Department of Finance
Ministère des Finances

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Taxation and Economic Efficiency: Results from a Canadian CGE Model

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Abstract

This paper introduces a dynamic general equilibrium tax model of the Canadian economy. The model incorporates each of the major taxes in Canada and features adjustment dynamics, intertemporal optimization, imperfect substitution between domestic and foreign goods and assets, and industry disaggregation. In addition to describing the model, this study uses it to compare the effects of different tax measures on the Canadian economy with a focus on measures that directly target investment and saving.

Résumé

Cette étude présente un modèle d’équilibre général dynamique de taxation de l’économie canadienne. Le modèle, qui incorpore les principales taxes canadienne, se caractérise, entre autres, par l’optimisation intertemporelle des agents, la substitution imparfaite entre biens et actifs de provenances domestique et étrangère, ainsi que par la désagrégation sectorielle de l’économie. Outre la description du modèle, l’étude compare les effets de différents instruments de taxation sur l’économie canadienne avec une emphase sur les instruments ciblant directement l’investissement et l’épargne.

1. Introduction

Ever since the resuscitation of the Walrasian model by Arrow, Debreu, and Koopmans in the 1950s, the scope and breath of general equilibrium models has steadily increased. Their use and popularity has duly followed suit. Because they explicitly embody behavior and take account of interactions between agents, general equilibrium models provide an ideal framework for evaluating the effects of policy changes on resource allocation and welfare. While analytical models prospered in academia, their pragmatic counterparts, applied general equilibrium models, flourished in policy-oriented organizations. Today, academics and governments throughout the world use both as guides for policy analysis.

This paper introduces a Canadian dynamic, multi-sector, open economy, neo-classical tax model. The model features adjustment dynamics, intertemporal optimization, imperfect substitution between domestic and foreign goods and assets, and some industry details. In addition, the model incorporates each of the major taxes in Canada. Although the general qualitative impacts of tax changes are well known, the effects of various policies on some variables of interest are analytically indeterminate and are thus an empirical issue. In addition, the relative attractiveness of different tax measures is also (at least in part) an empirical question. Since the model is fully calibrated with Canadian data it provides a useful tool for addressing these issues.

The templates for our model are Goulder and Summers (1989) and Goulder and Eichengreen (1989). In fact, we follow their specification quite closely. Hence, the novelty of our work lies not in ingenious new theories of economic behaviour but rather in the application of an existing framework to Canada. It is particular in providing a detailed treatment of taxation in the Canadian context. Although James (1994) and Macklem et al. (1994) use models of the Canadian economy that are similar to the one developed in this paper, they represent production in a simplified, aggregate matter. Our work, although paying less attention to certain macroeconomic aspects, provides a more detailed consideration of industries within an integrated framework.

In addition to describing the model, this study uses it to compare seven different policies, focussing on measures that target investment and saving, and rank them according to their impact on domestic welfare[1]. The results indicate that taxes on saving and investment impose higher efficiency costs than taxes on wages and consumption. In particular, the results suggest that investment-promoting policies geared towards new capital and personal capital income tax reductions yield the greatest efficiency gains.

From the onset, the reader should keep in mind that the model does not take into consideration all channels through which tax policy can affect the economy. It examines the effects of altering the tax mix on four key decisions: the decision to consume or invest, the decision to invest abroad or at home, the labour-leisure decision, and the composition (in terms of industry output) of the consumption basket and capital good.

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[1] This paper uses the standard economic definition of welfare: a utility measure that encompasses the value of consumption and leisure.

Limiting the scope of analysis has the advantage of making the analysis more transparent and permits a clearer identification of the sources of distortion. The drawback, of course, is that several other factors of importance are neglected. For example, the model does not provide information about the effects that altering taxes might have on capital and labour quality or innovation. Issues related to household heterogeneity, asset heterogeneity, tax progressivity, migration, tax planning, equity (both horizontal and vertical), administrative costs, and dynamic inconsistency are but a few more examples of important considerations that are ignored. Since these criteria, and others, are essential to final policy judgements the analysis provided herein provides only part of a larger picture.

Because we draw so heavily on the Goulder model, a short section describing its various applications seems appropriate. Apart from being interesting in its own right, such an overview highlights the kind of issues that can be tackled with such a model. The remainder of the paper is organized as follows. Section 3 presents an overview of the model. Section 4 provides data sources for calibration as well as the main behavioural parameters and benchmark values. Simulation results are reported and analysed in section 5. Sensitivity analysis is conducted in section 6. The final section provides caveats and concludes.

2. The Goulder model: origin, evolution, and contemporary applications

The first manifestation of the Goulder model is Goulder and Summers (1989). The essence of their paper was the application of the asset price approach to investment to GE economics. By so doing, they were able to consider a wider range of policy simulations than had traditionally been possible. The asset price approach synthesized Tobin's *q* theory of investment (Tobin (1969)) and the adjustment cost investment framework (Lucas (1967) and Treadway (1968)). In such a setting, firms invest until the market value of an additional unit of capital equals the after-tax cost of purchasing and installing it. That is, managers invest as long as each dollar spent raises the market value of the firm by more than one dollar. Other features of the model include immobile physical capital between industries, differentiation between old and new capital, and assessment of short and long run effects of tax policy. The principal conclusion of the paper was that the effects of policies on investment depend critically on whether they are oriented towards old or new capital, with policies geared towards new capital being most effective.

In a subsequent paper Goulder and Eichengreen (1989) expand the above framework to an open economy. They add explicit behaviour of the foreign sector and introduce an international market for financial capital. Their simulations served to highlight the radically different results that can be obtained once international capital mobility is introduced, making a strong case for considering international transactions in CGE models.

The Goulder model was then used to analyze a panoply of issues. For example, Goulder and Thalmann (1990) use it to measure the benefits of bringing marginal effective tax rates (METRs) across industries into agreement, Goulder and Eichengreen

(1992) examine the effects of removing U.S. tariff and non-tariff barriers to trade, and corporate tax cuts are compared to investment tax credits in Bovenberg and Goulder (1993). More recently, the model was modified to incorporate environmental considerations and is widely used to assess the impact of energy taxes and abatement policies; see Goulder (1993) or Bovenberg and Goulder (2000, 2002), to name but a few.

3. Model structure

The foundation of any economic model is the set of assumptions made regarding technology and behaviour. In this section we describe available technologies as well as the assumptions underlying the behaviour of firm managers, consumers, government, and foreign residents. Here, we present a heuristic overview of the model to allow the reader to grasp the intuition without getting bogged down with technical details. Complete derivations are provided in Appendix A. The description of the model draws heavily on that given in Goulder and Summers (1989) and Goulder and Eichengreen (1989). Time and industry subscripts, as well as scaling constants, are for the most part suppressed to simplify the notation.

3.1 Production structure and firm technology

A representative corporation owned by consumers characterizes each industry. Each industry produces a single output (commodity) using available technology and inputs of capital, labour, and intermediate goods. The outputs of the industries are used for four purposes. First, they are used as intermediate inputs by each of the industries. Second, along with foreign inputs, they combine to form a representative capital good. Third, consumers demand them for final consumption. Fourth, they satisfy the export demands of the foreign sector.

Production technologies in each industry have the following multi-level structure:

$$X_j^D = f\left(K, L, \overline{M}\right) \tag{1}$$

$$\overline{M} = g\left(\overline{m}(x_1^D, x_1^F), \overline{m}(x_2^D, x_2^F), \; . \; . \; . \; , \overline{m}(x_N^D, x_N^F)\right) \tag{2}$$

where X_j^D is gross output of the *j*th domestic industry, *K* is capital, *L* is labour, and $\overline{M}$ is the intermediate good composite. This composite is itself a multi-level composite of domestic and foreign output ($x_1^D, x_1^F, x_2^D, x_2^F, . . .$). *f* and *g* are Cobb-Douglas functions while $\overline{m}$ is a CES. Figure 1 illustrates the structure of firms' production technology. It also highlights that the capital stock is made up of capital good purchases from previous periods (past investment). The capital good in which firms invest is itself a composite of output from different sectors and countries[2]. It is assumed that all firms are price takers on markets for both inputs and outputs.

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[2] Aggregation for the intermediate composite, representative investment good, and representative consumption good (see below) follow the same procedure. Allocation across commodities derives from the maximization of a Cobb-Douglas while allocation across geographical origins are determined by an

3.2 Corporate policy

To raise funds the corporation can either issue equity or debt and payments to shareholders are either made through dividends or share buybacks. It is assumed that corporate managers seek to maximize the value of the firm. Managers exhibit forward-looking behaviour and are endowed with perfect foresight. Therefore, at any given time, their choice for current and future amounts of labour inputs, intermediate inputs, and investment is that which maximizes the present value of the firm. The value of the firm at time *t* is given by:

$$V_t = \sum_{s=t}^{\infty}\left[\left(\frac{1-\theta}{1-c}\right)DIV_s - VN_s\right]\prod_{u=t}^{s}\left[\frac{1}{\left(1+\rho_u/(1-c)\right)}\right] \tag{3}$$

where V is the value of the firm, DIV are dividends, and VN represents new share issues (or share buybacks if negative) . θ and c are the effective tax rates on dividends and capital gains, respectively, while ρ is the risk adjusted required rate of return for holding shares of a given industry. The above equation simply states that the value of the firm is the discounted value of the stream of after-tax dividends net of new share issues[3] (or plus share repurchases for negative VN). In order to calculate the value of the firm one needs to know the streams of dividends and new share issues (or buybacks). These will depend on corporate financial policy, to which we now turn.

Firm dividends and new share issues are related through the cash flow identity that equates sources and use of funds:

$$EARN + BN + VN = DIV + IEXP \tag{4}$$

where $EARN$ is earnings, BN is the value of new debt issues, and $IEXP$ is investment expenditures. Firm earnings in each period are given by:

$$\begin{aligned} EARN = &\left(p^X X - (1+\tau^w)wL - (1+\tau^m)p^M \overline{M} - \tau^k \overline{p}^K K - iBOND\right)(1-\tau^{cit}) \\ &+ \tau^{cit}(\delta^T KDEP) \end{aligned} \tag{5}$$

X, K, L, and $\overline{M}$ were described previously. $BOND$ is nominal debt and $KDEP$ is the depreciable capital stock for tax purposes[4]. p^X, w, p^M are the prices of gross output, labour, and materials while $\overline{p}^K$ is the replacement price of capital (net of sales taxes). τ^w, τ^m, τ^k, and τ^{cit} are the indirect tax on labour, the intermediate input tax, the property and corporate franchise tax, and the corporate income tax rate. Finally, i is the nominal interest rate and δ^T is the geometric equivalent of the rate of capital cost allowance.

Armington (1969) type CES. Hence products produced by the same industry but in different countries are treated as imperfect substitutes (see appendix A for details).

[3] The intuition behind equation (3) is mired by the *(1-c)* term. The division of dividends and the discount rate by *(1-c)* reflects the fact that equity is trapped in the firm, that is, equity cannot be paid out to shareholders without at least paying the capital gains tax.

[4] It differs from the real capital stock, K, because of historical cost and accelerated depreciation.

