S. fiscal deficit caused by a permanent rise in U.S. government spending are shown in Figures 8a through 8c. The U.S. fiscal expansion raises U.S. demand, which raises interest rates and appreciates the U.S. dollar, and depreciates the Canadian dollar by close to 4 per cent. This leads to an outflow of capital from Canada to the United States. As part of this adjustment, Canadian exports boom both because of higher income in the United States raising the demand for goods from all countries and also because the appreciation of the U.S. dollar makes Canadian goods relatively more competitive in the U.S. market. The rise in exports tends to raise output in Canada. In contrast, the shock also significantly raises interest rates in Canada which tends to lower investment and raises the cost of servicing the large Canadian foreign debt. The latter effect lowers private consumption which further dampens Canadian activity. The strong link between Canadian and U.S. interest rates can be seen in Figure 8b. In addition to the direct effect on interest rates, the depreciation of the Canadian dollar raises inflation by 0.3 percentage point. The nonaccommodating monetary policy offsets this after a number of years.

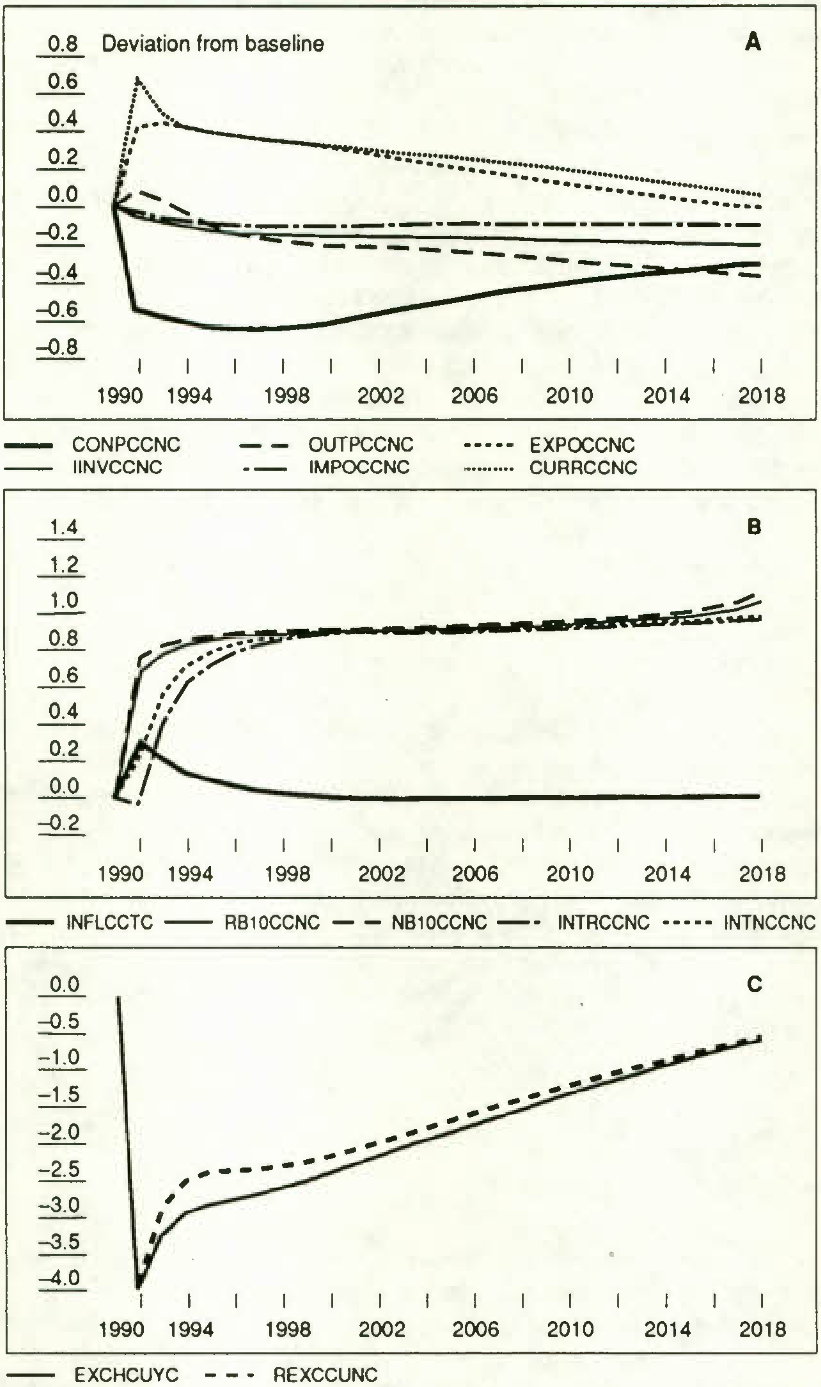
Note that in addition to the effects on demand in Canada there are also some important supply effects. A large part of Canadian investment is undertaken using imported capital goods from the United States. The Canadian depreciation raises the price of these inputs from the United States which acts to dampen aggregate supply in Canada. This also adds to the effect of higher demand on Canadian inflation.

### *U.S. Monetary Expansion*

Two monetary policy changes in the United States are considered. The first is an increase in the level of U.S. money balances; the second is an increase in the rate of U.S. monetary growth.

First, consider the results for the change in the level of U.S. money balances shown in Figures 9a through 9c. The shock is transmitted to Canada

**Figure 8**
**Permanent U.S. fiscal expansion, 1990-2018**



through a change in the U.S. aggregate demand, a change in the U.S./Canadian real exchange rate, and through a change in interest rates. The fall in U.S. interest rates leads to an increase in demand in the United States which spills over into higher demand for Canadian exports. Acting against this, however, is the depreciation of the U.S. dollar (shown in Figure 9c) due to lower U.S. interest rates and a resulting capital outflow. The U.S. dollar depreciation raises the price of Canadian goods in the U.S. market. The net effect of the change in U.S. demand and the change in the relative price of Canadian goods in the United States is an initial fall in Canadian exports. The fall in U.S. interest rates has a different effect on Canadian interest rates than on the interest rates in other countries. Usually the outflow of capital from the United States as a result of lower U.S. interest rates tends to lower interest rates in other countries. In the case of Canada, the lower U.S. interest rates lower the servicing costs of Canadian external debt which raises Canadian consumption through a relaxation of liquidity constraints. This boosts the demand and, for a given stock of money in Canada, initially raises short-term interest rates in 1992. In 1993, this effect is offset by the capital inflow into Canada which pushes down interest rates. On the supply side, the relative appreciation of the Canadian dollar makes the cost of imports of intermediate goods cheaper. This is especially the case for imports of U.S. capital goods. The demand increase in Canada is therefore met with some higher supply. The resulting effect of the demand stimulus on Canadian inflation is less than otherwise would be the case.

