The Economic Consequences of Alternative Exchange Rate and Monetary Policy Regimes in Canada *

R. Tiff Macklem, Patrick N. Osakwe and Lawrence L. Schembri

Bank of Canada
234 Wellington Street
Ottawa, Ontario
K1A OG9

E-mail: posakwe@bank-banque-canada.ca
October 1999

*Paper prepared for presentation at the 1999 annual meetings of the Network of American Central Bank Researchers in Santiago, Chile. The invaluable research assistance of Hope Pioro is gratefully acknowledged. The views expressed in this paper are those of the authors. No responsibility for them should be attributed to the Bank of Canada.
Introduction

Over the last fifty years, interest in the related issues of the definition of an optimum currency area and the choice of an exchange rate regime has fluctuated with the perceived instability of the prevailing regime. The early work on optimum currency areas by Mundell (1961), McKinnon (1963) and Kenen (1969) was in part a reaction to the growing dissatisfaction with the failings of the Bretton Woods system. This literature developed subjective criteria for defining an optimum currency area. After a brief probationary period in the 1970s, the flexible rate system also came under scrutiny after it proved to be more volatile than expected, especially the dramatic Reagan-Volcker appreciation of the U.S. dollar. The adoption of the pegged rate system among Western European countries and the movement towards a common currency also served to spur further research into optimum currency areas.1

Two events -- the successful adoption of the euro by eleven European countries in 1999 and the disruptive currency crises of the 1990s -- have once again stimulated the debate on the choice of an exchange rate regime. The debate, however, has become more focused on a smaller set of alternative exchange rate regimes: namely, a flexible regime versus some form of permanent fixed regime, whether it be a currency board, dollarization or a common currency. Intermediate managed regimes, in particular, garden-variety fixed exchange rates (de facto adjustable pegs) are no longer seen as viable. The currency crises of the 1990s clearly demonstrated that such regimes are unsustainable because market participants understand that most countries are unable or unwilling to take the measures necessary to maintain such regimes under intense speculative pressure and thus, the pressure becomes self-fulfilling.2 Concomitantly, the debate has broadened to include a larger set of countries, such as emerging market countries, who in the past were not considered as viable candidates for either a flexible or permanently fixed exchange rate regime.

In Canada, the recent debate has crystallised around two alternatives: the current flexible regime (in conjunction with an inflation target) and a monetary union with a common currency, similar to the EMU, that would include Canada, the United States and possibly Mexico, and other Latin American countries.3 A North American monetary union (NAMU) is preferred to a currency board or dollarization because it is viewed as being more politically palatable to Canadians and because it would likely produce the largest economic gains in terms of reduced transaction costs.4 Thus, the purpose of this paper is to examine the choice between a flexible exchange rate and a permanently fixed rate under a monetary union by analysing the economic and welfare implications for Canada.

Although the theoretical literature on optimum currency areas and alternative exchange rate regimes is extensive, with long lists of relevant criteria, advantages and disadvantages, it provides

---

1. Fenton and Murray (1993) provide a useful review of the older literature.
2. Compelling arguments in support of this view are provided by Obstfeld and Rogoff (1995).
3. Courchene and Harris (1999), Crow (1999), Grubel (1999), Laidler (1999), McCallum (1999), and Murray (1999) are recent contributions to the Canadian debate.
4. Argentina and, to a lesser extent, Mexico are considering dollarization. However, the Argentinian proposal, as outlined by Central Bank President Pedro Pou (1999), moves in the direction of a monetary union as it maintains that the U.S. authorities should return the seniorage and act as a lender of last resort.
only limited guidance for making a practical choice between alternative exchange rate regimes. In particular, the existing research has three significant weaknesses: first, none of the current models adequately captures the crucial trade-off between microeconomic efficiency and macroeconomic flexibility in a rigorous welfare-analytic framework (Krugman (1994)); second, few of the models are empirical, and of those, most are calibrated to data at the most aggregate level. This is an important limitation because the exchange rate is fundamentally a relative price and aggregate models have very limited role for relative prices. Finally, existing formal general equilibrium models of optimum currency areas are either static or ignore international borrowing and lending driven by intertemporal consumption/savings and investment behaviour.\(^5\)

The ultimate objective of our research program is to overcome these weaknesses in the existing research by modelling the economic and welfare consequences of a flexible exchange rate and common currency using a calibrated stochastic dynamic general equilibrium model for Canada. We develop a multi-sectoral choice theoretic model in which there is a well-specified role for relative prices, international borrowing is permitted, and short-run non-neutralities ensure a meaningful role for the choice of monetary regime. The model is used to examine the trade-off between the microeconomic efficiency gains (i.e., the reduction in transactions costs) resulting from a common currency versus the gains in macroeconomic stabilization provided by a flexible rate adjusting to asymmetric exogenous shocks; this trade-off is the central economic issue in the Canadian debate.\(^6\)

A flexible exchange rate generates transactions costs because it, like any other forward-looking asset price, is inherently volatile; in particular, it will respond to the release of new (and therefore, unexpected) information and to shifts in the expectations of investors about the future path of the underlying fundamentals.\(^7\) Although the real cost of this volatility is difficult to gauge, there is no doubt that it exists. For example, the spread on foreign exchange transactions is in general proportional to the volatility in the exchange rate. This conversion cost could hinder international transactions in merchandise, services and assets. In addition, risk-averse investors must pay to hedge against short-term exchange rate risk. Moreover, because forward cover for longer-term transactions does not exist, exchange rate volatility may also deter longer-term investments. While most empirical studies do not find a statistically significant effect of exchange rate volatility on trade or investment flows, other research finds that national borders have an unexpectedly large and negative impact on trade flows, which may be due, in part, to the costs resulting from different currencies.\(^8\) There are also other potential real costs associated with exchange rate volatility: segmented

\(^5\) For example Ricci (1997) is static and Beine and Docquier (1998) assumes that agents do not save. Lafrance and St-Amant (1999) surveys the recent literature.

\(^6\) The other main argument in favour of a flexible rate is an independent monetary policy to exert control over the domestic rate of inflation. However, when comparing prospective Canadian monetary policy to that of the United States or to that of a potential NAMU central bank with an explicit low-inflation target (like the European Central bank), the loss of monetary independence is not likely to be very significant.

\(^7\) Others have argued that exchange rates are not only subject to short-term volatility, but also longer-term misalignment because of the existence of speculative bubbles and rational noise traders. While these arguments may be appealing there is limited empirical evidence to support them. See Murray et al (1996).

\(^8\) Coté (1994) provides a survey on the impact of exchange rate volatility on trade. McCallum (1995) and Helliwell (1996) find that the Canada-U.S. border is a significant barrier to trade and Engel and Rogers (1996) find that it hinders price arbitrage.
capital markets, higher interest rate risk premiums and efficiency losses due to incomparable prices.

A common currency, however, produces more variable output and employment in the face of external real shocks than a flexible exchange rate because nominal wages, and to a lesser extent, prices are sticky. In contrast, a flexible rate responds when these shocks hit the economy, accelerating the adjustment process. In the case of Canada and the United States, the crucial point is that the two countries are exposed to asymmetric external shocks because of their different industrial structures. In particular, Canada’s exports are more heavily based on commodities; they represent approximately 9.5 per cent of GDP and 28 per cent of exports as opposed to 1.2 percent of GDP and 10 of exports for the United States. Thus, the flexible bilateral exchange rate helps the Canadian economy adjust to the differential impact of such shocks. This is important because of the lack of labour mobility between the two countries and the absence of supranational fiscal transfers.

By revealed preference, the Canadian authorities must believe that the transactions costs associated with the flexible rate do not (significantly) exceed the losses due to the volatility of output and employment under a fixed exchange rate. However, it is possible to envision ongoing processes that could reverse this inequality sometime in the future. In particular, exchange-rate related transactions costs could increase over time as trade flows between Canada and the United States, as well as investment flows between the two countries and also from third parties rise. Furthermore, it is likely that Canada’s endowment of productive factors and thus its industrial base will become more similar to the United States over time, primarily as human and physical capital accumulate and technology is transferred. Hence, Canada’s relative reliance on natural resources would diminish and the external shocks affecting the two economies would become less asymmetric. Hence, the benefit of having a flexible exchange rate serve as a macroeconomic buffer would be reduced. One of the goals of this research program is to model and assess these ongoing processes and to gauge if and when a switch to a common currency may be welfare improving. Although the focus of our research program is on Canada, our model and methodology are sufficiently general that they can be applied to other countries facing a similar choice between alternative exchange rate regimes.