Figure 1: Production Nesting

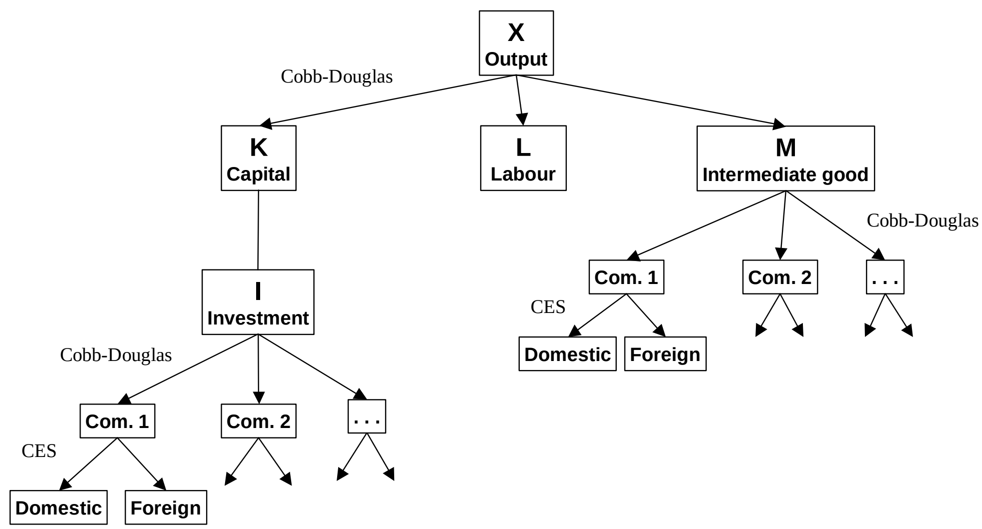
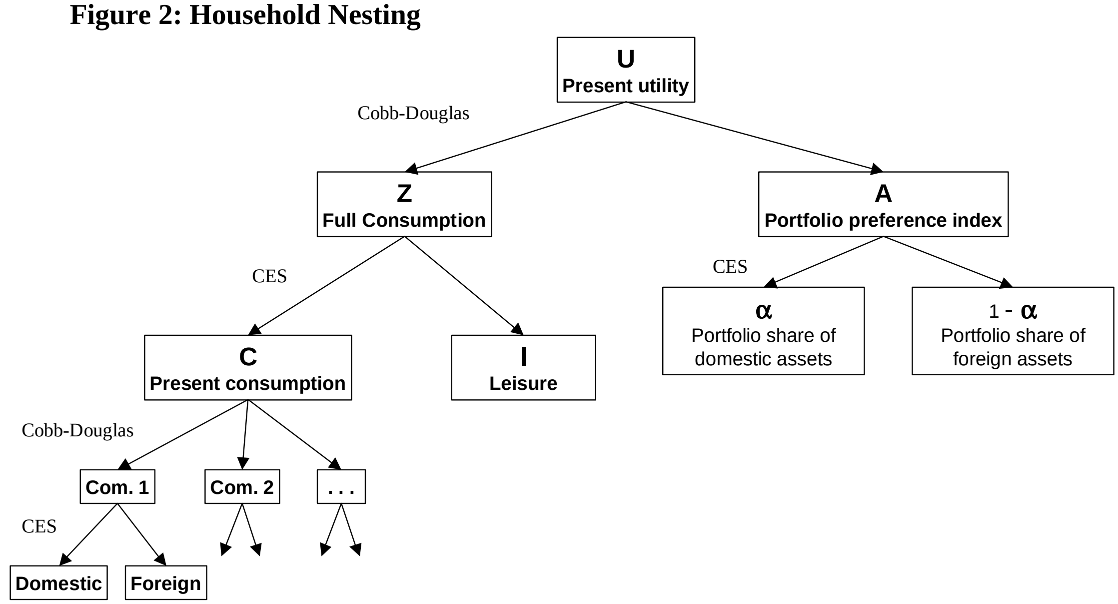


Figure 2: Household Nesting



Dividend payments and bond and share issues will depend on corporate financial policy. With regards to dividends (*DIV*) it is assumed that managers pay dividends equal to a fixed proportion of earnings net of the capital stock's appreciation and its economic depreciation. For debt financing it is assumed that managers maintain debt as a constant fraction of the value of the capital stock. Then, the value of new debt issues (*BN*) is just the change in the stock of corporate debt required to maintain the constant debt-capital ratio. Finally, investment expenditures are given by:

$$IEXP = (1 - ITC)\, p^K I + AC \tag{6}$$

where *I* is real investment, *ITC* is the investment tax credit, p^K is the replacement price of capital (gross of all taxes) and *AC* are total adjustment costs associated with the installation of new capital. The intuition behind the adjustment cost concept is that in order to install new capital, firms must devote resources (labour, materials, and capital) to set up, and learn about, the new equipment. The resources devoted to such tasks cannot also be used in production so output is lower as a result.

With the above information we can identify four of the five components in the cash flow identity (equation (4)). The remaining component, *VN*, is determined residually. This means that if expenditures (dividends plus investment expenses) are greater than cash inflows (earnings plus new bond issues) the firm will issue new shares to meet the shortfall. In the opposite case (inflows greater than outflows) the firm will use the extra cash to repurchase its own shares. Hence, our specification implies that, at the margin, investment is financed by new share issues and new bond issues necessary to maintain the constant debt-capital ratio.

Finally, we impose the natural constraint that the change in the real capital stock must equal investment minus depreciation.

$$\Delta K = I - \delta^R K \tag{7}$$

As detailed in appendix A, equation (3) can now be re-written in terms of the choice variables *I*, *L*, and $\overline{M}$. Managers maximize *V* subject to equation (7). The solution yields three central results[5]. First, labour is hired until its marginal product and net of tax wage are equal. Second, materials are purchased until their marginal product and net of tax price are equal. Third, managers will invest in the firm up to the point where the market value of an additional unit of capital minus its acquisition costs equals the after-tax cost of installation.

3.3 Housing sector

Although modelling of the housing sector follows the methodology outlined above there are a few nuances that differentiate it from the other sectors. First of all, the tax code treats the three broad types of housing capital (owner-occupied, tenant occupied

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[5] These three results reflect the first order conditions of the problem; they are given by equations (A22) to (A24) in the appendix.

non-corporate, and tenant occupied corporate) in a different manner. Second, corporate decisions and the maximization problem cannot be interpreted in the same way since non-corporate house owners cannot issue shares; *V*, *VN*, and *DIV* must be interpreted differently.

We deal with these issues by making three assumptions: the share of the capital stock belonging to each kind of housing is constant, the services of owner occupied housing and rental housing are perfect substitutes, and corporate policy is analogous to that followed by other sectors. Under these assumptions we can treat the three sectors as a unified sector that makes housing investment decisions to maximize the value of its assets. The corporate policy governing owner's behaviour is identical to that outlined in section 3.2 but *V* is interpreted as the value of the home, *DIV* is the net service flow from owning a home[6], and *VN* is the remainder of financial income not subject to income tax. A positive *VN* represents the out of pocket expenses incurred by homeowners who invest in their home.

A large share of the gains and service flows associated with housing are not taxable or are taxable at the personal tax rate. To capture this, we calculate effective housing tax rates based on the shares of each kind of housing.

3.4 Consumer behaviour

A representative domestic agent characterizes consumer behaviour. The agent is infinitely lived, forward-looking and endowed with perfect foresight. It owns all domestic labour and holds both domestic and foreign assets. The agent faces a multi-level decision problem and must choose paths for consumption, leisure, and portfolio holdings that maximize its welfare. The consumer maximizes a nested utility function of the form:

$$U_t = \sum_{s=t}^{\infty} (1+\omega)^{t-s} \left(\frac{\sigma}{\sigma-1}\right)(Z_s^{\beta} A_s^{1-\beta})^{\frac{\sigma-1}{\sigma}} \tag{8}$$

$$Z = \left(\varepsilon_c C^{\psi} + \varepsilon_l l^{\psi}\right)^{\frac{1}{\psi}} \tag{9}$$

$$C = f\left(g(x_1^D, x_1^F), g(x_2^D, x_2^F), \; . \; . \; . \; , g(x_N^D, x_N^F)\right) \tag{10}$$

$$A = \left(\alpha_0^{1-\rho}\alpha^{\rho} + (1-\alpha_0)^{1-\rho}(1-\alpha)^{\rho}\right)^{\frac{1}{\rho}} \tag{11}$$

where ω is the rate of time preference, σ is the intertemporal elasticity of substitution, *Z* is full consumption, and *A* is the portfolio preference index. Full consumption is itself a CES composite of *C* (the overall consumption basket) and *l* (leisure). *C* is in turn a multi-level composite of domestic and foreign output ($x_1^D, x_1^F, x_2^D, x_2^F, \; . \; . \; .$) while *A* is a function of α and $1-\alpha$, the shares of the household's portfolio devoted to domestic and foreign assets, respectively. α_0 and $1-\alpha_0$ are constants while ρ is a parameter related to

[6] The housing sector is assumed to pay out all of its net products in "dividends."

the elasticity of substitution between asset shares. Figure 2 illustrates the household's nested utility function.

The idea behind modelling portfolio choice through a preference index is that it is a simple way to capture the empirical observation that households invest the bulk of their portfolios in assets from their home country, even when rates of return on comparable assets abroad are higher. Therefore, when rates of return are equal across countries, households will choose asset share α_0 and $1-\alpha_0$. However, when rates of return differ, holding preferred shares leads to lower returns and hence lower consumption. The consumer must therefore balance the loss in utility arising from a deviation from preferred shares with the gains in utility due to higher consumption arising from higher returns. The extent of substitutability between assets depends on ρ, a parameter related to the elasticity of substitution between asset shares. Few would argue that this approach is realistic, it is hard to see why consumers would derive welfare from holding specific shares per se. Nonetheless, it does provide a simple and consistent way of accounting for home bias in portfolio choice.

With regard to intra country portfolio choice our approach is even simpler. It is assumed that households invest in the market portfolio, that is, they buy stocks and bonds from the various companies according to their market capitalization. Therefore, when an individual decides to invest an extra dollar, a fraction α of that dollar is invested in the agent's home country and the remainder, $1-\alpha$, is invested abroad. The sum invested at home is then divided among stocks and bonds from all companies according to their market capitalization share.

It follows that the change in a consumer's financial wealth in each period is:

$$\Delta WK = r_D \alpha WK + r_F (1-\alpha) WK + (1-\tau^{pit}) wL - p^Z Z \qquad (12)$$

where WK is financial wealth, r_D and r_F are the domestic and foreign net of tax rates of return, τ^{pit} is the personal income tax rate, and p^Z is the implicit price of full consumption.

The domestic consumer's financial wealth (WK) is related to industry liabilities through the following:

$$TWK = \sum_{j=1}^{s} \left[V_j + BOND_j \right] \qquad (13)$$

where j is the industry subscript (with s being the total number of industries) and TWK denotes the value of total physical assets located in Canada. WK is then given by:

$$WK = \gamma \cdot TWK / \alpha \qquad (14)$$

where γ is the proportion of the debt and equity of domestic firms held by domestic residents and α is the share of domestic household's portfolio devoted to domestic assets (from equations (11) and (12) above).