In Figures 10a through 10c, the results for a permanent 1-per-cent change in U.S. monetary growth are shown. The qualitative results on aggregate demand are similar to those for the change in money balances. The capital outflow from the United States into Canada now drives down Canadian interest rates which further raises the positive demand stimulus in Canada. Note again that the U.S. dollar depreciates by 1 per cent per year, reflecting the change in the inflation differential between the United States and Canada. This does not affect Canadian competitiveness over time, however, because the real exchange rate returns to baseline after the initial period of wage stickiness.

### *OPEC Oil Price Rise*

#### *Long Run*

The long-run effects of a permanent rise in oil prices (in real and nominal terms) are primarily determined by the supply side of the model. The rise in the relative price of oil leads to a substitution away from oil towards labour, capital, and other imported inputs in all industrialized regions. Output is permanently lower in all regions even though the growth rates in all regions

**Figure 9**
**Permanent U.S. monetary expansion, 1990-2018**

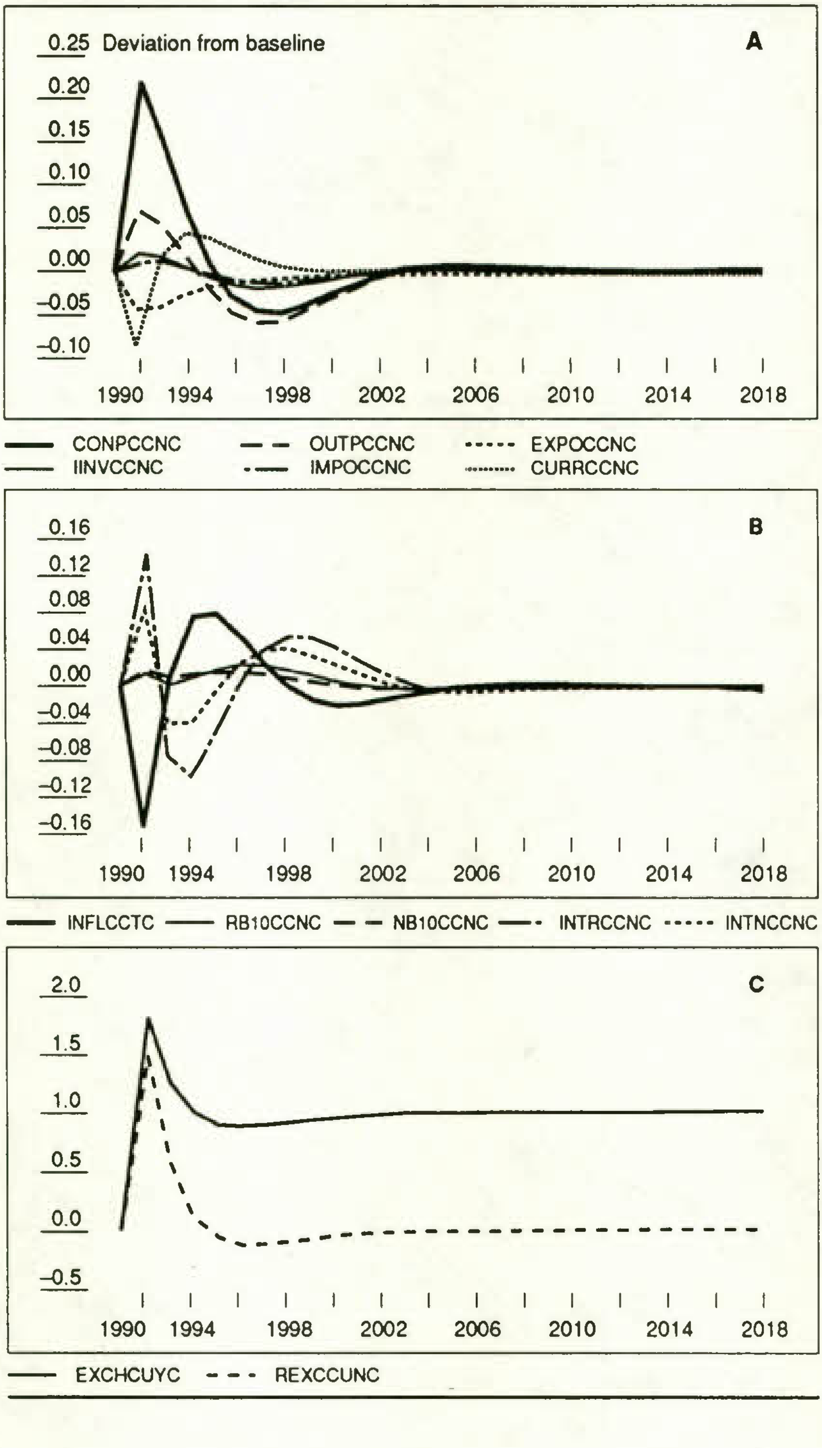
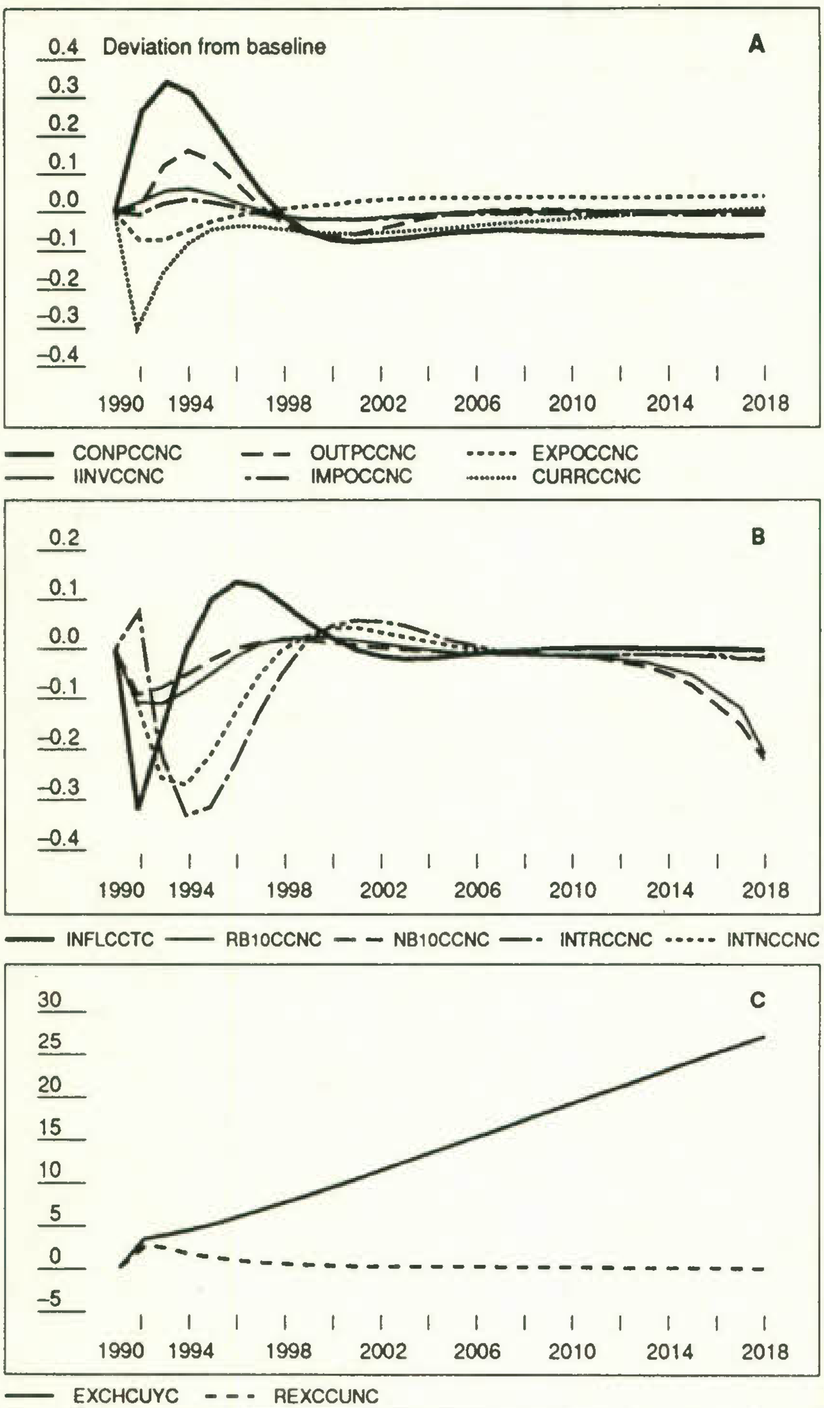