To evaluate the relative economic implications of the current flexible regime and inflation (price-level) targeting versus a common currency, we adopt the small open economy dynamic general equilibrium (DGE) model of Macklem (1993). The Macklem model is a useful starting point because it explicitly addresses the particular structural features of the Canadian economy, which has a well-developed domestic manufacturing sector and an export-oriented resource sector. How-

9. Dupasquier et al (1996) find evidence that the external shocks hitting the two economies are asymmetric.
10. These commodity export data are from OECD 2-digit trade data on primary exports. These data are intended to be comparable across countries. Statistics Canada data, which also include commodity-based manufactured products, such as lumber, would put these figures higher for Canada; that is, commodity-based exports are 11 per cent of GDP and 35% to total exports.
11. We are assuming here that as the volume of trade and investment increase (i.e., the country becomes more open), the asymmetric nature of the shocks remains unchanged. Krugman (1993) and others have argued that as openness increases the asymmetry of the shocks may rise as countries become more specialized in production.
12. Note that in the context of the model, inflation and price-level targeting are the same. In practice, they have different implications for monetary policy.
However, we modify and extend the original Macklem model in several important ways: first, we analyse stochastic as well as deterministic shocks, second, we incorporate endogenous transactions costs due to exchange rate variability, third, we perform welfare-based comparisons of the different outcomes, and fourth, we analyse different inflation targets in conjunction with a flexible rate.

The primary type of shocks analysed in the model are terms of trade shocks because of the relative importance of exogenously determined commodity prices to the Canadian economy. The relatively rich structure of the model precludes analytical solutions to these shocks, so the model is calibrated to Canadian data and solved numerically in two versions: deterministic and stochastic. To the extent that the main elements of the model are common to other advanced commodity-exporting countries, the principal conclusions have implications for these countries as well. In a Canadian context, the model provides an opportunity to begin to address questions quantitatively as well as qualitatively.

The main findings of the paper are: one, in the presence of nominal wage rigidities, a flexible exchange rate substantially reduces fluctuations in employment relative to the case of a fixed exchange rate, but in the presence of perfect domestic and international capital markets, the implications for consumption and thus welfare are much more muted since households can borrow and lend to smooth consumption in the face of volatility in employment; two, the introduction of small transaction costs due to exchange rate uncertainty can have significant negative impact on welfare in a long-horizon, relatively frictionless model characterized by optimizing behaviour; three, assuming that the monetary authority always achieves its inflation target, employment and consumption are less volatile if the inflation rate is measured in terms of the CPI rather than the CPI less resources or the domestic price level in terms of an importable good; and four, for a flexible exchange rate to be welfare superior to a permanently fixed exchange rate in the presence of transaction costs, the costs of employment volatility need to be larger, either because of greater risk aversion on the part of households, reduced opportunities to insure against bad states (such as restrictions on borrowing), or the possibility of more extreme states. Although the link between employment fluctuations and the choice of exchange rate regime is well-known, the remaining results are not because this paper represents one of the first applications of welfare-based DGE modelling to the choice of exchange rate regimes.

The paper is organized as follows. In section one we present a deterministic version of the model with terms-of-trade disturbances and find the market clearing solution. We then add nominal wage rigidities and compare the results under alternative exchange rate regimes. The emphasis here is on the short-run, as opposed to the long-run, effects of terms-of-trade disturbances. Section two introduces stochastic shocks into the model, establishes the case for a flexible exchange rate regime, and examines the effects of adding exchange rate related transactions costs on the choice of exchange rate regimes. The paper concludes with a summary of the interesting results and some suggestions for future research.

13. There is a recent literature on the role of private risk-sharing mechanisms in the choice of exchange rate regimes. Antia, Djoudad and St-Amant (1999) provide a useful review. It is important to note that in our model all agents are essentially identical; hence, all the risk in the model is aggregate, rather than idiosyncratic risk.
1. The deterministic model

The model describes a growing, resource-exporting, small open economy. There are three types of goods in the economy: non-tradables (good 0), resources (good 1) and manufactured goods (good 2). All three goods are produced domestically, resources are exported, and manufactured goods are imported. There are two sources of growth in the economy: population growth (at rate \( \upsilon \)) and productivity growth (at rate \( \phi \)). The rest of the world is assumed to grow at the same rate as the small country, so the small country remains small in the sense that it takes the world real interest rate and the world prices of tradable goods as given. There are three sets of agents in the economy: consumers, firms, and a government.

1.1 Consumers

The economy is inhabited by a growing population of overlapping generations (OLG) of consumers who do not care about the well-being of future generations. The consumer’s problem is to maximize the discounted value of utility over his lifetime. Consumer behaviour is modelled following the Blanchard-Weil uncertain lifetimes approach in which consumers face a constant probability of death (\( \pi \)) throughout their lives. Relative to the standard infinitely-lived representative-agent model, the impact of introducing uncertain lifetimes is to increase the rate at which the consumer discounts the future above the pure rate of time preference (\( \rho \)). Labour supply is treated as exogenous. Each period consumers receive an endowment of one unit of time of which they take \( \Lambda \) units in leisure and work the remaining \( 1 - \Lambda \) units. Aggregate consumption is obtained by integrating over generations of consumers. In order to induce stationarity, aggregate variables are deflated by the labour force measured in efficiency units.\(^{14}\)

Assuming the momentary utility function is log-linear in the three consumption goods, optimal consumption plans give rise to the following aggregate equations measured in efficiency units:\(^{15}\)

\[
\begin{align*}
    c &= (\rho + \pi)[a + h] \\
    c_0 &= \theta_0 c / p_0 \\
    c_1 &= \theta_1 c / p_1 \\
    c_2 &= (1 - \theta_0 - \theta_1)c
\end{align*}
\]

---

\(^{14}\)For a more complete description of the uncertain lifetimes model of consumption behaviour see Blanchard (1985) and Weil (1989). The details of aggregation in the presence of growth are discussed in detail in Buiten (1988), and Obstfeld (1989) extends the standard model to the case of more than one consumption good.

\(^{15}\)Throughout the paper time subscripts are suppressed except in cases in which this could lead to confusion. A complete list of the variable and parameter definitions is provided in Appendix I.
Total consumption \( (c) \) is proportional to total wealth, which is the sum of human wealth \( (h) \) and non-human wealth \( (a) \). Human wealth is the present value of wage income \( ((1 - \Lambda)w) \) net of consumer taxes \( (\tau) \). Non-human wealth is the value of capital in firms \( (qk) \), plus government debt \( (b) \), foreign assets \( (f) \) and the value of land \( (p_L L) \). Land \( (L) \) is in fixed total supply and has value \( (p_L) \) because land is used in the production of resources. Consumption expenditures on non-tradables \( (c_0) \), resources \( (c_1) \) and manufactured goods \( (c_2) \) are proportional to total consumption expenditures where the \( \theta \)'s are the share weights in the log-linear utility function.

The prices that appear in (1)-(6) are relative prices with the import good selected as the numeraire. The prices of non-tradables \( (p_0) \) and resources \( (p_1) \), as well as the world real interest rate \( (r) \), are therefore defined in terms of the manufactured good. Since the small country exports resources and imports manufactured goods, \( p_1 \) is also the terms of trade.

### 1.2 Firms

There are three types of firms: non-tradables producers, resource firms and manufacturers. The problem facing all three types of firms is to maximize the value of the firm. This problem is dynamic because capital is costly to adjust. Firms are assumed to discount the future at the world real interest rate \( r \) plus a premium \( \psi \). At a formal level, this premium is a transactions cost associated with obtaining investment funds, and it is included in the model to capture the real equity premium documented by Mehra and Prescott (1985) that is required for the model to generate the observed aggregate capital-to-output ratio.\(^{16}\) Firms producing non-tradables and manufactured goods are modelled symmetrically, although their behaviour can differ substantially given different factor intensities. Resource production is modelled slightly differently in order to capture the importance of natural resource endowments for the production of resource-based goods.