The net of tax rates of return (r_D and r_F) received by domestic consumers are directly related to payments made by firms. In particular, r_D is given by:

$$r_D = \sum_{j=1}^{s} \left[(1-c)(\Delta V_j - VN_j) + (1-\theta) DIV_j + (1-\tau^{pit}) iBOND_j \right] / TWK$$

$$r_F = \sum_{j=1}^{s} \left[(1-c)(\Delta(V*_j / e) - VN*_j / e) + (1-\theta) DIV*_j / e + (1-\tau^{pit}) i*BOND*_j / e \right] / TWK*/e_{-1}$$

where all symbols (except for *e*) are as defined previously and the asterisk (*) denotes foreign country variables denominated in the foreign currency. *e* is the exchange rate, defined as units of foreign currency per Canadian dollar. e_{-1} represents the exchange rate lagged one period, it is necessary to capture gains (or loses) arising from exchange rate fluctuations.

We assume that consumers behave in a way that maximizes their welfare. The rules for consumer behaviour are obtained by maximizing equation (8) subject to equation (12) with respect to the three choice variables, C, l, α. The solution yields three general results[7]. First, the higher the after-tax rate of return the higher future full consumption relative to current full consumption. Second, the domestic portfolio share (α) is a decreasing function of (r_F - r_D). That is, the higher the rate of return on foreign assets relative to domestic assets, the lower the share of domestic assets in the agents portfolio. Third, the ratio of consumption to leisure is a function of their price ratio and CES parameters (ε_c, ε_l, ψ).

Government behaviour

Although the model contains a large amount of detail on the tax side, government behaviour is modelled in a very simple fashion: it collects taxes and re-distributes the proceeds to domestic agents through lump sum transfers. Since it does not issue debt, the government budget balance is zero in every period. The taxes and their treatment in the model are described implicitly throughout this section.

Foreign sector

Demand for Canadian exports derive from constant elasticity export demand functions of the form:

$$EX = EX_0 \left(\frac{ep^X (1+\tau^{ex})}{p^F} \right)^{-\varepsilon^{ex}} \qquad (15)$$

[7] These three results reflect the first order conditions of the problem; they are given by equations (B8') to (B10') and (B14) to (B15) in the appendix.

where EX_0 is the expenditure on exports by foreign residents at prices of unity, p^X is the price of domestic gross output (as described previously), p^F is the foreign price for similar commodities, e is the exchange rate, τ^{ex} is the tax rate on exports, and ε^{ex} the export price elasticity of demand.

A similar relation holds for capital investment from abroad:

$$FW = FW_0 \left(\frac{r_D^*}{r_F^*} \right)^{\varepsilon^w} \tag{16}$$

FW_0 is foreign wealth invested in the domestic market when rates of return are equalized. r_D^* and r_F^* are the domestic and foreign net of tax rates of return faced by foreign residents, and ε^w is the interest elasticity of demand.

4. Data sources and benchmark values

The model integrates data from several different sources to form a Canadian benchmark data set. Our calibration is based on figures averaged over a three-year period (1996-1998) and our steady state solution closely replicates the 1996-1998 average Statistics Canada input-output matrix.

Much of the data is drawn from Statistics Canada's input-output matrices. These are the source for most share parameters on both the producer and consumer side as well as tax rates on output and inputs. They also provide most of the basic data for the steady state solution.

Capital stocks and depreciation rates by industry are derived from Statistics Canada's capital stock and investment series. Dividend payout ratios and debt capital ratios were derived from Statistics Canada's Quarterly Financial Statistics for Enterprises while data on foreign ownership and portfolio shares are from the National Balance Sheet Accounts, and Canada's International Investment Position. Adjustment costs parameters are from Summers (1981) while risk premiums are based on beta estimates from Jog (1995).

Average marginal personal tax rates originate from the Department of Finance T1 Tax model while effective investment tax credits and capital cost allowance rates are from the Department of Finance METR model.

Currently the model distinguishes between four industries: 1) Primary , 2) goods producing, 3) services, and 4) housing services. Table 1 gives benchmark values for the principal industry tax and behavioural parameters.

The level of aggregation is the private sector of the economy, that is, the entire economy net of the government sector and non-profit organizations. Our starting point is the input-output matrices to which we make three adjustments: we remove the government and non-profit sectors, we adjust capital income to match observed industry risk premiums[8], and we re-allocate a small share of exports to ensure that, in the base case, rates of return are equal at home and abroad and the current account balance is zero.

The IO matrix provides aggregate investment but not investment by sector. We must therefore appeal to the standard steady state investment rate constraint:

$$I / K = \delta^{R} + g \tag{17}$$

which requires that, in equilibrium, the investment rate in each sector be equal to economic depreciation plus the growth rate of effective labour. Since depreciation rates and the capital stocks for each industry and aggregate investment are known, we cannot impose the exogenous growth rate. The value of g must be such that (17) is satisfied for each industry and that the sum of investments in all industries equals aggregate investment from the input-output matrix. The value of g that satisfies this requirement is 0.028[9]. Once the industry investment rates are known, we can impose the replication and balanced growth path requirements and use the parameters from Table 1 to solve for the steady state values for all firm variables.

On the household side, labour supply is set equal to aggregate labour demand derived for firms and the time endowment is set at one and a half times labour supply. Combining information on benchmark asset shares and portfolio shares with information on total physical wealth located in Canada (obtained by summing the value of all domestic debt and equity) we obtain nonhuman wealth held by domestic agents.

Table 2 displays base case values for important aggregate variables while Table 3 presents key steady-state values for variables in each industry.

[8] Capital income (or operating surplus) is arguably the most volatile entry in the input-output accounts and the one most likely to deviate significantly from its trend.
[9] This figure is in line with the standard 0.03 found in the literature. The closeness of our estimate seems to vindication the choice of 1996-1998 as equilibrium years for the Canadian economy.

Table 1
Benchmark tax and behavioural parameter values

	Microeconomic parameters			
	Primary	Goods	Services	Housing
Economic depreciation rate (δ^R)	0.066	0.056	0.066	0.022
Dividend payout ratio (a)	0.130	0.336	0.401	1.0
Debt-capital ratio (b)	0.080	0.110	0.226	0.486
Risk premium (μ)	0.069	0.041	0.056	0.061
Effective investment tax credit (ITC)	0.013	0.004	0.0003	0.0
Tax depreciation rate (δ^T) (i.e. capital cost allowance)	0.303	0.127	0.097	0.013
Effective tax rate on inputs (τ^m)	-0.012	0.008	0.017	-0.007
Effective property and franchise tax (τ^k)	0.010	0.019	0.031	0.024

	Effective tax rates
Corporate income tax (τ^{cit})	0.322
Capital gains tax, accrual basis (c)	0.086
Dividend tax (θ)	0.203
Personal income tax (τ^{pit})	0.252
Payroll tax[a] (τ^w)	0.024
Tax on non-housing consumer goods (τ^{out})	0.115
Tax on purchases of the investment good	0.043

	Values for domestic macroeconomic parameters
Real risk-free interest rate (i)	0.026
Aggregate net of tax real rate of return	0.060
Growth rate of effective labour (g)	0.028
Adjustment cost parameters	
γ	0.076
β	19.6

	Household behavioural parameters
Intertemporal elasticity of substitution (σ)	0.5
Rate of time preference (ω)	0.02
Consumption parameter in utility (β)	0.5
Elasticity of substitution between portfolio shares (ϕ)	1.0
Elasticity of substitution between consumption and leisure (ν)	0.7

	Trade elasticities and benchmark share parameters
Elasticity of substitution between domestic and foreign goods	4.0
Export price elasticity of demand (ε^{ex})	4.0
Foreign investment interest elasticity of demand (ε^w)	1.0
Proportion of the physical wealth located in Canada owned by domestic residents (γ)	0.864
Proportion of the physical wealth located in Canada owned by foreign residents (1-γ)	0.136
Share of domestic agent's wealth held in domestic assets (α)	0.888
Share of domestic agent's wealth held in foreign assets (1-α)	0.112

[a] The effective payroll tax represents federal EI premiums and provincial workers' compensation paid by employers. It does not include CPP/QPP premiums.

Table 2
Base case values for aggregate output, wealth, and income (billions of 1997 Canadian dollars)

Macroeconomic aggregates	
Gross Domestic Product	751
Consumption	596
Investment	151
Exports	305
Imports	303
Adjustment costs	3
Canadian Firms	
Gross output	1,328
Total value of capital stock located in Canada	2,190
Owned by Can. households	1,892
Owned by Foreign households	298
Capital income payments	103
To Can. Households	89
To Foreign households	14
Labour income payments	351
Total taxes paid (net of subsidies)	108
Canadian Households	
Financial wealth	2,131
Labour income	351
Capital income	106
Transfers from government	264
Taxes paid	157
Household consumption	596
Investment expenditures and financing	
Investment expenditures	153
Domestic saving	132
Foreign saving	21

Table 3
Base case values for each industry (billions of 1997 Canadian dollars)[a]

	Primary	Goods	Services	Housing	Total
Gross Output (*X*)	118	555	554	101	1,328
Labour inputs (*L*)	17	117	215	02	351
Material inputs ($\overline{M}$)	50	366	212	15	643
Capital inputs (*K*)	241	431	565	804	2,041
Value of the firm (*V*)	237	384	545	439	1,605
Outstanding debt (*B*)	19	47	128	391	585
Investment (*I*)	23	36	53	40	151
Earnings (*EARN*)	39	50	82	53	224

[a] Benchmark prices are equal to unity therefore all numbers given for quantity variables can be interpreted as values or as quantities.

5. Simulation results and analysis

In this section we analyze the impact of various tax changes on the Canadian economy. Seven different tax instruments are examined and the results are ranked according to changes in domestic welfare. Each policy shock is assumed unanticipated, permanent, and to take effect immediately. All policy changes are scaled so that they involve the same present value of lost tax revenue.[10] Since our study attempts to assess marginal excess burdens (rather than the impact of fundamental tax reform), the magnitudes of the shocks are kept small. The first subsection deals with aggregate effects while the second briefly examines some sector specific implications.

5.1 Aggregate results of various policy initiatives

In this section, we present the aggregate results for seven tax policy initiatives. A subsection for each measure describes the shock and results. All figures (unless mentioned otherwise) are reported as percentage change from the base case equilibrium (percent shock minus control). The first column in Table 4 reports the welfare gain[11] per dollar of lost present value of government revenue. The second column is the percentage change in the new steady state GDP given a one percent-of-GDP reduction in ex ante government revenue[12]. Table 5 examines the effects on macroeconomic variables of interest. As can be seen from the tables, the two shocks that dominate are the increase in capital cost allowances and the lowering of personal capital income taxes. As a result our analysis will focus on these two measures as well as on the corporate income tax measure as it provides a good benchmark for comparison. The four other measures are treated summarily.

The results from Table 4 and 5 are in line with the general equilibrium tax model literature. In a survey of this literature, Baylor (2004) reports that most neoclassical GE models show that taxes on capital are the most distortionary, followed by taxes on labour and then by taxes on consumption. In addition, models that examined the impact of investment incentives found them to be among the most effective measures.

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[10] Specifically, all policy shocks are scaled to yield a 0.25% decrease in the present value of government revenue. Government revenue is discounted using the fixed steady state aggregate rate of return (6.0%).

[11] The welfare gain is the dollar change in first period wealth that would make the consumer as well off as the proposed policy change.

[12] Unlike the shocks used to evaluate welfare gains, these shocks are scaled to yield an ex ante 1%-of-GDP reduction in government revenue. The welfare measure is the preferred one since it relates to welfare and takes the transition into account; as such all figures reported in this paper (with the exception of this column) relate to the welfare simulations scaled according to the decrease in the present value of government revenue. Nonetheless, the output measure may provide a more familiar concept that some readers may find useful.