**Figure 10**
**Rise in U.S. monetary growth, 1990-2018**



ultimately return to 3 per cent. As shown in McKibbin and Sachs [1991, Chapter 2], the capital stock must fall given the constant returns technology we assume.

The effect on real interest rates is ambiguous and depends on the impact of the shock on world saving relative to world investment. Real interest rates rise because even though world investment falls, world saving falls more than world investment. Part of this effect is due to the assumption about fiscal policy in the simulation. The fall in output reduces the level of tax revenue which, in turn, reduces government saving in all countries. Alternative assumptions with appropriate policy responses will change this result, but using the current specification of policy will be helpful in understanding the properties of the model. More realistic specifications can easily be explored.

### *Short Run*

Figures 11a through 11c contain the results for a permanent cut in OPEC oil supply which raises oil prices by approximately 40 per cent.

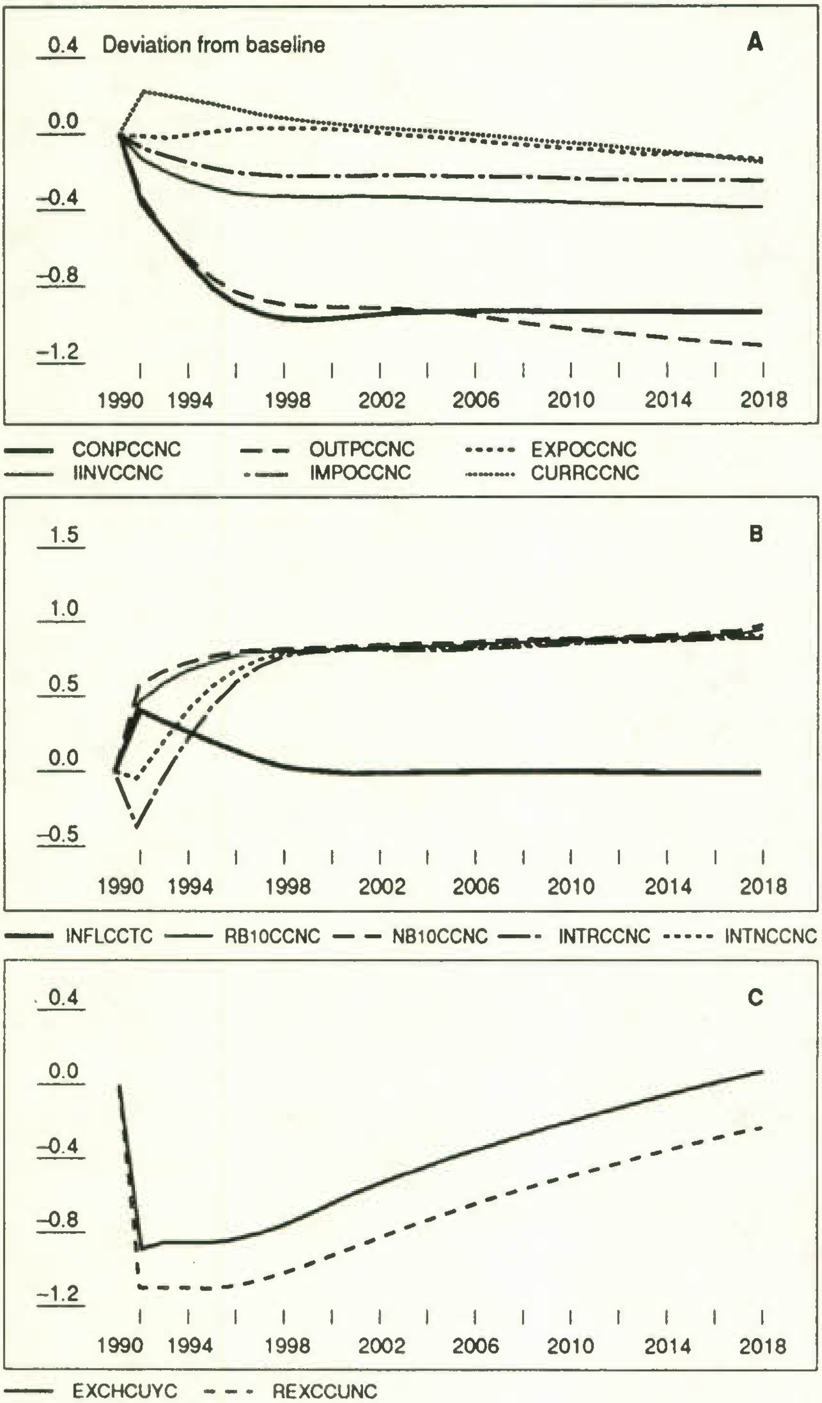
The shock is stagflationary. Output falls in Canada. Although Canadian oil reserves are incorporated into the model, it is assumed that these are priced at world oil prices and, therefore, the reduction in the production of goods is the same as in other countries. There are a number of effects on the value of Canadian wealth. On the one hand, the fall in gross output reduces future income from production which lowers wealth. Offsetting this is a higher value of Canadian oil which also forms a part of total wealth. In addition to these effects, a further key issue further worsens the outcome for Canada. In the current case where higher oil prices raise world interest rates, the interaction of higher interest rates and the higher cost of servicing the Canadian external debt drives down Canadian consumption. Even though the current account improves, this is the result of import reductions in an attempt to smooth the fall in consumption from permanently higher servicing costs of the Canadian external debt. The net result is a fall in wealth and a modest depreciation of the Canadian dollar by close to 1 per cent.

Inflation rises by about 0.3 per cent as a direct result of higher import prices, higher oil prices, and higher domestic prices which rise because of rising input prices. However, the inflation shock is not sustained because monetary policy is assumed not to accommodate the shock.

## A Baseline from 1987 to 2066 and Tracking Performance

In this section, the procedure followed to generate a baseline with the model over the period 1987-2066 is outlined. The approach followed here is the same

**Figure 11**
**Permanent cut in OPEC oil supply, 1990-2018**



as in McKibbin [1990*b*] which used an earlier version of the model and generated a baseline for the period 1989-2050. Many of the characteristics of the baseline presented here are familiar from that earlier work.

### *The Procedure*

Generating a baseline path for a model with rational expectations is not a straightforward exercise. The path for each variable in the model will depend on the model structure (including arbitrage conditions); the initial values of all state variables (such as capital stocks, asset stocks, and nominal wages); terminal values of jumping values (such as Tobin's $q$, human wealth, and exchange rates) given by sustainability conditions; and the entire future paths of exogenous variables in the model. The exogenous variables in the model are labour force growth, technical progress, money stocks, and fiscal deficits[18] in each industrial region, and OPEC oil supply and lending to developing countries.

The model is calibrated based on 1987 data. A baseline is generated from 1987. The technique used is an intertemporal version of a technique followed by Computable General Equilibrium modelers. It is standard in CGE modelling to generate the base year of the database as an equilibrium of the CGE model. This is part of the calibration process of the model. In the current case, this procedure is more difficult because the solution for the base year of 1987 will be conditional on assumption about the future paths of all exogenous variables in the model. For example, to calculate investment in 1987 requires a calculation of $q$ which depends on the expected future path of firm profitability. Similarly, to calculate consumption requires a value for human wealth which depends on the future path of after-tax labour income.

The way this problem is resolved is to add constants to particular equations such that when we solve the model for 1987, all variables in 1987 are exactly equal to their actual (or assumed) values in 1987. From 1988, without any revisions to expectations, the path of variables will be determined by the inherited dynamics from 1986 and the paths of exogenous variables from 1988. In the case where the state variables are unchanged from 1986 to 1987, and where exogenous variables are constant as a share of the GDP from 1988 onwards, this technique would generate a solution for 1988 which is identical to 1987, except for the levels of nominal variables which would be changing, given the inflation rate in the model implied by the monetary growth rate. In effect, 1988 would be a steady-state solution of the model in this case. By introducing initial dynamics, we begin the simulation assuming that the data are not a steady state of the model but are on the unique stable path towards a steady state.

One constant is calculated for each jumping variable in the model. In the case of Tobin's $q$ and human wealth, constants are added to the investment and consumption equations, respectively, for each country. In effect, for these jumping variables, the solution value for 1987 is normalized to be equal to their database values. For real exchange rates, wherever they appear in the model, *except in the arbitrage equations*, the model solution is replaced by the model solution plus a normalizing constant. A constant is added to the wage equation to ensure that expected inflation in 1987 equals the assumed value so that simulated real and nominal interest rates match the database. This effectively changes the gap between current employment and full employment in that equation.