#### 1.2.1 Non-tradable and manufactured goods

Producers of non-tradables and manufactured goods combine inputs of capital, labour and resources to produce output using a constant-returns-to-scale Cobb-Douglas technology. There are two types of capital: structures which are formed from the non-tradable good, and machinery

\[ h = E\int_t^\infty \{(1 - \Lambda)w(s) - \tau(s)\}\exp\left[\left\{-\left(r + \pi - \phi\right)(s - t)\right\}\right]ds \]  

\[ a = \sum_{i=0}^{2} (q_{i0}k_{i0} + q_{i2}k_{i2}) + b + f + p_L L \]  

---

\(^{16}\)Explaining the observed equity premium as a payment for risk bearing has proven to be a difficult task in a general equilibrium setting. The approach pursued in this paper of treating the equity premium as an exogenous transactions charge has the attraction of simplicity. Cochrane and Hansen (1992) and Kocherlakota (1996) provide excellent surveys of the literature on the equity premium puzzle.
which is formed from the manufactured good. Investment in both types of capital is subject to quadratic installation costs following the $q$ approach associated with Tobin (1969) and the cost-of-adjustment analysis developed by Lucas (1967) and Treadway (1969).

The behaviour of firms producing non-tradables and manufactured goods is described by the following equations. Again, quantity variables which exhibit trend growth are measured on a per productivity-adjusted-worker basis to induce stationarity.

\[
y_j = \Phi_j k_j^{\alpha_j} z_j^{\beta_j} n_j^{1-\alpha_j-\beta_j} \quad (7)
\]

\[
k_j = \frac{\sigma_j}{k_{j0} k_{j2}}^{1-\sigma_j} \quad (8)
\]

\[
k_{jm} = i_{jm} - (\delta_{jm} + \upsilon + \phi)k_{jm} \quad (9)
\]

\[
i_{j0} = \left( \frac{q_{j0} - p_0}{\eta_{j0} p_j} + (\delta_{j0} + \upsilon + \phi) \right) k_{j0} \quad (10)
\]

\[
i_{j2} = \left( \frac{q_{j2} - 1}{\eta_{j2} p_j} + (\delta_{j2} + \upsilon + \phi) \right) k_{j2} \quad (11)
\]

\[
q_{j0} = \mathcal{E}_t \int_t^\infty \left( \frac{\sigma_j \alpha_{j0} p_j(s) y_j(s)}{k_{j0}(s)} + \frac{(q_{j0}(s) - p_0(s))^2}{2\eta_{j0} p_j(s)} - p_0(s)(\delta_{j0} + \upsilon + \phi) \right) \exp[-(r + \psi - \upsilon - \phi)(s-t)] ds \quad (12)
\]

\[
q_{j2} = \mathcal{E}_t \int_t^\infty \left( \frac{(1-\sigma_j) \alpha_{j2} p_j(s) y_j(s)}{k_{j2}(s)} + \frac{(q_{j2}(s) - 1)^2}{2\eta_{j2} p_j(s)} - (\delta_{j2} + \upsilon + \phi) \right) \exp[-(r + \psi - \upsilon - \phi)(s-t)] ds \quad (13)
\]

\[
\gamma_{jm} = \frac{\eta_{jm} (i_{jm} - (\delta_{jm} + \upsilon + \phi))^2}{2} k_{jm} \quad (14)
\]

\[
z_j = \beta_j p_j y_j / p_1 \quad (15)
\]
Output in the non-tradables sector \((j = 0)\) and the manufacturing sector \((j = 2)\) is produced using inputs of an index of the capital stock \((k)\), resources \((z)\) and labour \((n)\) according to (7). The index of capital is a constant-returns-to-scale Cobb-Douglas function of capital formed from non-tradables \((k_{j0})\) and capital formed from manufactured goods \((k_{j2})\). Capital of both types \((m = 0, 2)\) depreciates at rate \(\delta_{jm}\) according to (9). From (10) and (11), investment in sector \(j\) in type-\(m\) capital \((i_{jm})\) depends on the difference between the market value of type-\(m\) capital in sector \(j\) \((q_{jm})\) and the spot price of new type-\(m\) capital. If this difference is positive, investment is above its steady-state level, while if it is negative, investment is below its steady-state level. The value of type-\(m\) capital in place in sector \(j\) is given by the asset-pricing relationships (12) and (13). The value of capital in place is equal to the expected present value of the current and future marginal products of capital where this marginal product is the sum of the marginal product of capital in production and the marginal reduction in the cost of installing a given flow of investment. As specified in (14), adjustment costs \((\gamma)\) are assumed to be a rising function of investment relative to the existing capital stock and are only incurred when investment is above or below its steady state. From (15) and (16), resource inputs are used until their marginal product equals their relative price, and labour is hired until its marginal product equals the real wage.

### 1.2.2 Resources

The structure of production in the resource sector is similar to the non-tradables and manufacturing sectors with one important difference. In addition to labour and capital, resource production requires the input of a fixed factor called land. This fixed factor is best interpreted broadly to include natural resource endowments such as forests, minerals, fish, and hydroelectric potential, as well as arable land in the case of agriculture. Land is in fixed total supply, but its productivity is assumed to increase over time as a result of exogenous technical progress associated with improved methods of finding and extracting natural resources. In order to obtain a balanced growth path in the model, it is further assumed that the productivity of land grows at the rate of labour augmenting technical progress in production plus the rate of population growth. This assumption is motivated largely by the practical benefits of obtaining a balanced growth path for the solution of the model, but may be justified by the fact that, over the horizon of interest in this paper, the resource sector can be reasonably expected to have the same average growth rate as the other sectors. With the introduction of land in this form, the production function for resources in terms of efficiency units is:

\[
y_1 = \Phi_1 k_1^{\alpha_1} L^{\omega_1} n_1^{1-\alpha_1-\omega_1}
\]

where \(L\) is land. The production function is constant returns to scale in the three inputs, but in terms of the variable factors -- capital and labour -- production exhibits decreasing returns to scale. It is worth noting that the presence of a fixed factor in resource production plays an important role in determining the equilibrium structure of this economy. In the absence of a fixed factor in the resource sector, the small economy would specialize in the production of a single tradable
good -- either resources or manufactured goods (as in Macklem (1993a)). The presence of land limits the ability of the resource sector to expand, and permits both resource production and manufacturing to coexist in equilibrium for a range of parameter values.

In other respects resource firms are the same as non-tradables producers and manufacturers. The behaviour of resource firms is therefore also described by equations (8)-(14) with \( j = 1 \). The labour demand equation is slightly different reflecting the presence of land in the production function:

\[
n_1(t) = (1 - \alpha_1 - \omega) p_1(t) y_1(t) / w_1(t). \tag{18}
\]

### 1.3 Government

The government is assumed to have exogenously fixed total spending requirements \( g \). Expenditures are allocated to non-tradables \( (g_0) \), resources \( (g_1) \) and manufactured goods \( (g_2) \) according to the decision rules

\[
g_0 = \xi_0 g / p_0 \tag{19}
\]

\[
g_1 = \xi_1 g / p_1 \tag{20}
\]

\[
g_2 = (1 - \xi_0 - \xi_1) g \tag{21}
\]

where the \( \xi \)'s are fixed share weights. These decision rules are not derived from a theory of government but have the attraction that they are symmetric with consumer behaviour and the share weights are easily calibrated to the data.