Table 4

Impact of revenue equivalent tax initiatives on welfare and steady state GDP

Tax measure	Welfare gain (in dollars) per dollar of lost present value government revenue	Percentage change in steady state GDP for an ex ante 1%-of-GDP reduction in government revenue
Increase in capital cost allowances on new capital	1.35	4.39
A cut in personal capital income taxes	1.30	3.36
A cut in sales taxes on capital goods	1.29	3.05
A cut in corporate income taxes	0.37	1.94
A cut in personal income taxes	0.32	1.29
A cut in payroll taxes	0.15	0.66
A cut in consumption taxes	0.13	0.19

Table 5

Impact of revenue equivalent tax initiatives on variables of interest [a]

Indicator/Period	**1**	**5**	**15**	**25**	**∞**
Real GDP					
Capital cost allowances	0.04	0.18	0.42	0.57	0.87
Personal capital income taxes	0.04	0.10	0.39	0.39	0.66
Sales taxes on capital goods	0.04	0.20	0.44	0.60	0.91
Corporate income taxes	0.02	0.05	0.13	0.19	0.32
Personal income taxes	0.04	0.05	0.08	0.11	0.16
Payroll taxes	0.04	0.04	0.05	0.05	0.06
Consumption taxes	0.03	0.03	0.03	0.03	0.04
Consumption					
Capital cost allowances	-0.18	-0.11	0.08	0.22	0.54
Personal capital income taxes	-0.27	-0.14	0.07	0.21	0.50
Sales taxes on capital goods	-0.20	-0.13	0.06	0.22	0.56
Corporate income taxes	-0.14	-0.09	0.01	0.07	0.21
Personal income taxes	-0.02	0.01	0.05	0.08	0.13
Payroll taxes	0.03	0.04	0.05	0.05	0.06
Consumption taxes	0.04	0.04	0.04	0.04	0.05
Capital Stock					
Capital cost allowances	0.00	0.25	0.70	1.01	1.66
Personal capital income taxes	0.00	0.10	0.45	0.73	1.33
Sales taxes on capital goods	0.00	0.34	0.87	1.20	1.91
Corporate income taxes	0.00	0.04	0.20	0.33	0.62
Personal income taxes	0.00	0.03	0.10	0.15	0.26
Payroll taxes	0.00	0.01	0.03	0.04	0.06
Consumption taxes	0.00	-0.03	-0.05	-0.05	-0.04
Net Foreign Asset Position[b]					
Capital cost allowances	-0.04	-0.14	-0.19	-0.13	0.17
Personal capital income taxes	0.04	0.33	0.70	0.86	1.18
Sales taxes on capital goods	-0.02	-0.19	-0.21	-0.08	0.29
Corporate income taxes	-0.13	-0.01	0.14	0.21	0.36
Personal income taxes	0.00	0.05	0.11	0.14	0.20
Payroll taxes	-0.01	0.00	0.01	0.01	0.02
Consumption taxes	0.02	0.05	0.07	0.07	0.08

a Figures are percentage changes from base case (shock minus control) except where otherwise indicated.
b All net foreign asset position entries are expressed as changes from base case relative to base case GDP.

A cut in the corporate income tax (cit) rate

As shown in equation 5 of section 3, corporate income taxes are modeled as an ad valorem tax on corporate profits with deductions allowed for interest payments and capital depreciation. We simulate a 1.0 percentage point reduction in the *cit* rate (from 32.2% to 31.2%). The results are reported in Table 6.

In the non-housing sectors, lowering the *cit* raises the after-tax marginal product of capital and immediately raises firm earnings (and thus dividends) in every period. This increases the value of the firm (or the market value of existing capital) and raises the market value of an additional unit of capital above its acquisition costs (net of installation costs) and leads to higher investment. Investment will continue to increase throughout the transition period; the rising investment profile results both from firms only gradually adding to their capital stock due to adjustment costs and from the fact that a higher level of investment is required to maintain the higher stock. In the new equilibrium, the real aggregate capital stock stands 0.62% above its initial value.

The higher real rate of return increases the benefits of postponing consumption so that it initially falls (by 0.14%) but later rises as the economy begins to benefit from the increase in capital; in the long run consumption stands 0.21% above its base case value. However, rate of return changes do not only affect the saving-consumption decision. They also affect the labour-leisure decision. A higher rate of return raises the benefit of trading work today for leisure tomorrow (that is, by working more today and investing at the higher rate of return one can afford more leisure in the future). This results in a small 0.06% initial rise in the labour supply. Over time, higher physical wealth puts downward pressure on labour supply while the higher wage (resulting from capital deepening) puts upward pressure. The net result is a gradual ebbing of the labour supply over the transition period. In the end, labour returns to its base case level.

Lowering the *cit* also has important effects on the international front. First off, higher savings by domestic agents resulting from the higher domestic rate of return and the higher labour supply are allocated to both domestic and foreign assets. Initially, a greater proportion of wealth is awarded to domestic assets reflecting the rise in the domestic rate of return relative to that available on international markets. With time, however, the domestic rate of return falls and domestic households shift assets back to foreign capital markets. In the long run, total wealth owned by domestic residents rises by 1.14%, distributed evenly between the domestic and foreign market. Since the foreign investor is not modelled explicitly the only variable of interest is foreign assets held in the domestic market. This variable reacts solely to the interest rate differential (see equation 16). The result is straightforward: foreign portfolio investment simply mirrors the change in the domestic rate of return faced by foreign agents; it rises initially but then slowly returns to its base case value.

Table 6

Results from tax policy experiments: a cut in the corporate income tax rate[a]

Year:	**1[d]**	**5**	**25**	**∞**
Firms				
Gross Output				
Primary	0.03	0.08	0.31	0.55
Goods producing	0.07	0.10	0.24	0.34
Services	0.01	0.05	0.18	0.27
Housing services	-0.03	-0.08	0.04	0.26
Investment				
Primary	0.22	0.31	0.57	0.79
Goods producing	0.39	0.49	0.71	0.86
Services	0.35	0.45	0.68	0.83
Housing services	-0.59	-0.19	0.21	0.29
Firm earnings				
Primary	0.76	0.80	0.99	1.18
Goods producing	0.71	0.73	0.88	1.00
Services	0.75	0.76	0.91	1.02
Housing services	-0.18	-0.20	0.11	0.27
Asset value of firms				
Primary	1.27	1.33	1.53	1.74
Goods producing	1.07	1.12	1.28	1.43
Services	1.02	1.07	1.23	1.38
Housing services	-0.23	-0.14	0.12	0.34
Households				
Consumption	-0.14	-0.09	0.07	0.21
Wages	-0.02	0.02	0.17	0.31
Labour Supply	0.06	0.05	0.02	0.00
Wealth of domestic agents (total)	0.51	0.60	0.87	1.14
- located domestically	0.52	0.60	0.87	1.14
- located abroad	0.41	0.53	0.85	1.14
Wealth of foreign agents				
- located domestically	0.65	0.45	0.15	0.00
Welfare	0.37			
Aggregate indicators				
Aggregate net of tax rate of return faced by domestic agents[b]	6.04	6.03	6.02	6.02
Net of tax rate of return faced by foreign agents on domestic assets[b]	6.05	6.04	6.02	6.01
User cost of capital	-0.04	-0.03	-0.17	-0.34
Real Capital Stock	0.00	0.04	0.33	0.62
Government revenue	-0.04	-0.38	-0.25	-0.11
Real GDP	0.02	0.05	0.19	0.32
GDP per unit of effective labour	-0.04	0.00	0.17	0.32
Trade				
Real exchange rate	-0.06	-0.03	-0.03	-0.05
Trade Balance[c]	0.08	0.04	0.00	-0.01
Net Investment Income Flow[c]	-0.21	-0.01	0.01	0.03
Capital Account Balance[c]	0.13	-0.03	-0.01	-0.01
Net Foreign Asset Position[c]	-0.13	-0.01	0.21	0.36

a Figures are percentage changes from base case (shock minus control) except where otherwise indicated.
b The rates of return are expressed in levels (percentage points). The base case level is 6.00.
c Balance of Payment entries are in changes from base case relative to base case GDP.
d First period figures for asset values, wealth, and rates of return are values for period 2 (since they are fixed in the first period).

In the short run, the balance of payments reflects these changes. Net investment income flows fall as foreign investors capitalize on the large increase in domestic asset values and benefit from the higher rate of return. Similarly, the initial increase in the trade balance primarily reflects the weaker net foreign asset position and the higher rate of return obtained by foreign investors. These both force the domestic economy to transfer more real resources abroad by running a larger trade surplus. The initial decline in the exchange rate accommodates the rise in exports and fall in imports.

In the long run, however, the impact is quite different. As the domestic rate of return falls foreign investors progressively withdraw their funds and sell the capital to domestic agents. Even though the overall rate of return faced by domestic agents goes back to its initial value, the rise in domestic wealth (both human and physical) prompts them to save more in the new steady state. Since domestic agents also accumulate wealth on the international market the net foreign asset position improves in the long run. Furthermore, higher aggregate domestic demand raises the demand for imports leading to a slight trade deficit. The exchange rate will also fall in the long run since the accumulation of domestic capital will raise the supply of domestically produced goods relative to foreign goods, which depresses the relative price of domestic goods (i.e. the real exchange rate).

Overall, for each dollar of lost present value of government revenue the *cit* cut yields a benefit equivalent to increasing the first period wealth of domestic agents by 0.37 dollars.

A cut in personal capital income tax (pcit) rates

Personal capital income taxes are taxes on capital gains, dividends, and interest income. The taxes are a linear function of the respective capital income revenue earned by domestic residents on both foreign and domestic sources. We simulate a 1.25 percentage point decrease in each of the three tax rates. The results are reported in Table 7.

Like the corporate income tax cut, a cut in personal capital income taxes reduces the tax rate levied on income from capital. The immediate effect of lowering personal capital income taxes is to increase the after-tax return to domestic investors on both domestic and foreign assets. This immediately raises the after-tax value of dividends net of new share issues. For reasons identical to those outlined in the *cit* section this leads to higher investment and capital stock, lower consumption in the short run but higher consumption in the long run, and an initial rise in labour supply that erodes over time. Although the pattern of results resembles those observed for the *cit* shock the magnitudes are altogether different. In the long run, real output rises by 0.66%, the capital stock by 1.33%, and consumption by 0.50%. Welfare increases by more than three times as much.

At first thought, one might have surmised that two revenue neutral initiatives aimed at reducing the tax on proceeds from capital would have identical consequences. Although this is the case in simple, closed economy models, it is not true in general. In our model the reasons for the discrepancy are two fold.