All calculated constants are conditional on the model and the future paths of all variables as well as the values of each constant. The exact solution to this problem is not developed further here. This involves an iterative procedure which includes numerically calculating partial derivatives of all variables in the model with respect to small changes in each constant, and then solving a set of simultaneous equations, linking constants to actual and simulated values of all variables in an intertemporal setting.

To summarize, residual adjustments are added to each equation to replicate 1987. The world economy will evolve, given the future paths of all exogenous variables in the model and inherited dynamics from 1986.

### *The Baseline*

The particular baseline produced in this paper assumes that the (inflation adjusted) fiscal deficits as a share of own country GDP for each country are forever equal to those occurring in 1987. In addition, real government expenditure as a share of the GDP is fixed at the 1987 share which implies that taxes adjust to be consistent with both assumptions about fiscal policy. The monetary growth rates in each country are assumed to be equal to the inflation rates in each country in 1987. Finally, the real price of oil is assumed fixed at its 1987 value forever, and long-run productivity plus population growth are assumed to be 3 per cent per year everywhere. Given these assumptions, the procedure outlined above is then used to project from 1987 given the exogenous assumptions about future trends and the inherited dynamics from 1986.

This approach exactly replicates 1987 which means by default that tracking for 1987 is perfect. For 1988, it is not just a matter of comparing actual realizations in 1988 with the baseline projection because in 1988, new information was presumably received in each economy about shocks and unanticipated policy changes. This must be taken into account every year.

The procedure for doing this involves solving the model for 1987 then solving it again for 1988, inheriting the results for 1987 from the 1987 simulation, and changing any paths of exogenous variables or shocks. The model is then solved for 1989 to generate a new solution conditional on inherited dynamics and expected future policies and current shocks. If fully implemented, this is a very laborious procedure. The required software is built into the package which can undertake this comprehensive test of the model. In this section, results for the baseline from 1987 are presented without any revisions. This is then compared to the Canadian experience since 1987, and the simulation results from the section on Properties of the Model are used to see whether the policies identified can explain why the actual outcome deviated from the baseline that was projected given the information available in 1987.

The baseline for gross output is presented in Figure 12a. The figure contains the level of output relative to potential in each period. Note that the units are scaled to the 1987 ratio multiplied by 100 to get a percentage. For example, in 1987, the ratio of Canadian gross output to GDP was approximately 104.1 per cent. By this measure the ratio of GDP to the 1987 GDP would be 100. Long-run potential output is growing at 3 per cent, so a flat line in the figure implies that gross output is growing at the growth rate of potential output.

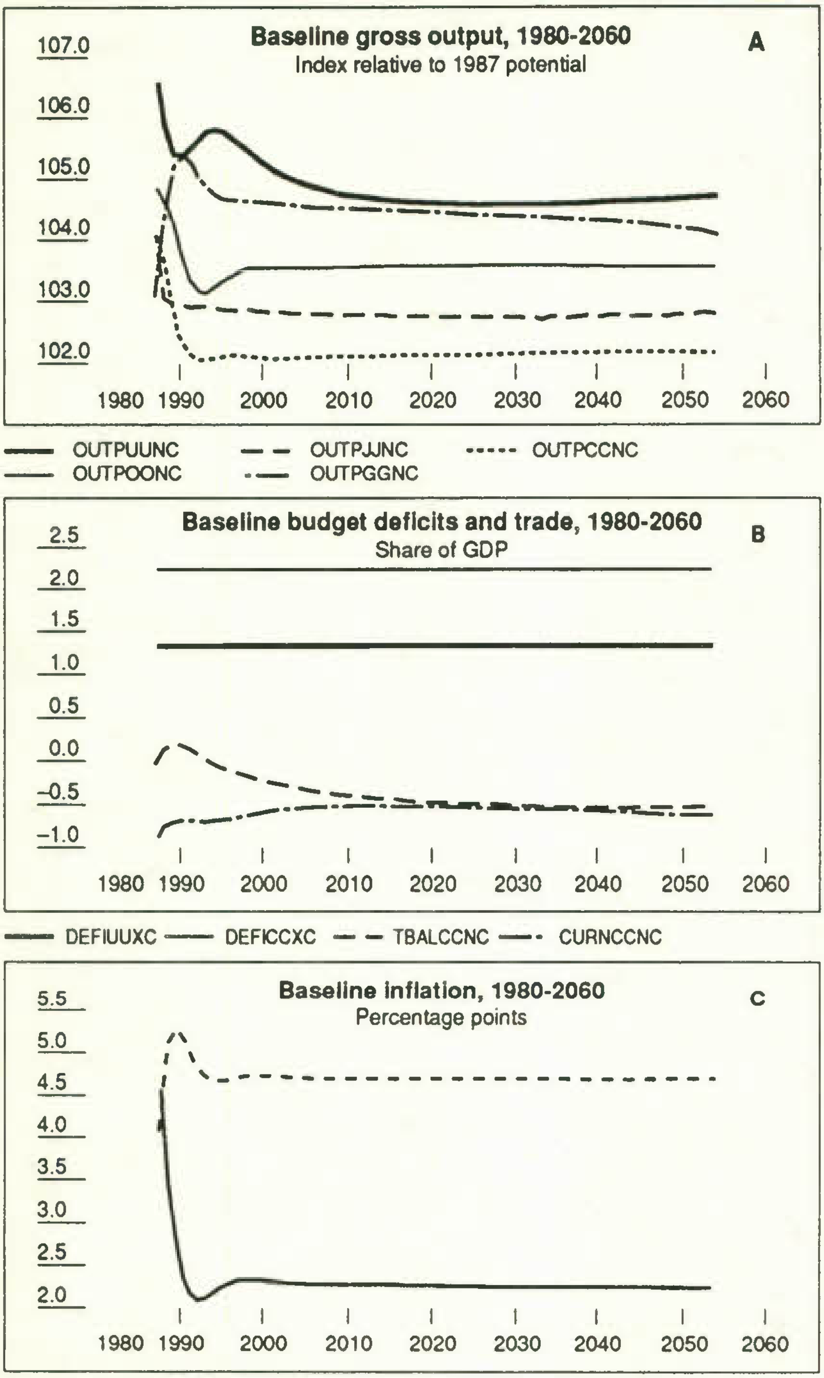
Results are presented for each major country in the model. In each case, inherited dynamics from 1986 and adjustments to long-run equilibrium lead to deviation from long-run trends for about a decade. After this time, output in each country returns to the shock-free long-run growth rate. Note, however, that even though growth rates converge, the levels of output differ.