Expenditures are financed by imposing taxes \( (\tau) \) and issuing government debt \( (b) \). The government is assumed to target a fixed level of debt in efficiency units (so the debt-to-GDP ratio remains constant along the steady-state growth path). Taxes are set to cover the net service cost on the outstanding stock of government debt and government spending on goods and services.

\[
\tau = (r - \nu - \phi) b + g \tag{22}
\]
1.4 Market clearing

Market clearing requires that demand equals supply in goods, labour and asset markets.

\[ \tilde{y}_0 = c_0 + i_{00} + i_{10} + i_{20} + \gamma_{00} + \gamma_{02} + g_0 \]  
(23)

\[ \tilde{y}_1 = c_1 + z_0 + z_2 + \gamma_{10} + \gamma_{12} + g_1 + x_1 \]  
(24)

\[ \tilde{y}_2 = c_2 + i_{02} + i_{12} + i_{22} + \gamma_{20} + \gamma_{22} + g_2 + x_2 \]  
(25)

\[ 1 - \Lambda = n_0 + n_1 + n_2 \]  
(26)

\[ w_0(t) = w_1(t) = w_2(t) \]  
(27)

\[ \dot{p}_L = (r + \psi - \nu - \phi)p_L - \omega_p y_1 / L \]  
(28)

\[ ca \equiv \dot{f} = (r - \nu - \phi)f + x \]  
(29)

\[ x = p_1 x_1 + x_2 \]  
(30)

Equations (23)-(25) set demand equal to supply in the goods markets for non-tradables, resources and manufactured goods where \( \tilde{y}_j \) is gross output net of the transactions costs associated with financing investment.\(^{17}\) Since non-tradables are neither imported nor exported, (23) is the familiar closed-economy equilibrium condition with the addition of adjustment costs (the \( \gamma \)s).\(^{18}\) Equilibrium in the labour market requires that labour is fully employed and the expected real wage is equal in all three sectors. The demand for land equals its fixed supply when the price of land equals the expected present discounted value of the current and future marginal products of land. In the steady-state the relative price of land grows at the rate at which land becomes more productive; \( p_L \) in (28) is the relative price of land adjusted for productivity. The model is closed by equations (29) and (30) which describe the evolution of foreign assets and define the trade balance \( (x) \).

---

17 In terms of the algebra of the model, \( \tilde{y}_j = y_j - \psi(q_{j0} k_{j0} + q_{j2} k_{j2}) / p_j \).

18 In the steady state, adjustment costs are zero, so the goods-market equilibrium condition is consistent with national accounts’ concepts. In the short run, adjustment costs can be included as part of investment to be consistent with the structure of the national accounts, but since installation costs are generally very small (relative to output), this adjustment has little practical importance.
1.5 Some definitions

Before turning to calibration issues, it is useful to define several macro variables of interest in the context of the model. Since non-tradables producers and manufacturers both use inputs of an intermediate good in production, output in these sectors as defined above is gross output. The more familiar value-added concept \( y_{va} \) can be constructed by subtracting off resource inputs:

\[
y_{va} = \hat{y}_j - p_1 z_j / p_j
\]

Aggregate income or output at current prices \( y^{va} \) is then obtained by summing the value added of each sector, all measured in units of a common numeraire. Following the convention of expressing prices and quantities in terms of manufactured goods, we have:

\[
y^{va} = p_0 y_0^{va} + p_1 y_1^{va} + y_2^{va}
\]

In standard fashion, other macro aggregates, such as total investment or investment in structures, can be obtained by adding up goods across sectors all priced in a common numeraire. The choice of manufactured goods as the numeraire is somewhat arbitrary. An alternative approach is to measure macro aggregates in terms of the consumption basket. In the economy described above there is a natural real consumer price index \( rcp_i \) which is embodied in the expenditure function associated with the solution to the consumers problem:

\[
rcpi = \left( \frac{p_0}{\theta_0} \right)^{\theta_0} \left( \frac{p_1}{\theta_1} \right)^{\theta_1} \left( \frac{1}{1 - \theta_0 - \theta_1} \right)^{1 - \theta_0 - \theta_1}
\]

The \( rcp_i \) is the relative price of consumption basket in units of the manufactured good. Relative prices and thus aggregate quantities can therefore be measured in units of the consumption good by dividing relative prices in terms of the manufactured good by \( rcp_i \).

The real consumer price index also provides a convenient basis on which to define the real exchange rate. In empirical work, the real exchange rate is typically measured as the ratio of a foreign aggregate price index to the corresponding domestic aggregate price index, all measured in a common currency. If we use consumption-based price indices, the corresponding definition of the real exchange rate in the model is:

\[
er = \frac{rcpi^*}{rcpi}
\]

where \( rcpi^* \) is the real consumer price index in the foreign country. If we assumed that \( rcpi^* \) has the same form as \( rcpi \) and the share weights in utility (the \( \theta \)s) are the same in both countries, the real exchange rate simplifies to:

\[
er = \left( \frac{p_0^*}{p_0} \right)^{\theta_0}
\]
where $p_0^*$ is the (exogenously determined) relative price of non-tradables in the foreign country. For a given $p_0^*$, movements in the real exchange rate will therefore reflect demand and supply conditions for non-tradables in the domestic economy.

### 1.6 Calibration

The model is calibrated to capture the salient features of the Canadian economy based on three types of evidence: the input-output and final demand structure of the Canadian economy, average shares or ratios from aggregate time-series data, and econometric evidence from micro and macro studies. A complete list of the chosen parameter values is provided in Table 1. The Canadian final demand tables are used to compute the expenditure shares for both consumption and government purchases, and the input-output tables form the basis of the share parameters in production. In all cases, shares are obtained from 1986 current-dollar figures at the M-level of aggregation.\(^{19}\)

As shown in Table 1, the share of non-tradables in consumption is 50 per cent followed by manufacturing goods at 45 per cent, while the government spends 96 per cent of its budget on non-tradables. The input-output tables do not explicitly account for inputs of land. Following Stuber (1988), the share of land in the production of resources is set at 20 per cent, implying returns to scale in this sector of 80 per cent. The stock of land is normalized to unity.

The expenditure and input shares are based on the following classification of non-tradables, resources and manufactured goods. The non-tradables sector includes construction; transportation and storage; communications; wholesale and retail trade; insurance, finance and real estate;\(^{20}\) community, personal and business services; and the unallocated portion of final demand (almost all of which is government services). This definition of non-tradables is consistent with international classification adopted by Kravis, Heston and Summers (1980), with the exceptions that they do not include retail and wholesale trade or government services, but do include utilities (electricity, gas and water). In the context of the Canadian economy, utilities would seem to fit more naturally in the resource sector since Canada exports electricity. With respect to retail and wholesale trade, a strong case can be made that they belong in non-tradables, while unallocated demand is included so that the production of all three sectors sums to GDP.

The resource sector is defined to include primary industries and resource processing, as well as utilities. The primary industries are agriculture, fishing, forestry and mining, and resource processing includes pulp and paper, wood products, primary metals, chemicals, and petroleum and coal refining. The decision to include processing in the resource sector reflects the integrated nature of many resource industries and the view that including processing in manufacturing (as in the national accounts) understates the importance of the resource sector. The manufacturing sector is defined residually as anything which is neither non-tradables nor resources. Table 2 reports selected ratios which describe the initial steady state of the model. The non-tradables sector com-

\(^{19}\)The M-level of aggregation is the “medium” level in the input-output and final demand tables, and disaggregates into 50 industries and 50 goods.

\(^{20}\)Real estate includes the imputed return to owner-occupied dwellings.
prises 56 per cent of GDP followed by the resource sector at 24 per cent and the manufacturing sector at 20 per cent. The resource sector is the least labour intensive, so while it produces about one quarter of GDP, it is less important as an employer.

The parameters governing the evolution of capital and labour are based on average ratios in the data or draw on other studies. Capital is assumed to depreciate at the same rate in all three sectors, and, based on aggregate capital stock data, the depreciation rates for structures and machinery are set at 3 per cent and 12 per cent respectively. Capital of both types is defined to include private-sector and government capital, and structures is defined to include housing as well as non-residential construction. Although the sectors differ in their capital intensities, all three sectors are also assumed to combine structures and machinery in the same proportion to form the composite capital good which enters the production function. This simplifying assumption is motivated by the fact that the input-output tables measure the return to capital residually, so there is no information on the breakdown of capital inputs. At the aggregate level, machinery has been rising as a proportion of the capital stock, but structures remain the bulk of capital. From 1985 to 1991 the stock of structures averaged about five times the stock of machinery. The share parameter $\sigma$ in the model is chosen to deliver this 5-to-1 ratio; this requires a value for $\sigma$ of 0.74. The adjustment cost parameters for capital (the $\gamma$s) average 2.0 following Lipton and Sachs (1983). However, based on the casual observation that it takes longer to build structures than to install machines, the adjustment cost parameters for structures are set at 2.5 and those for machinery are set at 1.5. In the absence of sectoral evidence on installation costs, adjustment cost parameters are set equal across sectors.