Table 7
Results from tax policy experiments: a cut in personal capital income taxes[a]

Year:	**1**[d]	**5**	**25**	**∞**
Firms				
Gross Output				
Primary	0.07	0.23	0.88	1.47
Goods producing	0.14	0.19	0.43	0.63
Services	0.02	0.08	0.31	0.48
Housing services	-0.05	-0.09	0.28	0.76
Investment				
Primary	0.71	0.96	1.63	2.17
Goods producing	0.64	0.83	1.27	1.58
Services	0.54	0.74	1.18	1.48
Housing services	-0.81	-0.01	0.71	0.83
Firm earnings				
Primary	0.15	0.30	0.80	1.25
Goods producing	0.20	0.24	0.53	0.77
Services	0.02	0.07	0.37	0.62
Housing services	-0.42	-0.22	0.42	0.75
Asset value of firms				
Primary	1.03	1.18	1.68	2.15
Goods producing	0.89	1.01	1.36	1.69
Services	0.78	0.91	1.27	1.59
Housing services	-0.31	-0.08	0.50	0.95
Households				
Consumption	-0.27	-0.14	0.21	0.50
Wages	-0.03	0.04	0.36	0.64
Labour Supply	0.12	0.08	0.02	-0.03
Wealth of domestic agents (total)	0.45	0.66	1.31	1.88
- located domestically	0.44	0.65	1.28	1.84
- located abroad	0.47	0.76	1.53	2.15
Wealth of foreign agents				
- located domestically	0.27	-0.22	-0.93	-1.26
Welfare	1.30			
Aggregate indicators				
Aggregate net of tax rate of return faced by domestic agents[b]	6.07	6.06	6.03	6.02
Net of tax rate of return faced by foreign agents on domestic assets[b]	6.03	6.00	5.96	5.94
User cost of capital	-0.08	-0.07	-0.38	-0.73
Real Capital Stock	0.00	0.10	0.73	1.33
Government revenue	-0.29	-0.52	-0.23	0.05
Real GDP	0.04	0.10	0.39	0.66
GDP per unit of effective labour	-0.08	0.01	0.37	0.68
Trade				
Real exchange rate	-0.12	-0.06	-0.05	-0.10
Trade Balance[c]	0.16	0.05	-0.05	-0.08
Net Investment Income Flow[c]	-0.12	0.03	0.08	0.12
Capital Account Balance[c]	-0.04	-0.08	-0.04	-0.04
Net Foreign Asset Position[c]	0.04	0.33	0.86	1.18

a Figures are percentage changes from base case (shock minus control) except where otherwise indicated.
b The rates of return are expressed in levels (percentage points). The base case level is 6.00.
c Balance of Payment entries are in changes from base case relative to base case GDP.
d First period figures for asset values, wealth, and rates of return are values for period 2 (since they are fixed in the first period).

First, the two differ in that the *cit* cut is a tax cut for all owners of capital located in Canada (including foreign residents) while the *pcit* cut, because of resident based taxation, is a tax cut for domestic investors alone. Since all government proceeds are re-distributed to domestic agents, cutting taxes on inframarginal capital income to foreign residents is akin to diverting a lump sum transfer from domestic households to foreign households. Clearly, the higher the foreign share of the capital, the smaller the benefits from reducing the *cit* and the greater the discrepancy between the two shocks.

Second, as highlighted in Summers (1981), a reduction in the corporate income tax lowers the value of accelerated depreciation and immediate expensing of adjustment costs, thereby raising the after-tax cost of new capital goods. On the other hand, the cost of new capital is not directly affected by personal capital income tax reductions. This implies that, for revenue equivalent tax reductions, a larger proportion of the tax cut is channelled to new capital under the *pcit* cut than under the *cit* cut. Put another way, the "leakages" to the existing capital stock are larger for the *cit* cut than for the *pcit* cut. This explains why the value of company shares jump by such a large amount under the *cit* cut; not only have we increased the after-tax rate of return on existing capital but we have raised the after-tax cost of new capital goods (thereby raising the value of existing capital).

The discrepancy in capital formation (1.33% rise vs a 0.62% rise) reflects these two factors. Clearly, minimizing leakages to existing capital in favour of greater tax reductions for new capital will favour capital formation. Additionally, minimizing leakages to foreign residents also leads to greater capital formation since transfers to domestic residents give rise to greater demand for domestic output[13].

On the international side the *pcit* cut, unlike the *cit* cut, raises the rate of return to domestic agents on both domestic and foreign assets. Foreign residents, on the other hand, receive no tax cut and their only incentive to increase portfolio investment stems from the rise in the risk free interest rate required to maintain asset market equilibrium. Over the transition, the domestic rate of return will fall as the domestic capital stock increases. Not so on international markets since Canadian contributions are assumed not to affect the international rate of return. Hence, in the long run, although wealth invested in both regions rises it increases relatively more abroad. Similarly, the rate of return received by foreign investors on domestic assets will decline over time (since they don't receive the benefit of the tax cut and the pre-tax rate of return must fall as the capital stock rises) and hence foreign portfolio investment will drop. These two phenomena explain the marked increases in the net foreign asset position. The initial increase in the trade balance offsets the withdrawal of funds by foreign investors and the purchase of foreign assets by domestic agents. In the long run, however, higher aggregate domestic demand raises import demand leading to a slight trade deficit.

[13] Although this need not be the case, it reflects the observation that consumption bundles in a given country are primarily made up of goods from that country.

An increase in capital cost allowances (cca) on new capital

Capital cost allowances are modelled as a corporate income tax credit based on the value of the depreciable capital stock (see equation 5, section 3). Since the depreciation of capital is a cost borne by firms in the production process the government allows them to deduct depreciation costs according to a legislated rate. The deduction that the tax system allows for depreciation is called a capital cost allowance (*cca*). The legislated rate for tax purposes, however, need not equal the actual rate of economic depreciation. Moreover the legislated rate can differ across vintages, allowing different depreciation rates for capital purchased in different years. Since the present value of depreciation tax shields are an important determinant of the effective price of new capital goods, the legislated rate at which firms can depreciate capital for tax purposes will be important in determining the level and composition of investment. We simulate a 2.7 percentage point increase in the tax depreciation rate allowable on both structures and equipment in all industries. Table 8 illustrates the results.

The effect of increasing capital cost allowances is to lower the effective acquisition cost of new capital to domestic industries below its market value and thus stimulate investment demand. Higher investment demand raises the domestic interest rate, which elicits a rise in savings by both domestic and foreign agents. As in the two previous simulations, consumption initially falls but then rises in the long run as people benefit from the higher capital stock. The labour supply reaction though is somewhat different. Although labour supply rises initially in reaction to the higher price of current leisure, it does not decline thereafter in response to higher wealth. In fact, labour supply continues to increase for the first 15 periods before beginning to fall. The reason is quite straightforward. The higher capital accumulation under the increase in *cca* results in a higher rise in the marginal product of labour and hence a higher wage. The wage increase initially outweighs the wealth increase in the labour supply decision. After some time, however, the wealth effect dominates and the rise in the labour supply begins to recede.

In the long run, the capital stock rises by 1.66%, real output by 0.87%, and consumption by 0.54%. The welfare gain is 1.35, slightly higher than that for the *pcit* cut. The key insight is that increases in *cca* focus on marginal investment while the other measures do not. Lowering *cit* and *pcit* rates reduces the tax not only on marginal but also on inframarginal capital and therefore results in cutting transfers to consumers in favour of lower non-distortionary wealth taxes rather than lower effective tax rates on marginal investment. The *cca* on the other hand, channels the tax benefits only to new capital by maintaining the non-distortionary wealth tax on existing capital. However, it does provide a transfer to foreign residents in the form of lower investment costs on their inframarginal investment (foreign investment that would have been undertaken even without the credit). Our results indicate that, when compared to the *pcit* cut, the benefits of a higher domestic capital stock resulting from increasing capital cost allowances marginally outweigh the leakage to foreign residents.

Table 8
Results from tax policy experiments: increasing capital cost allowances[a]

Year:	1[d]	5	25	∞
Firms				
Gross Output				
Primary	0.03	0.14	0.49	0.90
Goods producing	0.11	0.26	0.64	0.87
Services	0.03	0.19	0.62	0.86
Housing services	-0.03	0.00	0.29	0.76
Investment				
Primary	0.39	0.46	0.83	1.23
Goods producing	1.28	1.40	1.87	2.22
Services	1.51	1.66	2.21	2.59
Housing services	0.23	0.20	0.65	0.83
Firm earnings				
Primary	0.06	0.86	0.72	1.08
Goods producing	0.15	1.86	1.61	1.68
Services	0.05	1.66	1.73	1.65
Housing services	-0.26	-0.36	0.46	0.93
Asset value of firms				
Primary	0.14	0.04	0.10	0.52
Goods producing	0.43	0.49	-0.40	-0.21
Services	0.39	0.59	-0.33	-0.34
Housing services	-0.82	-0.68	0.12	0.66
Households				
Consumption	-0.18	-0.11	0.22	0.54
Wages	0.00	0.13	0.53	0.85
Labour Supply	0.09	0.10	0.07	0.03
Wealth of domestic agents (total)	0.03	0.11	0.06	0.53
- located domestically	0.04	0.12	0.07	0.53
- located abroad	0.02	0.05	0.01	0.53
Wealth of foreign agents				
- located domestically	0.10	0.40	0.33	-0.01
Welfare	1.35			
Aggregate indicators				
Aggregate net of tax rate of return faced by domestic agents[b]	6.04	6.04	6.04	6.02
Net of tax rate of return faced by foreign agents on domestic assets[b]	6.02	6.04	6.03	6.01
User cost of capital	-0.06	-0.16	-0.58	-0.97
Real Capital Stock	0.00	0.25	1.01	1.66
Government revenue	0.09	-0.74	-0.21	0.22
Real GDP	0.04	0.18	0.57	0.87
GDP per unit of effective labour	-0.05	0.08	0.50	0.84
Trade				
Real exchange rate	-0.04	-0.08	-0.16	-0.21
Trade Balance[c]	-0.06	0.00	0.02	0.00
Net Investment Income Flow[c]	0.03	-0.02	-0.02	0.01
Capital Account Balance[c]	0.04	0.02	0.00	-0.01
Net Foreign Asset Position[c]	-0.04	-0.14	-0.13	0.17

a Figures are percentage changes from base case (shock minus control) except where otherwise indicated.
b The rates of return are expressed in levels (percentage points). The base case level is 6.00.
c Balance of Payment entries are in changes from base case relative to base case GDP.
d First period figures for asset values, wealth, and rates of return are values for period 2 (since they are fixed in the first period).

On the international front the dynamics are quite different from those observed under the two previous policy experiments. In fact, in the short run, the results are almost opposite. The key difference is the much smaller capitalization effect. Because increasing *cca* is essentially an implicit wealth tax on existing capital, the capital gain will be much smaller (and could be negative)[14]. Therefore, while changes to the balance of payments were driven by the large capitalization effect in the two previous shocks, the impetus, in this case, originates from a rise in imports resulting from a shift in demand from the consumption good to the capital good (the foreign good comprises a larger share of the capital good). The decline in the trade balance is accommodated by a depreciation of the exchange rate and offset by slight rises in the net investment income flow (resulting from the decline in the exchange rate) and a positive capital account (reflecting repatriation of foreign funds by domestic households). Note that, in the long run, the depreciation of the exchange rate is much more pronounced than for either the *pcit* or *cit* cuts; this reflects the increased supply of domestic goods resulting from the policy's larger effect on the capital stock.

Consumption tax reduction

Consumption taxes are often lauded as being one of the most efficient taxes around. In fact, in simple models with inelastic labour supply they are non-distortionary. Although this characteristic is not preserved in more complex models it remains quite efficient. Consumption taxes are embedded in the price of full consumption (p^Z) in equation (12). We simulate a 0.003 percentage point decrease in the consumption tax.