Now focus on the result for Canada. A fall in the output ratio implies a growth rate less than baseline potential but output could still be growing. For example, between 1987 and 1988, output in Canada relative to trend falls from 104 to 103.5. This implies a growth rate of about 2.5 per cent in output between 1987 and 1988. Output growth then returns to 3 per cent by 1993.

It is important to stress once again that the results for 1988 onwards are projections which are conditional on the policy environment and the absence of new shocks from 1988 onwards. This is the underlying path for Canadian output over which shocks and policy changes need to be overlaid.

The results for fiscal deficits and the trade and current account balances are shown in Figure 12b. The U.S. fiscal deficit is also shown. These variables are scaled to the GDP. The inflation-adjusted fiscal deficit in Canada is projected to be a little over 2.2 per cent of the GDP forever. In the United States, it is assumed to be forever 1.4 per cent of the GDP. With the hindsight of 1992, both projections are underestimates of fiscal deficits after 1987.

**Figure 12**




SOURCE MSG model.

Although already discussed in the section on Properties of the Model, it is worth highlighting that a permanent fiscal deficit is sustainable in the MSG model as long as taxes rise to cover the servicing costs of a higher ratio of debt to GDP. This is achieved by the primary fiscal deficit (net of servicing costs) eventually moving into surplus.

Figure 12c contains the results for inflation in Canada and the United States. The initial assumption about monetary growth rates in the medium term are clearly shown in this figure. Inflation in Canada initially rose above 5 per cent in 1989, reflecting a depreciation in the Canadian dollar. In the medium term, inflation settles down to 4.8 per cent. In the United States, the steady-state inflation rate is closer to 2.4 per cent. This again reflects the arbitrary assumption about monetary growth rates. By 1990, there would need to be a substantial revision implemented in expected long-run inflation which could be incorporated into the baseline. The implications of doing this are discussed below.

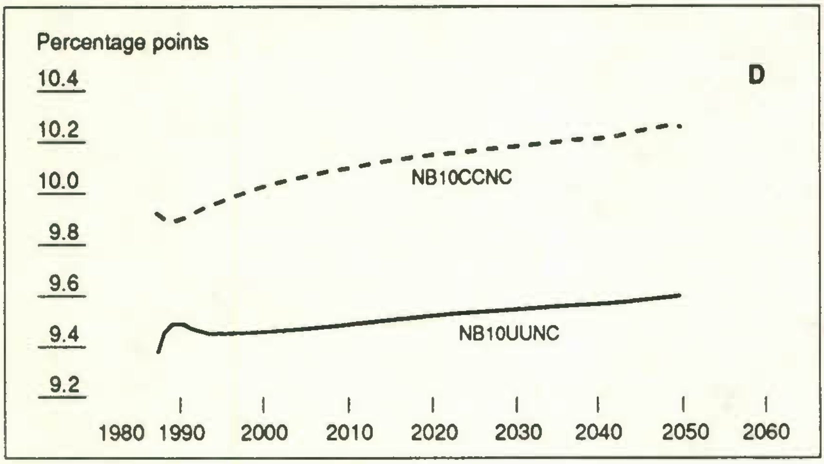
Figure 12d contains the results for interest rates on Canadian and U.S. 10-year bonds. The Canadian rate is above the U.S. rate reflecting the higher long-run inflation in Canada. In addition, long interest rates are trending up in both countries due to the continual accumulation of government debt in both countries.

The results for the real and nominal exchange rates of the Canadian dollar relative to the U.S. dollar are shown in Figure 12e. The inflation differential assumed in the baseline is clear from this figure which has the Canadian nominal exchange rate depreciating by about 2.4 per cent per year. Note that the real exchange rate initially depreciates but then returns close to the 1987 level.

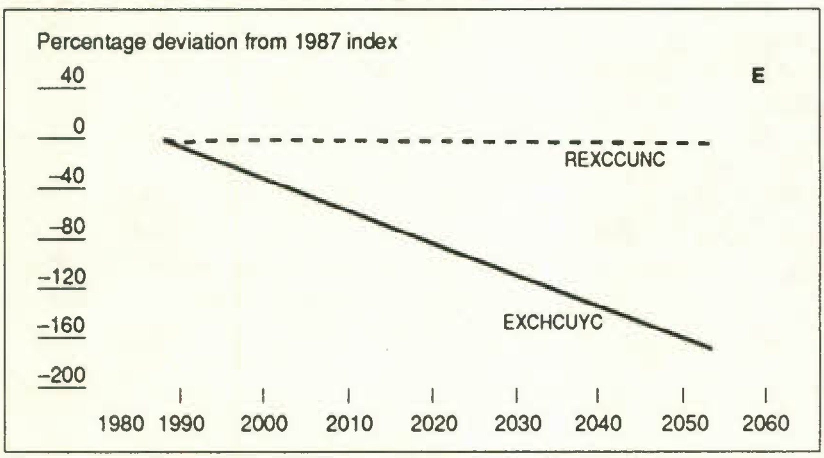
How do these results compare to the actual outcomes for Canada from 1987 to 1992? Some indication comes from examining Figures 13a to 13d. These figures contain actual data from 1974 to 1992 where the 1992 numbers are forecasts from the *OECD Economic Outlook.*