The initial levels of productivity in the resource and manufacturing sectors (the $\Phi$s) are chosen so that the small economy exports resources and imports manufactured goods in the initial steady-state. In Canada, net exports of resources and net imports of manufactured goods have both averaged between 11 per cent and 12 per cent of GDP. In the model, the initial level of productivity in the manufacturing sector is normalized to unity, and the initial level of productivity in the resource sector is set at 1.120 to deliver a steady-state exports-to-GDP ratio of 12 per cent. The initial level of productivity in the non-tradables sector is normalized such that the price of non-tradables relative to manufactured goods is unity. Since the terms of trade is also normalized to unity, all three goods have the same relative price in the initial steady state.

The government sector in the model is calibrated to match average shares obtained from aggregate time series data. Consumer taxes are set at a level sufficient to sustain government expenditures at 18 per cent of GDP with a debt-to-GDP ratio of 50 per cent.

This leaves three unassigned parameters in the model -- the probability of death, rate of time preference, and the premium in the firm’s discount rate. The probability of death is set at 5 per cent, which implies that consumers have a horizon of 20 years. This choice was made on the basis that the typical individual works about 40 years, so the average worker has 20 remaining years. The rate of time preference is chosen so that the ratio of foreign assets-to-GDP in the model is -30 per cent, which, based on historical experience, is roughly consistent with a government debt-to-GDP ratio of 50 per cent. The rate of time preference required to deliver the -30 per cent ratio is about 1.3 per cent, which is well within the plausible range. The premium which enters the firm’s dis-
count rate is chosen in order to obtain the observed capital-to-GDP ratio of 263 per cent. The required premium is about 5 per cent which is marginally below the real equity premium of 6 per cent to 7 per cent reported by Mehra and Prescott (1985).

The model cannot be solved analytically so numerical solutions are employed. A static or steady-state version of the model is solved as a non-linear system using Newton’s algorithm. The saddle-path dynamics resulting from shocks to the model are solved using the Stacked Newton algorithm available in TROLL (see Armstrong, Black, Laxton and Rose, 1998). The model has eight non-predicted variables (or jumpers) -- human wealth, the price of land, and the prices for the two types of capital in each of the three sectors. The standard Blanchard and Khan (1980) stability and uniqueness conditions are satisfied for a linearized version of the model, but all simulations use the full non-linear model.

1.7 Adding Nominal Wage Rigidity

The market-clearing model described above provides a useful tool for studying the medium-term and steady-state effects of terms-of-trade disturbances, but is less useful for short-run analysis. In particular, because it is based on flexible prices and wages, it is not a useful framework for comparing alternative exchange rate regimes since the choice of regimes is irrelevant for real outcomes if wages and prices are perfectly flexible.

In order to overcome this limitation and address some short-run features of Canadian data, wage inflexibility is introduced into the model by assuming that consumer-workers and firms enter into nominal wage contracts. The form of the contracts considered in the model and their implementation draws on work by King (1990), Cho and Cooley (1995) and Rankin (1998), and is closely related to the earlier work of Gray (1976) and Fischer (1977). The optimization problems facing firms and consumers are not resolved subject to the nominal contracts. Instead, the nominal contracts are simply overlaid on the market-clearing model. While this is a limitation of the analysis, a comparison of the results in Cho (1993) and Cho and Cooley (1995) suggest that this simplification does not have important implications for the results.

The basic form of the contract is that workers and firms set nominal wages to clear the labour market \textit{ex ante}, and, in return for a fixed nominal wage for the duration of the contract, workers agree to supply as much labour as the firm demands \textit{ex post}. Let $W_{j,t-s}(t)$ be the nominal wage for transactions at time $t$ set at time $t-s$ in sector $j$. At time $t$, non-tradables producers and manufacturers demand labour inputs

$$n_j(t) = \frac{P_j(t)p_j(t)\{1 - \alpha_j - \beta_j\}y_j(t)}{W_{j,t-s}(t)}$$

\[ (36) \]

\[ \]

\[ \]

21.For a review of the literature on nominal price and wage setting, see Taylor (1998).
where $P_2$ is the nominal price of manufactured goods. Recall that manufactured goods are the numeraire in the model, so $P_2 p_j$ is the nominal price of good $j$ and $W_{j,t-s}/P_2 p_j$ is the producer real wage. Resource firms demand labour inputs:

$$n_1(t) = \frac{P_2(t)p_1(t)\{1 - \alpha_1 - \omega\}y_1(t)}{W_{j,t-s}(t)}$$

(37)

The nominal wage for transactions at time $t$ is set as the expectation at time $t-s$ of the nominal wage that would prevail in the market-clearing model at time $t$. For the non-tradables and manufacturing sectors this gives:

$$W_{j,t-s}(t) = E_{t-s} \hat{P}(t) \hat{p}_j(t)\{1 - \alpha_j - \beta_j\} \hat{y}_j(t)/\hat{n}_j(t)$$

(38)

where the hats over the right-hand-side variables denote market-clearing quantities and prices. A similar wage setting equation is required for the resource sector which is the analogue of (38). In equilibrium nominal wages must be equal across sectors.

To make the nominal wage contracts more realistic, the basic contract is embedded into a system of overlapping contracts. Each period half the contracts are set and contracts are assumed to last two years. At any time $t$, half the workers will therefore have one year left in their contract and half the workers will have two years. Nominal wages are set as in (39) to clear the labour market in an expected sense. Labour demand in each sector is then determined by the average wage

$$W(t) = [W_{t-1}(t) + W_{t-2}(t)]/2$$

(39)

and $W(t)$ replaces $W_{j,t-s}(t)$ in (37) and (38).

Finally, the model is closed by an exogenous monetary authority that controls the value of the nominal anchor. Several choices for the nominal anchor are possible. The monetary authority can fix the nominal exchange rate, thereby setting domestic inflation equal to foreign inflation in the long run. Alternatively the monetary authority can allow the nominal exchange rate to float and achieve other goals such as a constant nominal price level or a given path for nominal income growth. The analysis abstracts from important issues associated with the implementation of monetary policy, so the monetary authority is always capable of achieving its target, providing it targets a nominal variable.
1.8 Analyses of Results

In this section, we explain the intuition behind the model by analyzing the deterministic version. We begin by examining the implications of the market-clearing and sticky wage assumptions and then compare results under a fixed exchange rate and a flexible exchange rate regime in which the monetary authority targets the inflation rate measured in terms of the consumer price index. Note that since the monetary authority always hits its target exactly, the inflation target is equivalent to a price-level target. The deterministic shock considered is a temporary 5 per cent decline in the terms of trade. All results presented in this section are expressed as percentage changes from the initial steady state.

1.8.1 Market clearing versus sticky wage model

To isolate the impact of nominal wage rigidities, we focus on a flexible exchange rate regime in which the monetary authority targets the inflation rate based on the domestic price level (in terms of the manufactured good) and compare results for the market clearing and sticky wage versions of the model. These results are presented in figure 1. The solid and dashed lines represent the dynamics of the model for the market-clearing and sticky wage models respectively.

In the market-clearing model, a decrease in the price of resources (a terms-of-trade deterioration) makes resource production less attractive, resulting in a reduction in employment, investment and output in the resource sector. The fall in employment demand in the resource sector leads to a real wage decline. Lower real wages and resource prices create an incentive for the nontradables and manufactured goods sectors to use more resources and employ labour displaced from the resource sector leaving aggregate employment in the economy unchanged. Increased use of labour and resources raises the marginal product of capital resulting in an increase in investment and output in the nontradables and manufactured goods sectors. Note that although there is a decrease in investment in the resource sector, aggregate investment rises because the increase in investment in the nontradables and manufactured goods sectors is larger than the decrease in the resource sector.

There is also a decrease in the value of land and aggregate income due to the fall in the price of resources (recall that land is a specific factor in the resource sector). Aggregate consumption declines because of the decrease in consumer wealth and the fact that all goods are normal. However, consumption declines less proportionately than income because the shock is temporary and consumers are able to smooth consumption by increasing their net foreign liabilities. Note that the decrease in consumption of the nontradable good depresses its price resulting in a real exchange rate depreciation.