The tax change affects the economy through two main channels. First, there will be a re-allocation effect between sectors. Since housing output is not subject to the consumption tax, lowering it causes agents to re-weight their consumption bundle towards non-housing goods. Second, and more importantly, a reduction in consumption taxes positively affects labour supply by increasing the after-tax real wage (in terms of goods in the non-housing sector). Most of the impact occurs in the initial period through the labour supply channel. As shown in Table 5, consumption rises by 0.04% initially and 0.05% in the long run.

The capital stock figures need to be interpreted with care. By raising the real wage in terms of non-housing goods we have decreased the economy's desired capital intensity: demand for the most capital intensive good (housing) falls and higher output in the other, more labour intensive, industries can be achieved without significant capital formation. Nonetheless, capital formation in the non-housing industries occurs as the increased labour supply raises the marginal product of capital. This rise is pitted against the large decline in housing capital. As can be seen in Table 5, the decline in housing initially dominates but capital formation in the other industries eventually catches up and some of the lost ground is recouped. It is important to realize that, in this case, the decline in the capital stock is not a reflection of an adverse shock; it represents a shift in demand towards more labour intensive goods.

[14] Due to adjustment costs, the effect of reducing the price of new capital on the value of old capital is ambiguous.

On the international side, the higher domestic wealth created by increased work effort raises portfolio holdings both at home and abroad. Higher foreign holdings give rise to a small improvement in the net foreign asset position (0.08%). Overall, the welfare gain resulting from lowering this tax is only 0.13, making it the most efficient tax.

Payroll tax reduction

As shown in equation 5 of section 3, payroll taxes are modeled as an ad valorem tax on labour inputs. We simulate a 0.003 percentage point reduction in the rate.

Much like the consumption tax, the payroll tax cut initially increases the after-tax real wage. However, it is not as discriminating as the consumption tax when it comes to industry taxation. Although we observe a similar level shift in labour supply in the initial period, the increased demand for work raises the marginal product of capital and, hence, the demand for capital. Clearly, the initial benefit will accrue primarily to those industries that are labour intensive but the wage increase raises the demand for all products rather than only for those products for which the price has fallen. This gives rise to fairly uniform rises in long run industry outputs.

Dynamics on the international side are similar to those observed for the consumption tax. As can be seen in tables 4 and 5, this measure raises both long run consumption and capital stock by 0.06%. The welfare gain (0.15) is only slightly above that observed for the consumption tax.

Personal income tax reduction

The personal income tax reduction is essentially a weighted average of the personal capital income tax reduction and the payroll tax. Consequently the result is to stimulate both labour supply (through a rise in the after-tax real wage) and domestic saving (through a rise in the after-tax rate of return) in the fashion described previously. We simulate a uniform 0.002 percentage point decline on all sources of personal income. Since the labour income base is larger than the capital income base this policy shock is weighted primarily towards labour income tax reductions.

The results (see tables 4 and 5) come as no surprise. As expected, the variables follow paths that lie between those observed for the *pcit* shock and payroll tax shock, with the payroll tax effects carrying the most weight. The dynamics are identical to those described above. It is interesting to note, however, that the aggregate welfare effect (0.32) is quite close to that of the *cit* shock, putting these two policies in second place.

A cut in sales taxes on capital goods

As detailed in Appendix A[15], the representative capital good is a composite of commodities from various sectors and countries. The sales tax on capital goods is

[15] Although sections 2.3 and 2.4 of appendix A deal with consumption, investment is allocated in an identical fashion. See section 3 in appendix A for details.

modelled as an ad valorem tax on commodities purchased for the sake of investment (see τ^{OUT} in section 2.4). We simulate a 1.15 percentage point reduction in the effective rate.

Like the increase in *cca*, a reduction in sales taxes on capital goods has the advantage of only targeting marginal investment. In particular, the after-tax price of commodities used as capital goods declines, translating into a reduction in the replacement cost of capital. As with the *cca* shock this lowers the effective acquisition cost of new capital below its market value and stimulates investment. In fact, as can be seen from Table 5, the economic dynamics of the two shocks are strikingly similar. There are, however, two noteworthy differences. First, the two shocks differ in their sectoral impacts. Although the aggregate impacts are very similar, the two policies affect individual industries in different ways. Second, cutting sales taxes is more expensive in the short run. This explains the relatively low percentage change in steady state GDP for an ex-ante 1%-of-GDP reduction in government revenue.

Despite higher paths for the aggregate output, consumption, and capital, the welfare gain from lowering the sales tax on capital goods is 1.29, slightly lower than that for *cca*. This presumably reflects the different sectoral incidences of the two shocks.

5.2 Industry nuances and considerations

Our simulations are mainly concerned with aggregate results and, as such, the benefits of the multi-sector feature of the model are implicit rather than explicit. Taking into account industry detail and intermediate input demands provides a richer and more realistic treatment of happenings in the real world. Although the results reported in section 5.1 are sufficient for our main purpose it is enlightening to examine some of the multi-sector features of the model.

In the housing sector, for example, the dynamics are somewhat different from those of other sectors since corporations own only a small fraction of housing capital. Thus the cut in corporate taxes (see Table 6) implies a much smaller reduction in the overall rate of return to housing and reduces the relative attractiveness of housing capital (in the short run). This will cause asset values in this sector to decline initially and investment will fall. In the long run, however, higher incomes put upward pressure on housing demand and lower production costs in the other sectors spillover to housing. Similar patterns occur for *cca* and *pcit* although they will be somewhat different because the gains accrue to corporate housing as well as non-corporate rentals (see tables 7 and 8, respectively).

Another important aspect of multi-sector analysis is that benefits accruing in the aggregate do not necessarily accrue evenly to various industries. A striking example occurs when we compare the *cca* and *pcit* shocks. Our aggregate analysis led us to conclude that they were more or less equivalent policies in terms of their welfare effects. A quick glance a tables 7 and 8 reveal that although the service industry would agree with this premise, the primary industry would not. Output and investment increase by a greater amount for the primary industry under the *pcit* shock while the service industry sees the smallest rise in output. The strong rise in output reflects the industry's high capital intensity. In fact, the ranking of increase in steady state output for *pcit* and *cit* in the non-housing industries is according to their capital intensity. In the case of the *cca* the benefit accruing to the primary industry is relatively small because the *cca* is already much larger than economic depreciation in this sector. Hence, the percentage change in the acquisition cost of new capital is smaller than for industries were the initial gap is lower (such as the goods producing and service sectors).

6. Sensitivity analysis

In this section, we test the robustness of our results by reconsidering all our policy simulations under alternative values for important model parameters. We find that the ranking reported in Table 3 is more or less unaffected by parameter values but that the magnitudes of the welfare gains are fairly sensitive. The parameters tested, along with their low, central, and high values, and the results for welfare gains under each sensitivity test are reported in tables 9a to 9d. Changes in the intertemporal elasticity of substitution (Table 9a) affect the domestic interest elasticity of savings. In general, a lower elasticity of substitution leads to a smaller change in domestic saving, a larger rise in the domestic interest rate and, as a result, a higher inflow of savings from foreign residents. For tax measures aimed at capital, this results in smaller welfare gains for domestic agents. The converse is true for a higher elasticity of substitution. Varying this parameter is inconsequential for tax simulations that alter the real wage. Overall, the ranking of the tax measures is unaffected by either an increase or decrease in this parameter.

Adjustment costs primarily affect the speed at which the economy approaches its new steady state but have little effect on the steady state itself. When they are lower the transition occurs faster and the benefits of a higher capital stock are reaped earlier, resulting in greater welfare gains. As with the intertemporal elasticity of substitution, the impact of varying adjustment cost parameters is commensurate with capital formation. This is borne out in Table 9b. Lowering adjustment costs increases the welfare gains accruing from both the *cca* and *pcit* policies but the relative increase is greatest for the former, widening its lead. Were adjustment costs to be higher, however, the policy ranking would be reversed with the *pcit* shock taking the lead[16].

The elasticity of substitution between goods and leisure affects the response of labour to changes in wages and wealth. Implicitly, it regulates the potential for tax distortions on the work-leisure margin. The results in Table 9c reveal that this is a powerful parameter. Higher values imply higher wage elasticities of labour supply. Hence, the beneficial effects resulting from a higher real wage (either from capital deepening or lower direct wage taxes) are more significant and hence lead to greater welfare gains. The converse is true for a lower elasticity. In fact, lowering the elasticity actually tilts the balance in favour of the *pcit* policy since the greater capital formation arising from the *cca* shock induces only a smaller labour supply response.

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[16] Summers (1981) results were originally criticized for being too high (see Tobin and White (1981)) and it seems plausible that, if anything, adjustment costs have fallen since the early 1980s. It is therefore unlikely that adjustment costs are higher.

Table 9a
Sensitivity analysis: Intertemporal elasticity of substitution
Welfare gain (in dollars) per dollar of lost present value government revenue

Tax measure	Low (0.33)	Central (0.5)	High (0.75)
Capital cost allowances	1.20	1.35	1.48
Personal capital income taxes	1.15	1.30	1.43
Sales taxes on capital	1.14	1.29	1.42
Corporate income taxes	0.33	0.37	0.41
Personal income taxes	0.31	0.32	0.34
Payroll taxes	0.14	0.15	0.15
Consumption taxes	0.13	0.13	0.13

Table 9b
Sensitivity analysis: Adjustment costs
Welfare gain (in dollars) per dollar of lost present value government revenue

Tax measure	Low (13.1)	Central (19.6)	High (29.4)
Capital cost allowances	1.65	1.35	1.06
Personal capital income taxes	1.49	1.30	1.11
Sales taxes on capital	1.57	1.29	1.03
Corporate income taxes	0.47	0.37	0.27
Personal income taxes	0.33	0.32	0.31
Payroll taxes	0.15	0.15	0.14
Consumption taxes	0.13	0.13	0.13

Table 9c
Sensitivity analysis: Goods-leisure elasticity
Welfare gain (in dollars) per dollar of lost present value government revenue

Tax measure	Low (0.45)	Central (0.7)	High (1.05)
Capital cost allowances	1.12	1.35	1.75
Personal capital income taxes	1.14	1.30	1.56
Sales taxes on capital	1.07	1.29	1.70
Corporate income taxes	0.33	0.37	0.44
Personal income taxes	0.25	0.32	0.43
Payroll taxes	0.09	0.15	0.24
Consumption taxes	0.08	0.13	0.20

The export price elasticity and elasticity of substitution between domestic and foreign goods affect the response of foreign and domestic demand (respectively) in response to relative price changes. The elasticities we use for our central simulations (see Table 1) may appear high to some readers. Indeed, they translate into price elasticities two to eight times as high as estimates from the literature[17]. However, such high elasticities are commonplace in general equilibrium models for small open economies. The problem with low trade elasticities is that they give rise to results that are inconsistent with general equilibrium small open economy assumptions. Therefore, rather than present results for high and low parameter values we focus on lower values to give a sense of results for a world of agents loyal to the products of their kin. The results in Table 9d show that trade elasticities have a significant impact, especially for shocks that give rise to large capital formation. Lower substitution exacerbates the declines in the terms of trade and the real exchange rate. The lower flexibility implied by lower substitution worsens domestic welfare. Moreover, the larger fall in the exchange rate reduces the profitability of domestic investment, reducing domestic capital formation. Much like lowering the labour supply elasticity, lower trade elasticities invert the ranking between *cca* and *pcit* since the former is much more sensitive to a decline in the terms of trade.