Referring to Figure 13a, we see that inflation in both the United States and Canada moves very close together, in contrast to the baseline results. Note however that the inflation rate for Canada is close to the baseline projection. The U.S. inflation rate is above that in the baseline. A reduction in interest rates in the United States after the October 1987 share market crash could contribute to this. The implication for the baseline of raising expected monetary growth in the United States can be seen from Figures 10a through 10c. Referring to Figure 13d, we see that in contrast to the baseline projection, the Canadian exchange rate appreciated in real and nominal terms relative to the U.S. dollar. However, the underlying baseline had a lower inflation in the United States and Canada. Adjusting for a higher inflation rate implies a

**Figure 12**
**Baseline 10-year bond rates, 1980-2060**



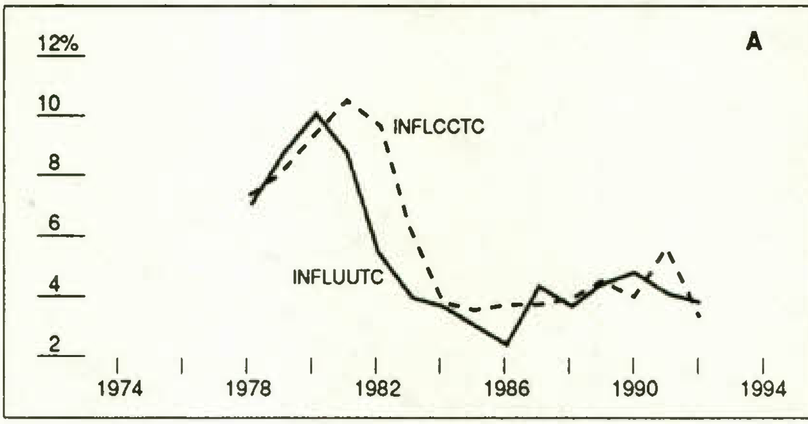

**Baseline real and nominal exchange rates, 1980-2060**



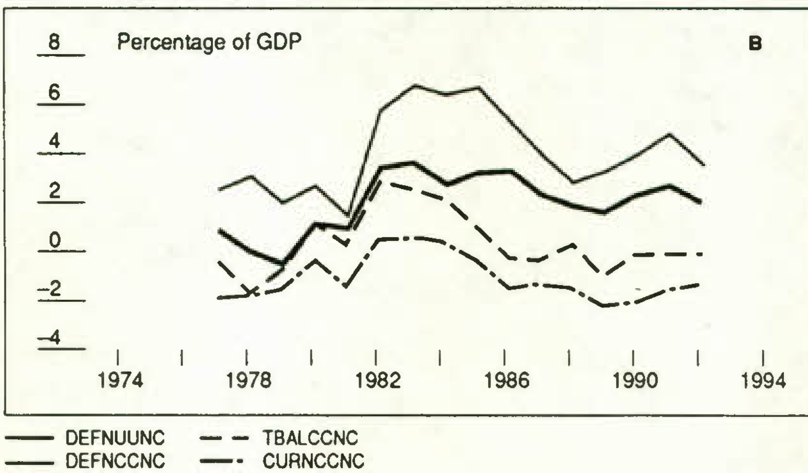

SOURCE MSG model.

substantially different path for the nominal exchange rate. Referring to Figure 10c, we see that an increase in expected inflation in the United States due to a higher steady-state rate of monetary expansion leads to a 4-per-cent appreciation of the Canadian dollar in the year of the shock, for a 1-per-cent higher monetary growth rate. If we adjust the baseline for the change on 2 per cent in the inflation outcome commencing in 1988, this appreciates the Canadian dollar in 1988 and eliminates the long-run depreciation on the Canadian dollar relative to the U.S. dollar. In addition, it also raises long-term U.S. interest rates.

**Figure 13**
**Canadian and U.S. inflation, 1974-94**




**Budget deficits and trade, 1974-94**

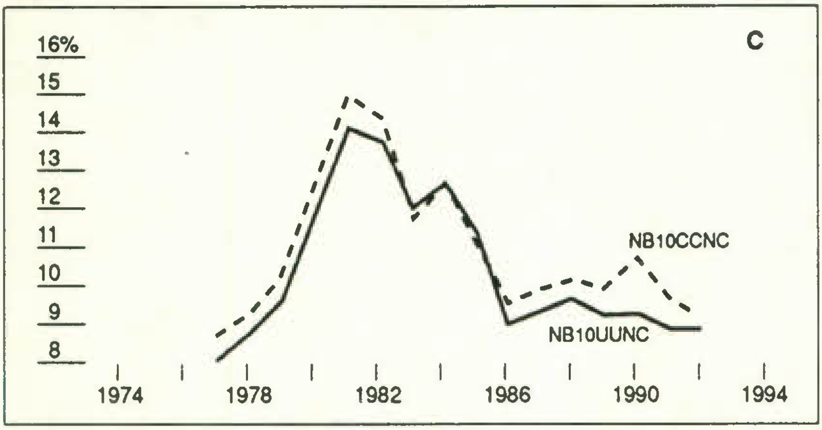



SOURCE OECD, *OECD Economic Outlook*, no. 49.

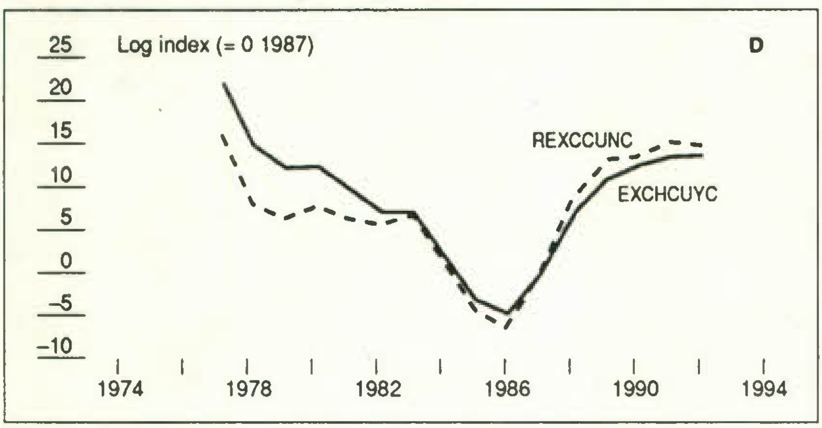
Next, turn to Figure 13b. We see from this figure that rather than staying a constant share of the GDP, the Canadian fiscal deficit increased during 1988-91. This should also have the effect of raising the Canadian interest rate and appreciating the Canadian dollar further given our simulation results in Figure 1a. In addition, the U.S fiscal deficit increased from 1989. This should offset the effect of the more expansionary Canadian fiscal policy on the Canadian trade and current account balances.