In contrast to the market-clearing model, in the sticky wage version, aggregate employment falls temporarily below the full employment level. This is because a sticky nominal wage and a fixed domestic price level (in terms of the manufactured good) preclude sufficient adjustment of the real wage in response to the terms of trade shock. With a constant real wage and a decline in the price of nontradables, employment falls in the nontradable goods sector. In the manufactured goods sector, employment rises because of lower resource price. However, the increase in employment in this sector is not large enough to absorb the decrease in the resource and nontradable good sectors. Aggregate employment therefore falls and is lower than in the market-clearing model. In addition, aggregate income and consumption fall more than in the market-clearing model partly because the decrease in wealth in the sticky wage model is larger than in the market-clearing model. In both the market-clearing and sticky wage models, the fall in the price of resources...
results in a trade deficit because exports fall more than imports. However, the trade deficit is higher under the sticky wage model because of a smaller decline in imports.

1.8.2 Fixed versus flexible regime (CPI inflation target)

Figure 2 presents results for the sticky wage version of the model under a fixed exchange rate regime and a flexible exchange rate regime in which the monetary authority targets the inflation rate measured in terms of the consumer price index (CPI). Here, the solid lines represent responses under a fixed exchange rate regime (EN) while the dashed lines represent responses under a flexible exchange rate regime with a CPI inflation target. Under both regimes, the value of land and wealth fall due to the fall in the price of resources. This results in a decrease in the consumption of the nontradable good and a fall in its price (a real exchange rate depreciation). In the flexible exchange rate regime with a CPI inflation target, the domestic price level (in terms of the manufactured good) rises so the real depreciation is achieved through a nominal exchange rate depreciation that is larger than the increase in the domestic price level. Because wages are sticky, the increase in the domestic price level results in a decrease in real wages thereby creating an incentive for firms in the nontradable and manufactured goods sectors to absorb labour displaced from the resource sector. There is an increase in aggregate investment because of the decrease in the price of the nontradable investment good and the fact that the use of more inputs in the manufactured and nontradable goods sectors increases the marginal product of capital. Also, aggregate income and consumption decline.

In the fixed exchange rate regime, however, the real depreciation of the exchange rate required to clear the nontradable goods market can only be realized through a decrease in the domestic price level. Because nominal wages are sticky, the decrease in the domestic price level results in an increase in the real wage and a decrease in aggregate employment, consumption and investment. Although aggregate employment and consumption decline as in the case of a flexible exchange rate with a CPI inflation target, the decrease in the two variables is larger under a fixed exchange rate regime. In a fixed exchange rate regime, the percentage decline in employment is 1.5 as compared to virtually no change in employment under a flexible exchange rate with a CPI inflation target. Unlike aggregate employment, the behaviour of consumption is more similar across regimes (0.5 and 0.2 per cent decline for the fixed exchange rate and the flexible exchange rate with a CPI inflation target respectively). The small difference in the behaviour of consumption across regimes can be explained by two factors. First, labour income is similar across regimes. Second, there is high consumption smoothing in the model since agents have perfect access to capital markets and the utility function has very little curvature (i.e., low risk aversion). Clearly, these results suggest that with sticky nominal wages, the creation of a currency union involves some costs since the exchange rate can no longer be used as an instrument of adjustment.

---

22. To understand why the domestic price level in terms of the manufactured good must rise when the monetary authority targets the inflation rate measured in terms of the CPI, note that the nominal CPI is the product of the real consumer price index and the domestic price level in terms of the manufactured good. The real consumer price index is increasing in the prices of resources and nontradables. Therefore, when the prices of resources and nontradables fall, the real consumer price index falls implying that the domestic price level in terms of the manufactured good must rise to maintain the CPI inflation target.
2. The stochastic model

In this section, we recast the model in a stochastic setting and examine the economic consequences of introducing transaction costs in the economy under different exchange rate regimes. To isolate the impact of each of these features of the model, we begin with a stochastic version of the model with no transaction costs and analyse the results, then we introduce endogenously-determined transaction costs and compare the results to those obtained under the assumption that there are no transaction costs. In each case, we focus on four exchange and monetary policy regimes: a fixed exchange rate, a flexible exchange rate with a CPI inflation target, a flexible exchange rate which the monetary authority targets the inflation rate measured in terms of the consumer price index less resources (CPIXR), and a flexible exchange rate with an inflation target for the domestic price level in terms of the manufactured good (PM). Exploring the implications of alternative price targets in the model is important given the increasing adoption of inflation targeting frameworks by central banks and the fact that policy makers in these institutions have to make a decision on which price target to use in the conduct of monetary policy.

Our comparison of alternative exchange rate regimes is based on consumer welfare as well as the volatilities of aggregate employment, consumption and net foreign assets. Since we do not want to deal with intergenerational issues, we focus on the average instantaneous utility as a measure of consumer welfare.

The simulation procedure is as follows. We run the model over 460 years, shock it in each period, and compute the means and standard deviations of the variables of interest. We then perform fifty replications of history and compute the average of the relevant moments across replications. Thus the total number of simulations is 23,000. The shocks used in the experiments are the same across exchange rate regimes so that the results would be comparable. Although the shocks are unanticipated, it is assumed that agents know the path of each shock.

The terms of trade $p_1$ is assumed to follow an AR(2) process. The distribution of the shock is based on the properties of the residuals from a regression of the terms of trade, proxied in the data by the relative price of non-energy commodities to manufacturing import prices, on a constant and 2 lags of the terms of trade using annual Canadian data for the period 1975 to 1998. Since the residual from the estimated AR(2) model is iid with a standard error of 0.05, the shocks used in the model were constructed to capture this feature of the data. The coefficients for the first and second period lags of the terms of trade variable in the estimated equation are 0.93 and -0.56 respectively.

Simulation results for the stochastic version of the model with no transaction costs are presented in figure 3. We compare the volatility of the nominal exchange rate, under alternative exchange rate regimes, to the volatility of aggregate employment (panel I), consumption (panel II), net foreign assets (panel III), and mean utility (panel IV). The results show that there is a trade-off between the variance of the nominal exchange rate and macroeconomic variables. In panel I, a fixed exchange rate regime has a higher variance of aggregate employment but lower variance of the nominal exchange rate. This is followed by a flexible exchange rate with a PM inflation target,
a flexible exchange rate with a CPIXR inflation target, and finally a flexible exchange rate with a CPI inflation target. The result that a fixed exchange rate regime has a higher variance of employment has been emphasized in the literature. What is more interesting is the quantitative differences across regimes and ranking of the flexible exchange rate regimes with different price targets. The CPI inflation target yields less volatility in employment, followed by the CPIXR inflation target and then the PM inflation target. The intuition for this result is as follows.

Suppose there is a temporary terms-of-trade deterioration. The value of land and wealth decline. Consumption of the nontradable good falls requiring a decrease in its price (a real exchange rate depreciation). In a fixed exchange rate regime the real depreciation can only be achieved through a fall in the domestic price level (in terms of the manufactured good). With sticky nominal wages, the fall in the domestic price level increases real wages resulting in a decline in employment. Under a flexible exchange rate with a PM inflation target, the real exchange rate depreciation required to clear the nontradable goods market is achieved through a nominal exchange rate depreciation. With sticky nominal wages, a PM inflation target leaves real wages unchanged. Therefore employment falls but by less than in the case of the fixed exchange rate.

For the CPI inflation target, we have shown that the nominal CPI is the product of the real CPI and the domestic price level in terms of the manufactured good (PM) and that the real CPI falls when there is a terms of trade deterioration because it is increasing in the prices of resources and nontradables. This implies that the domestic price level (PM) has to rise in order to maintain the nominal target. Because of sticky nominal wages, the increase in PM decreases real wages making it possible for displaced labour in the resource sector to be absorbed in the manufactured goods sector with a negligible impact on aggregate employment. Note that although the impact on aggregate employment is minimal, the nominal exchange rate changes more than in the case of the flexible exchange rate with a PM inflation target. This has to do with the fact that a CPI inflation target requires an increase in PM with the implication that the only way to achieve a real exchange rate depreciation is through a nominal exchange rate depreciation larger than the increase in PM. Therefore, the depreciation of the nominal exchange rate will be higher under a CPI inflation target compared to a PM inflation target or a fixed exchange rate.