Table 9d
Sensitivity analysis: Export and import elasticities
Welfare gain (in dollars) per dollar of lost present value government revenue

Tax measure	Central	Reduction in export price elasticity of demand (2.0)	Reduction in elasticity of substitution between domestic and foreign goods (2.0)
Capital cost allowances	1.35	0.99	1.15
Personal capital income taxes	1.30	1.03	1.18
Sales taxes on capital	1.29	0.89	1.10
Corporate income taxes	0.37	0.25	0.31
Personal income taxes	0.32	0.27	0.30
Payroll taxes	0.15	0.13	0.14
Consumption taxes	0.13	0.12	0.12

Overall, sensitivity analysis does not alter our initial postulate. It remains unclear which of the two policies, increasing *cca* or cutting *pcit*, yields the greatest welfare gain. Some parameter changes tilt the balance in favour of one will some tilt the balance in favour of the other.

[17] Estimates for import and export price elasticities tend to be somewhere between 0.5 and 2.0. See Wirjanto (1999) and Marquez (1990) for Canadian estimates.

Conclusion

This paper describes the general structure of a Canadian dynamic, multi-sector, open economy tax model. Putting the model to use, we compare seven different tax measures and rank them according to their impact on domestic welfare. As with most neoclassical GE models in the literature, tax reductions on saving and investment are found to yield greater efficiency gains than wage and consumption tax reductions. In particular, investment-promoting policies geared towards new capital and personal capital income tax reductions are found to be particularly effective.

To be sure, the model does not provide definitive answers. As highlighted in the introduction, many of the channels through which tax policy affects the economy are not modelled. For example, with respect to the corporate income tax, the benefits arising from income shifting (considered by many to be the main reason for corporate income tax reductions) are not modelled. Furthermore, the model assumes that, by and large, the taxable domestic resident is the marginal investor. If instead the marginal investor is a tax exempt foreign investor then the potency of personal capital income tax cuts would diminish while that of corporate income tax cuts would rise. Indeed, Gordon (1986) shows that for a small open economy it is optimal to set the corporate income tax rate to zero while optimal personal capital taxes are positive. Another salient example of the ignored benefits of the corporate income tax cuts can be found in Russo (2004). He builds a Romer (1990) type general equilibrium model and concludes that the corporate income tax rate has relatively large effects on R&D investment, which translates into substantial welfare gains.

Furthermore, one can think of several natural extensions to the current model that might impact the results. Currently, foreign ownership in each industry is calculated using the aggregate figure for all sectors. A more realistic approach would be to use sectoral foreign ownership figures. This is potentially important since many of the tax measures considered impact certain sectors more than others (this is especially true when we compare the non-housing sectors to the housing sector). Second, the treatment of foreign behaviour is somewhat rudimentary. In fact, on inspecting the results, one sometimes gets the impression that we are modelling a quasi-closed economy. A more comprehensive treatment of foreign agents and their behaviour seems a worthwhile enterprise. For example, some of our results are based on minimizing welfare gains to foreign residents. In our framework this has no repercussions. However, this ignores international policy coordination and retaliation issues, if foreign countries were to anticipate our policies, international capital flows may be discouraged.

Definitive answers to tax questions are seldom encountered; like all other puzzles they must be solved through ingenuity and patient effort, one piece at a time.

Appendix A

The following provides a complete derivation of the maximization problems for the firm and the consumer. For the purpose of numerical implementation, the intertemporal problem is formulated in discrete time. This allows direct comparison between the equations derived herein and the model's computer code. Discrete time derivations require a dating convention: stocks are defined as beginning of year and prices and flows are defined as end of year. Terms devoid of time subscripts are either exogenously determined tax rates or constants. Firm behaviour is modeled in identical fashion in all non-housing industries. Industry subscripts, however, are suppressed to simplify the notation. This appendix expands on section 3 of the text. The assumptions stated in the main body apply.

It should be noted that identical mnemonics are used for different variables and parameters in parts 1 and 2. This allows the use of "standard" notation in both parts.

1. The model of the firm

The starting point for specifying the value of the firm is the asset market equilibrium condition. That is, risk-adjusted rates of return must be the same across all assets:

$$(1-c)\frac{(V_{t+1}-V_t-VN_t)}{V_t}+(1-\theta)\frac{DIV_t}{V_t}=i_t(1-\tau^{pit})+\eta=\rho_t \qquad \text{(A1)}$$

where

V is the value of the firm
DIV are dividends
VN represents new share issues (or share buybacks if negative)
θ is the effective tax rate on dividends
c is the effective tax rate on capital gains
i is the nominal interest rate paid on debt
τ^{pit} is the marginal income tax rate
η is the equity risk premium
ρ is the risk adjusted required rate of return for holding shares of a given industry

The transversality condition required to rule out eternally speculative bubbles is:

$$\lim_{s\to\infty} \quad V_s\prod_{u=t}^{s}\left[\frac{1}{\left(1+\rho_u/(1-c)\right)}\right]=0$$

With this condition the differential equation (A1) can be solved for V_t:

$$V_t = \sum_{s=t}^{\infty}\left[\left(\frac{1-\theta}{1-c}\right)DIV_s - VN_s\right]\mu_t(s) \quad \text{(A2)}$$

$$\mu_t(s) = \prod_{u=t}^{s}\left[\frac{1}{\left(1+\rho_u/(1-c)\right)}\right]$$

Firm dividends and new share issues are related through the cash flow:

$$EARN_s + BN_s + VN_s = DIV_s + IEXP_s \quad \text{(A3)}$$

EARN is earnings
BN is the value of new debt issues
IEXP is investment expenditures

Firm earnings in each period are given by:

$$EARN_s = \left(p_s^X F(L_s, K_s, \overline{M}_s) - (1+\tau^w)w_s L_s - (1+\tau^m)p_s^M \overline{M}_s - \tau^k \overline{p}_s^K K_s - i_s BOND_s\right)(1-\tau^{cit})$$
$$+\tau^{cit}(\delta^T KDEP_s)$$
(A4)

$F(L_s, K_s, \overline{M}_s)$ is gross output (The production technology available to managers is detailed in sub-section 3.1)
K is capital
L is labour
$\overline{M}$ is the intermediate good composite
BOND is nominal debt
KDEP is the depreciable capital stock for tax purposes
δ^T is the geometric equivalent of the rate of tax depreciation

p^X, w, p^M, and are the prices of gross output, labour, and materials and $\overline{p}^K$ is the replacement price of capital net of Sales taxes.

τ^w, τ^m, τ^k, and τ^{cit} are the indirect tax on labour, the intermediate input tax, the property and corporate franchise tax, and the corporate income tax rate

Managers pay dividends equal to a fixed proportion of earnings net of the capital stock's appreciation and its economic depreciation.

$$DIV_s = a(EARN_s - (p_s^K - p_{s-1}^K)K_s - \delta^R p_s^K K_s) \quad \text{(A5)}$$

where p^K is the replacement price of capital gross of all taxes, δ^R is economic depreciation and a is the proportion paid out as dividends. With regard to debt finance it is assumed that managers maintain debt as a constant fraction of the value of the capital stock. Hence,

$$BOND_s = bp_{s-1}^K K_s \tag{A6}$$

$$BN_s = BOND_{s+1} - BOND_s = b(p_s^K K_{s+1} - p_{s-1}^K K_s) \tag{A7}$$

b being the fixed debt-capital ratio. Next, investment expenditures are given by

$$IEXP_s = (1 - ITC)p_s^K I_s + (1 - \tau^{cit})p_s^X \phi_s I_s \tag{A8}$$

I is real investment
ITC is the investment tax credit
ϕ are adjustment costs per unit of investment, these are modeled as a linearly homogenous convex function of the investment rate (see below for details)

Substituting (A3) through (A8) into (A2) yields:

$$V_t = \sum_{s=t}^{\infty} \begin{bmatrix} \left(\frac{1-\theta}{1-c}\right)\left[a(EARN_s - (p_s^K - p_{s-1}^K)K_s - \delta^R p_s^K K_s)\right] \\ - \begin{bmatrix} (a(EARN_s - (p_s^K - p_{s-1}^K)K_s - \delta^R p_s^K K_s)) \\ + ((1-ITC)p_s^K I_s + (1-\tau^{cit})p_s^X \phi_s I_s) \\ - EARN_s - (b(p_s^K K_{s+1} - p_{s-1}^K K_s)) \end{bmatrix} \end{bmatrix} \mu_t(s)$$

$$V_t = \sum_{s=t}^{\infty} \begin{bmatrix} (1-v)EARN_s + b(p_s^K K_{s+1} - p_{s-1}^K K_s) \\ - v((p_s^K - p_{s-1}^K)K_s - \delta^R p_s^K K_s) \\ - ((1-ITC)p_s^K I_s + (1-\tau^{cit})p_s^X \phi_s I_s) \end{bmatrix} \mu_t(s)$$

with $v = a - a\left(\frac{1-\theta}{1-c}\right)$

$$V_t = \sum_{s=t}^{\infty} \begin{bmatrix} (1-v)\left[\begin{pmatrix} p_s^X F(L_s, K_s, \overline{M}_s) - (1+\tau^w)w_s L_s \\ -(1+\tau^m)p_s^M \overline{M}_s - \tau^k \overline{p}_s^K K_s - i_s b p_{s-1}^K K_s \end{pmatrix}(1-\tau^{cit}) + \tau^{cit}(\delta^T KDEP_s)\right] \\ + b(p_s^K K_{s+1} - p_{s-1}^K K_s) \\ - v((1-\delta^R)p_s^K K_s - p_{s-1}^K K_s) \\ - ((1-ITC)p_s^K I_s + (1-\tau^{cit})p_s^X \phi_s I_s) \end{bmatrix} \mu_t(s)$$

(A9)

The term relating to tax depreciation:

$$\sum_{s=t}^{\infty}(1-v)\tau^{cit}(\delta^{T} KDEP_{s})\mu_{t}(s) \qquad \text{(A10)}$$

needs to be re-written to explicitly take into account different rates of tax depreciation for different "vintages" of capital. We can re-write (A10) as:

$$\sum_{s=t}^{\infty}(1-v)\tau^{cit}(\delta_{O}^{T} KDEPO_{s}+\delta_{N}^{T} KDEPN_{s})\mu_{t}(s) \qquad \text{(A11)}$$

KDEPO is the value of the depreciable capital stock of the old vintage for tax purposes
δ_{O}^{T} the geometric equivalent of the rate of tax depreciation for old capital
KDEPN is the value of the depreciable capital stock of the new vintage for tax purposes
δ_{N}^{T} the geometric equivalent of the rate of tax depreciation for new capital

The specification differentiates between two vintages of capital. That produced and used before period *t* and that produced after *t*. Hence, *KDEPO* and *KDEPN* can be re-written as:

$$KDEPO_{s} = KDEPO_{t}(1-\delta_{O}^{T})^{s-t} \qquad \text{(A12)}$$

$$KDEPN_{s} = \sum_{u=t+1}^{s} p_{u-1}^{K} I_{u-1}(1-\delta_{N}^{T})^{s-u} \qquad \text{(A13)}$$

and $KDEPN_{t} = 0$

(A11) now becomes:

$$\begin{aligned}&\sum_{s=t}^{\infty}(1-v)\tau^{cit}(\delta_{O}^{T} KDEPO_{t}(1-\delta_{O}^{T})^{s-t})\mu_{t}(s)\\&+\sum_{s=t}^{\infty}(1-v)\tau^{cit}(\delta_{N}^{T}(\sum_{u=t+1}^{s} p_{u-1}^{K} I_{u-1}(1-\delta_{N}^{T})^{s-u}))\mu_{t}(s)\end{aligned} \qquad \text{(A14)}$$