Finally, there is a rise in the bond rate in 1990. Part of this could be incorporated into the baseline through the impact of German unification, which in

**Figure 13**
**U.S. and Canadian 10-year bond rates, 1974-94**




**Real and nominal exchange rates, 1974-94**




Source OECD, *OECD Economic Outlook*, no. 49.

McKibbin [1990*b*] was shown to temporarily raise long-term interest rates by 100 basis points in the major economies. In addition, the temporary rise in oil price associated with the Gulf War also acts to raise interest rates for a given stock of money, as we saw in Figures 11a through 11c. Finally, the move to a more restrictive monetary policy in Canada during 1990 can also have this effect and can explain the gradual reduction in long-term bond rates after 1990 as expected inflation falls. In addition, this would further add to the appreciation of the Canadian dollar relative to the baseline.

The baseline generated from 1987 requires modification to allow for the events in Canada and the rest of the world since 1987. The preliminary attempt to do this using the simulation results from the section on Properties of the Model suggests that the revised baseline could be quite close to the actual outcomes.

## Conclusions and Direction for Future Research

This paper has presented the framework and properties of the MSG model of the Canadian economy. A number of important features have already been built into this model, such as the importance of trade and financial linkages between Canada and the United States. Although highly aggregated in its current form, we were able to incorporate the feature of Canada that a large share of investment is undertaken using capital goods imported from the United States. This has important implication for aggregate supply in Canada when exchange rates fluctuate. In addition, the model has been shown to have reasonable long-run properties including explicit treatment of accumulation of physical capital and financial assets. The important role of expectations in determining the short-run effects of policy changes has also been highlighted in the simulation results.

Further research on the current version of the model should involve a battery of sensitivity tests on key parameters and further econometric work on key substitution elasticities in production and consumption. As well as providing some preliminary empirical evidence on the response of the Canadian economy to internal and external shocks, the model in this paper is intended to lay out a framework for further research on the Canadian economy.

Future work should focus on more careful calibration of the short-run dynamics based on other Canadian research such as presented by Laxton and Tetlow [1991]. In addition, the distinction between traded and nontraded goods and resources versus manufactures should be explored in more detail (see Macklem [1990]). An attempt to deal with this in the Australian context, using the MSG model by McKibbin and Siegloff [1991], could be a useful next step. A further approach outlined in McKibbin [1991] which explicitly exploits the dynamic computable general equilibrium approach of the MSG model to provide detailed sectoral disaggregation in production and trade is probably the way to proceed in the medium term. Preliminary results from a multi-sectoral/macroeconomic approach in McKibbin and Sundberg [1990] have provided evidence that the sectoral composition of a small open economy does potentially matter for the adjustment to internal and external shocks.

Finally, a more detailed attempt to track the Canadian experience would be a valuable way to further develop the model. The complication of doing this correctly in a global model with rational expectations was amply demonstrated in the initial attempts to undertake this exercise in this paper. Nonetheless, the preliminary results in this paper suggest that the model is capable of explaining important aspects of the Canadian experience, just as it was able to explain key aspects of the experience of other major industrial economies during the 1980s.[19]

## Notes

1 Such models are the basis of the work by Dixon et al. [1982], Whalley [1985], and Deardoff and Stern [1986].

2 This bloc consists of Belgium, Denmark, France, Ireland, Italy, and Luxembourg.

3 This group of countries consists of Australia, Austria, Finland, Iceland, Norway, Spain, Sweden, Switzerland, the United Kingdom, and New Zealand.

4 Non-oil developing countries are based on the grouping in the IMF Direction of Trade Statistics.

5 Oil exporting countries are based on the grouping in the IMF Direction of Trade Statistics.

6 These countries are Bulgaria, Czechoslovakia, Eastern Germany, Hungary, Poland, Romania, Yugoslavia, and the USSR.

7 In general, quantity variables are linearized around their levels relative to potential GDP, while price variables are linearized in log form.

8 For notational convenience we will present all derivations assuming perfect foresight.

9 The treatment of oil is discussed in the next section. Note that in the model equations, *VOIL* and *VPE* do not appear separately but are included in the calculation of human wealth under the assumption that future streams of income are calculated using the same discount rates as for future labour income. This saves on the number of separate jumping variables that need to be solved.

10 See the section on the treatment of pass through of exchange rate changes into prices by firms operating in foreign markets.

11 This we find by imposing the transversality condition:

$$\lim_{t \to \infty} P_t^c C_t \, e^{-(Rt-n)t} = 0.$$

12 See, for example, Hayashi [1982*a* and 1982*b*] and Campbell and Mankiw [1987].

13 Steady-state human wealth is $(WL/P)(1-\tau_1)/(r-n)$.

14 Note that we have explicitly taken the change in the stock of money out of the government budget constraint. This implies that fiscal changes are funded by changes in debt or taxes. All changes in the stock of money occur through open market operations by the central bank.

15 The dynamics from an initial condition which is away from a steady state is a more important and interesting question for policy than the adjustment between steady states.

16 For fiscal policy the dollar appreciates, tending to reduce inflation, while for monetary policy the dollar depreciates, tending to increase inflation.

17 This was run with the deficit made exogenous by inverting the deficit equation to solve for an endogenous lump-sum tax on households.

18 In the usual version of the MSG2 model, we assume exogenous government spending on goods and services and determine the budget deficit endogenously. For the baseline exercise, it is convenient to make the overall deficit an instrument of policy.

19 See McKibbin and Sachs [1991, Chapter 5].

# List of Tables and Figures

## Tables



## Figures

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