The change in aggregate employment in a CPIXR inflation target is larger than the change in a CPI inflation target because in the former the real consumer price index does not depend on the price of resources. The consequence of this is that when the terms of trade deteriorates and the price of nontradables falls, the decline in the real consumer price index is less than in the case of the CPI inflation target. This implies that the economy needs less increase in PM in order to maintain the CPIXR inflation target. Therefore, real wages fall but by less than in the case of the CPI inflation target. Because the decline in real wages is not large enough, aggregate employment falls more than in the case of the CPI inflation target. The smaller increase in PM also implies that less nominal exchange rate depreciation is required to achieve a real exchange rate depreciation. Therefore, the change in the nominal exchange rate will be less than in the case of the CPI inflation target.

Panels II and III show that the volatilities of consumption and net foreign assets are higher under a fixed exchange rate regime. This is a direct consequence of the result that employment and income are more volatile under a fixed exchange rate regime. Because consumption is more vola-
tile under the fixed exchange rate regime consumers need to adjust their foreign asset positions more in order to smooth consumption. The difference in employment volatility between the fixed exchange rate regime and the flexible exchange rate regime with a CPI inflation target is about 1.4. This is worth emphasizing since it suggests that there are high costs to fixing the exchange rate in a small open economy. Turning to panel IV, we can see that welfare is higher under a flexible exchange rate regime with a CPI inflation target, followed by a flexible exchange rate regime with a CPIXR inflation target, then a flexible exchange rate regime with a PM inflation target and finally a fixed exchange rate regime. Although the welfare rankings are in favour of flexible exchange rate regimes, the magnitude of the difference between regimes is small. This is due to the fact that all idiosyncratic risk is insured away and the assumption that agents have perfect access to international capital markets to smooth consumption. When this is combined with quite modest curvature in utility (implied by a logarithmic function), volatility has little cost in welfare terms, so differences are small.

2.1 Adding transaction costs

To incorporate the microeconomic benefits of a permanently fixed exchange rate regime under a common currency, we assume that there are transactions costs associated with trade under flexible exchange rate regimes. In particular, we assume that for every unit of a good imported or exported (under a flexible exchange rate regime), a certain percentage is lost to the economy (as in the familiar iceberg model) because of currency conversion costs or costs associated with exchange rate uncertainty.23 Ideally, the percentage of the transactions costs paid by any agent would depend on the proportion of the traded goods used or exported by the agent. However, because there is no way to pin down the proportion of the traded goods used or exported by any agent, we introduce the transactions costs as a loss to the economy as a whole. This implies that all agents in the economy share the costs equally.

Suppose $x_1$ and $x_2$ are exports of goods 1 and 2 respectively, where $x_2$ is negative since the small country is assumed to import good 2 (manufactured goods). To sell $x_1$ units of good 1 on the world market, the resource sector would have to ship $\hat{x}_1 = (1 + \chi)x_1$ units of good 1 since a proportion $\chi$ of $x_1$ represents transaction costs. Similarly, if the economy imports $x_2$ units of good 2, it pays $\chi x_2$ as transaction costs so that the amount that is available to agents for consumption or investment is actually $\hat{x}_2 = (1 - \chi)x_2$. Note that because these costs are incurred only in flexible exchange rate regimes, $\chi$ is a function of the exchange rate regime. To make this dependence explicit, we assume that $\chi = \chi_1 \sigma_{EN}$, where $\sigma_{EN}$ is the standard deviation of the nominal exchange rate.

Note that incorporation of transaction costs alters the market clearing conditions for goods 1 and 2 (tradables). The modified equations are:

23. Note that because the home country is a price taker in world markets, it is assumed to absorb transactions costs on both imports and exports.
In the calibration experiments, the transaction costs parameter was determined as follows. Laidler and Robson (1991) suggest that the transaction costs associated with a flexible exchange rate are about 0.2 per cent of GDP in Canada. In addition, net exports of resources and imports of manufactured goods represent about 23 per cent of GDP in the model and the data. This implies that transaction costs represent about 1 per cent of trade in Canada. Setting the ratio of transaction costs to trade at 0.01, the transaction costs parameter $\chi_1$ can be computed given the estimated standard deviation of the nominal exchange rate $\sigma_{EN}$. The standard deviation of the nominal exchange rate was obtained using an iterative procedure that takes its value in the market-clearing model without transaction costs as a starting value.

For most of the variables of interest, the simulation results for the model with endogenous transaction costs are similar to those of the model without transaction costs. For example, employment, income and consumption are still more variable under the fixed exchange rate regime and the ranking of different inflation targets obtained in the stochastic model without transaction costs is preserved (see figure 4). The interesting result obtained in this section is that the introduction of transaction costs alters the welfare ranking between fixed and flexible exchange rate regimes. In particular, welfare is slightly higher under the fixed exchange rate regime and the flexible exchange rate with a CPI target has the worst outcome. To understand the intuition for this result, note that because transaction costs are a tax on trade they reduce the level of consumption in a flexible exchange rate regime. Although the volatilities of employment and consumption are higher in a fixed exchange rate regime, the welfare cost of this volatility is so small that it is dominated by the welfare loss due to the payment of transaction costs under a flexible exchange rate regime. As indicated earlier, in the model, agents have perfect access to capital markets, face no idiosyncratic risks and have instantaneous utility functions with very little curvature. This results in high consumption smoothing and is responsible for the small welfare effect of the volatility of employment and consumption.

\begin{align}
\tilde{y}_1 &= c_1 + z_0 + z_2 + \gamma_{10} + \gamma_{12} + g_1 + (1 + \chi)x_1 \\
\tilde{y}_2 &= c_2 + i_{02} + i_{12} + i_{22} + \gamma_{20} + \gamma_{22} + g_2 + (1 - \chi)x_2
\end{align}

24. Although transaction costs are difficult to quantify, Grubel (1999) suggests that for Canada, the United States and Mexico, it is .1 per cent of national income. Therefore, the .2 per cent figure used in this paper is likely an overestimate and may bias the results against flexible exchange rate regimes.
3. Concluding remarks

This paper examines the economic and welfare consequences of the formation of a North American Monetary Union for Canada using a stochastic dynamic general equilibrium model of a small open economy with three sectors - resources, nontraded goods and manufactures. The model is calibrated to Canadian data and its main purpose is to compare the implications of alternative exchange rate and monetary policy rules, chiefly a monetary union (i.e., a fixed exchange rate) and a flexible rate with an inflation target (essentially the current regime) under different assumptions concerning nominal wage rigidities and international transactions costs. At the heart of this comparison is the critical trade-off between the macro-stability benefits provided by a flexible rate and the micro-efficiency gains resulting from the elimination of exchange rate uncertainty under a monetary union.

In the first case considered, two-period overlapping nominal wage contracts are overlaid on the market-clearing deterministic version of the model and the impact of a temporary worsening of terms of trade (a fall in the world price of resources) is analysed. The standard result is obtained. With nominal wage rigidity, a permanently fixed exchange rate (as in a monetary union) results in a sharp drop in employment, output, consumption and welfare. In contrast, a flexible exchange rate would depreciate in response to the shock, reducing the real wage and thus mitigating the impact of the price decline on economic activity.

Next, the stochastic version of the model is employed to examine the impact of a random terms of trade shock in each period. Endogenous transactions costs are also introduced to capture the potential reduction in trade flows due to a volatile flexible exchange rate. In this case, welfare is higher under the fixed exchange rate than under the flexible rate. Employment and income are more volatile under the fixed rate and so is consumption, but to a smaller degree because agents have unfettered access to international capital markets and can optimally smooth the impact of these temporary shocks on consumption. However, under the flexible rate, the level of consumption is less because the transaction costs, although relatively small (less than 1% of trade flows), are essentially a tax on trade and thus reduce agents’ permanent income. In summary, the reduction in the level of consumption due to transaction costs under a flexible rate reduces welfare by more than does the higher volatility of consumption under the fixed rate. This result is very dependent on two factors: one, the access agents have to the international capital market because there is only aggregate risk and no idiosyncratic risk (because all agents are assumed to be the same), and two, the curvature of agents’ utility functions. Because the assumed logarithmic utility functions are relatively flat, consumption volatility does not significantly reduce welfare.

In the future, we intend to modify the model by using a utility function with more curvature, imposing borrowing constraints, and adding more extreme states with low probabilities. These modifications would magnify the costs of employment and consumption volatility in the model and reduce the net benefits of a fixed exchange rate.

In conclusion, this paper makes an important contribution because it presents a welfare-based comparison of alternative exchange rate regimes using a calibrated stochastic DGE model. It also provides important insights into the impact of different market rigidities and targeting inflation.
rates measured in terms of various price indices. Indeed it provides a useful framework for other small open economies considering entry into a monetary union.
Table 1

Values for the Parameters and Exogenous Variables

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_0$</td>
<td>0.260</td>
<td>$\alpha_1$</td>
<td>0.350</td>
<td>$\alpha_2$</td>
<td>0.310</td>
</tr>
<tr>
<td>$\beta_0$</td>
<td>0.070</td>
<td>$\beta_2$</td>
<td>0.140</td>
<td>$\omega$</td>
<td>0.200</td>
</tr>
<tr>
<td>$\theta_0$</td>
<td>0.500</td>
<td>$\theta_1$</td>
<td>0.050</td>
<td>$\rho$</td>
<td>0.013</td>
</tr>
<tr>
<td>$\pi$</td>
<td>0.050</td>
<td>$\xi_0$</td>
<td>0.960</td>
<td>$\xi_1$</td>
<td>0.020</td>
</tr>
<tr>
<td>$\phi$</td>
<td>0.010</td>
<td>$\nu$</td>
<td>0.010</td>
<td>$r$</td>
<td>0.040</td>
</tr>
<tr>
<td>$\Phi_0$</td>
<td>0.812</td>
<td>$\Phi_1$</td>
<td>1.120</td>
<td>$L$</td>
<td>1.000</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.050</td>
<td>$\chi$</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\delta_{i0}$</td>
<td>0.030</td>
<td>for $i = 0,1,2$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\delta_{i2}$</td>
<td>0.120</td>
<td>for $i = 0,1,2$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\eta_{i0}$</td>
<td>2.500</td>
<td>for $i = 0,1,2$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\eta_{i2}$</td>
<td>1.500</td>
<td>for $i = 0,1,2$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_{ij}$</td>
<td>0.741</td>
<td>for $i = 0,1,2; j = 0,2$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2

Selected Ratios Describing the Steady-State

<table>
<thead>
<tr>
<th></th>
<th>Aggregate</th>
<th>non-tradables</th>
<th>resources</th>
<th>manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>share of output</td>
<td>1.00</td>
<td>0.56</td>
<td>0.24</td>
<td>0.20</td>
</tr>
<tr>
<td>share of employment</td>
<td>1.00</td>
<td>0.62</td>
<td>0.17</td>
<td>0.21</td>
</tr>
<tr>
<td>labour income/ output</td>
<td>0.72</td>
<td>0.45</td>
<td>0.12</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Ratios of GDP

<table>
<thead>
<tr>
<th></th>
<th>Aggregate</th>
<th>government debt</th>
<th>foreign assets</th>
<th>capital</th>
<th>land</th>
<th>non-human wealth</th>
<th>human wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td>consumption</td>
<td>0.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>investment</td>
<td>0.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>government</td>
<td>0.18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>exports</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>imports</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Figure 1: Market Clearing versus Sticky Wage Model

Market Clearing solid, Sticky Wage dashed

- GDP: Output net of risk premiums and resource inputs
- C: Total consumption
- P1: Home price of resources
- P0: Price of non-tradables
- PM: Domestic price level in terms of importables
- CPI: Domestic price level in terms of the CPI
- EN: Nominal exchange rate
- W: Wage rate
- NN: Employment
- Y0: Output of non-tradable
- Y1: Output of resource good
- Y2: Output of manufactured good
Market Clearing solid, Sticky Wage dashed

ND0
LABOUR PRODUCING GOOD 0

ND1
SHARE OF LABOUR PRODUCING GOOD 1

ND2
LABOUR PRODUCING GOOD 2

Z0
RESOURCES INPUTS IN NON-TRADABLES

PL
PRICE OF LAND

Z2
RESOURCES INPUTS IN MANUFACTURED GOODS

I0
INVESTMENT IN SECTOR 0

I1
INVESTMENT IN SECTOR 1

I2
INVESTMENT IN SECTOR 2

I
TOTAL INVESTMENT
Figure 2: Fixed Versus Flexible Regime (CPI Target)

EN solid, CPI dashed

GDP

OUTPUT NET OF RISK PREMIUM AND RESOURCE INPUTS

C

TOTAL CONSUMPTION

P1

HOME PRICE OF RESOURCES

P0

PRICE OF NON-TRADABLES

PM

DOMESTIC PRICE LEVEL IN TERMS OF IMPORTABLES

CPI

DOMESTIC PRICE LEVEL IN TERMS OF THE CPI

EN

NOMINAL EXCHANGE RATE

W

WAGE RATE

NN

EMPLOYMENT

Y0

OUTPUT OF NON-TRADABLE

Y1

OUTPUT OF RESOURCE GOOD

Y2

OUTPUT OF MANUFACTURED GOOD
Figure 3

Stochastic Model Without Transaction Costs

CPI = consumer price index;  CPIXR = consumer price index less resources;
PM = domestic price level in terms of the manufactured good;  EN = fixed exchange rate
Figure 4

CPI = consumer price index; CPIXR = consumer price index less resources; PM = domestic price level in terms of the manufactured good; EN = fixed exchange rate
Appendix I
Variable and Parameter Mnemonics

Conventions:
good 0 non-tradables
good 1 resources
good 2 manufactured goods
All relative prices measured in units of manufactured goods.
All quantity variables are measured per productivity adjusted worker.

Variables:
\(a\) non-human wealth
\(b\) government debt
\(c\) total consumption
\(c_j\) consumption of good \(j\)
\(ca\) current account
\(en\) nominal exchange rate
\(er\) real exchange rate
\(f\) foreign assets
\(g\) total government expenditure
\(g_j\) government purchases of good \(j\)
\(h\) human wealth
\(i\) total investment
\(k_j\) index of capital in sector \(j\)
\(k_{ij}\) type \(i\) capital used in sector \(j\)
\(L\) fixed stock of land
\(n_j\) labour employed in sector \(j\)
\(p_0\) relative price of non-tradables
\(p_1\) relative price of resources = the terms of trade
\(P_j\) nominal price of good \(j\)
\(p_L\) price of land (detrended)
\(q_{ij}\) the value of type \(j\) capital in sector \(i\)
\(r\) world real interest rate
\(rcpi\) relative price of the consumption basket
\(w\) real wage
$W$  nominal wage
$W_{t-s}(t)$  nominal wage at time $t$ set at time $t-s$
$x_j$  exports of good $j$
$y_j$  gross output of sector $j$
$\tilde{y}_j$  gross output of sector $j$ net of transaction-cost-cum-risk-premium
$y_j^{va}$  value added of sector $j$
$\gamma_j^{va}$  aggregate income
$z_j$  resource inputs in sector $j$

$\gamma_{ij}$  adjustment costs in the installation of type $j$ capital in sector $i$
$\tau$  taxes
$E_{t-s}$  expectation conditional on time t-s information

**Parameters:**

$\alpha_j$  capital’s share in sector $j$
$\beta_j$  resource input’s share in sector $j$
$\delta_{ij}$  depreciation rate of type $j$ capital in sector $i$
$\eta_{ij}$  adjustment costs parameter for type $j$ capital in sector $i$
$\theta_j$  expenditure share weight for consumption of good $j$
$\Lambda$  amount of time consumers take in leisure
$\mu$  parameter in government’s consumer tax rule
$\upsilon$  rate of population growth
$\xi_j$  expenditure share weight for government consumption of good $j$
$\pi$  probability of death
$\rho$  pure rate of time preference
$\sigma_{ij}$  share of structures in total capital in sector $j$
$\phi$  rate of labour augmenting technical progress
$\Phi_j$  level of productivity in sector $j$
$\psi$  premium in the firm’s discount rate
$\omega$  share of land in resource production
$\chi$  transaction costs as a percentage of trade
References