The second term of (A14) can be re-written as:

$$\sum_{s=t}^{\infty} p_{s}^{K} I_{s}(1-v)\tau^{cit}\delta_{N}^{T}(\sum_{u=s}^{\infty}(1-\delta_{N}^{T})^{s-u}\mu_{t+1}(s+1))\mu_{t}(s) \qquad \text{(A15)}$$

Let $Z_{s} = \sum_{u=s}^{\infty}\tau^{cit}\delta_{N}^{T}(1-\delta_{N}^{T})^{s-u}\mu_{t+1}(s+1)$ (A16) and $B_t = \sum_{s=t}^{\infty}(1-v)\tau^{cit}(\delta_O^T KDEPO_t(1-\delta_O^T)^{s-t})\mu_t(s)$ (A17)

It follows that:

$$\begin{aligned}&\sum_{s=t}^{\infty}(1-v)\tau^{cit}(\delta^T KDEP_s)\mu_t(s)\\&= B_t + \sum_{s=t}^{\infty} p_s^K I_s(1-v)Z_s\mu_t(s)\end{aligned} \qquad \text{(A18)}$$

Substituting (A18) into (A9) yields our final specification for the market value of the firm:

$$V_t = \sum_{s=t}^{\infty}\left[\begin{array}{l}(1-v)\left[\left(\begin{array}{l}p_s^X F(L_s, K_s, \overline{M}_s) - (1+\tau^w)w_s L_s\\ -(1+\tau^m)p_s^M \overline{M}_s - \tau^k \overline{p}_s^K K_s - i_s b p_{s-1}^K K_s\end{array}\right)(1-\tau^{cit})\right]\\ + b(p_s^K K_{s+1} - p_{s-1}^K K_s)\\ - v((1-\delta^R)p_s^K K_s - p_{s-1}^K K_s)\\ -(1-ITC-(1-v)Z_s)p_s^K I_s - (1-\tau^{cit})p_s^X \phi_s I_s\end{array}\right]\mu_t(s) + B_t$$

(A19)

Finally, the change in the real capital stock must equal investment minus depreciation:

$$K_{s+1} - K_s = I_s - \delta^R K_s \qquad \text{(A20)}$$

Equations (A19) and (A20) contain all the information we need to characterize the behaviour of managers imbued with given *a* and *b*. As alluded to earlier, managers seek to maximize the value of the firm. Given an initial capital stock, they must choose the time paths of labour (*L*), investment (*I*), and intermediate inputs ($\overline{M}$) to maximize (A19) subject to constraint (A20). Write the Lagrangian as:

$$\begin{aligned}\zeta_t = &\sum_{s=t}^{\infty}\left[\begin{array}{l}(1-v)\left[\left(\begin{array}{l}p_s^X F(L_s, K_s, \overline{M}_s) - (1+\tau^w)w_s L_s\\ -(1+\tau^m)p_s^M \overline{M}_s - \tau^k \overline{p}_s^K K_s - i_s b p_{s-1}^K K_s\end{array}\right)(1-\tau^{cit})\right]\\ + b(p_s^K K_{s+1} - p_{s-1}^K K_s)\\ - v((1-\delta^R)p_s^K K_s - p_{s-1}^K K_s)\\ -(1-ITC-(1-v)Z_s)p_s^K I_s - (1-\tau^{cit})p_s^X \phi_s I_s\end{array}\right]\mu_t(s) + B_t\\ &- \sum_{s=t}^{\infty}\lambda_s(K_{s+1} - (1-\delta^R)K_s - I_s)\mu_t(s)\end{aligned} \qquad \text{(A21)}$$

The first order conditions for optimality are:

$$\frac{\partial F_s}{\partial L_s} = \frac{(1+\tau^w)w_s}{p_s^X} \tag{A22}$$

$$\frac{\partial F_s}{\partial \overline{M}_s} = \frac{(1+\tau^M)p_s^M}{p_s^X} \tag{A23}$$

$$(1-ITC-(1-v)Z_s-b)p_s^K + (1-\tau^{cit})p_s^X\left[\phi_s + \frac{\partial \phi_s}{\partial(I_s/K_s)}\cdot\frac{I_s}{K_s}\right] = \lambda_s \tag{A24}$$

$$\left[\begin{array}{l}(1-\tau^{cit})(1-v)\left[p_{s+1}^X\frac{\partial F_{s+1}}{\partial K_{s+1}} - i_{s+1}bp_s^K - \tau^K\overline{p}_s^K\right] + (b-v)\left[(1-\delta^R)p_{s+1}^K - p_s^K\right] \\ +(1-\tau^{cit})p_{s+1}^X\frac{\partial \phi_{s+1}}{\partial(I_{s+1}/K_{s+1})}\cdot\left(\frac{I_{s+1}}{K_{s+1}}\right)^2\end{array}\right]\mu_s(s+1)$$

(A25)

$$= \lambda_s\mu_t(s) - (1-\delta^R)\lambda_{s+1}\mu_t(s+1)$$

Equations (A22) and (A23) imply that labour and material inputs are demanded until their marginal product and net of tax price are equal. Equation (A24) defines λ as the marginal cost of investment to shareholders. λ is the shadow price of capital and corresponds to marginal *q*. (A24) implies that managers will invest in the firm up to the point were the market value of an additional unit of capital minus its acquisition costs equals the after tax cost of installation.

The observable counterpart to λ is linked to the market valuation of existing capital. In particular, one can show that under the assumptions made previously:

$$\lambda_{t-1} = \frac{V_t - B_t}{K_t} \tag{A26}$$

The proof is not provided here, it can be found in Hayashi (1982) and Summers (1981).

To solve for investment, I rely on (A24) and (A25). Solutions require the functional forms for the adjustment cost.

Adjustment costs are defined as:

$$\phi_s = \frac{\frac{\beta}{2}\left(\frac{I_s}{K_s} - \gamma\right)^2}{\frac{I_s}{K_s}} \quad \text{if } \frac{I_s}{K_s} \geq \gamma \tag{A27}$$

$$\phi_s = 0 \qquad\qquad \text{if } \frac{I_s}{K_s} \ \langle \ \gamma$$

Following Goulder and Summers(1989), define tax adjusted Q as:

$$Q = \phi_s + \frac{\partial \phi_s}{\partial (I_s / K_s)} \cdot \frac{I_s}{K_s} = \left[\frac{\lambda_s}{p_s^K} - 1 + ITC + (1-v)Z_s + b\right]\left[\frac{p_s^K}{(1-\tau^{cit})\, p_s^X}\right] \tag{A28}$$

Using the definition of adjustment costs in (A27) we can invert (A28) and obtain:

$$\frac{I_s}{K_s} = \gamma + \frac{1}{\beta} Q \tag{A29}$$

Finally, using (A27) in conjunction with (A25) we obtain the equation of motion for λ

$$\lambda_s = \left[\frac{1}{\left(1+\rho_{s+1}/(1-c)\right)}\right]\left[\begin{array}{l}(1-\tau^{cit})(1-v)\left[p_{s+1}^X \frac{\partial F_{s+1}}{\partial K_{s+1}} - i_{s+1} b p_s^K - \tau^K \overline{p}_s^K\right] + (b-v)\left[(1-\delta^R)\, p_{s+1}^K - p_s^K\right] \\ + (1-\tau^{cit})\, p_{s+1}^X \frac{\partial \phi_{s+1}}{\partial (I_{s+1}/K_{s+1})} \cdot \left(\frac{I_{s+1}}{K_{s+1}}\right)^2 + (1-\delta^R)\lambda_{s+1}\end{array}\right]$$

$$\lambda_s = \left[\frac{1}{\left(1+\rho_{s+1}/(1-c)\right)}\right]\left[\begin{array}{l}(1-\tau^{cit})(1-v)\left[p_{s+1}^X \frac{\partial F_{s+1}}{\partial K_{s+1}} - i_{s+1} b p_s^K - \tau^K \overline{p}_s^K\right] \\ + (b-v)\left[(1-\delta^R)\, p_{s+1}^K - p_s^K\right] \\ + (1-\tau^{cit})\, p_{s+1}^X \cdot \beta \cdot \left(\left(\frac{I_{s+1}}{K_{s+1}}\right)^2 - \gamma^2\right) + (1-\delta^R)\lambda_{s+1}\end{array}\right] \tag{A30}$$

2. The model of the consumer

As mentioned in the main body, the representative domestic consumer faces a multi-level decision problem and must choose paths for consumption of the various goods, leisure, and portfolio holdings that maximize his welfare. Figure 2 illustrates the nesting structure of the agent's decisions. These are separated into four stages; we deal with each of these in turn.

2.1 Intertemporal decision

The first decision stage faced by the domestic agent is intertemporal full consumption decision. At this stage the consumer determines the optimal time paths for international portfolio shares and full consumption. He maximizes a utility function of the form:

$$U_t = \sum_{s=t}^{\infty}(1+\omega)^{t-s}\left(\frac{\sigma}{\sigma-1}\right)(Z_s^{\beta}A_s^{1-\beta})^{\frac{\sigma-1}{\sigma}}$$

(B1)

$$\text{with } A_s = \left(\alpha_0^{1-\rho}\alpha_s^{\rho} + (1-\alpha_0)^{1-\rho}(1-\alpha_s)^{\rho}\right)^{\frac{1}{\rho}} \quad \text{(B2)}$$

$$\text{and } \rho = \frac{\phi-1}{\phi} \quad \text{(B3)}$$

subject to the intertemporal budget constraint and transversality condition:

$$W_{t+1}^K - W_t^K = r_t^D W_t^K + (1-\tau^{pit})\varpi_t L_t - T_t - PZ_t Z_t \quad \text{(B4)}$$

$$\lim_{s\to\infty} \quad W_s^K \prod_{u=t}^{s}\left[\frac{1}{(1+r_u^D)}\right] = 0 \quad \text{(B5)}$$

$$\text{with } r_t^D = \alpha_t r_t^{DD} + (1-\alpha_t) r_t^{DF} \quad \text{(B6)}$$

U is total intertemporal utility
Z is full consumption
PZ is the price of full consumption
A is the portfolio preference index
ω is the pure rate of time preference
σ is the intertemporal elasticity of substitution
α is the share of the household's portfolio devoted to domestic assets
α_0 is a constant and represents the asset shares that maximize *A*
ϕ is the elasticity of substitution between asset shares
W^K is physical wealth
r^D is the annual after tax rate of return for domestic households

r^{DD} is the annual after tax rate of return offered to domestic households on holdings of domestic assets
r^{DF} is the annual after tax rate of return offered to domestic households on holdings of foreign assets
ϖ is the wage rate
τ^{pit} is the tax rate on individual's wage income
L is the time endowment
T is net taxes and transfers

Write the Lagrangian as:

$$\zeta_t = \sum_{s=t}^{\infty}(1+\omega)^{t-s}(\frac{\sigma}{\sigma-1})(Z_s^{\beta}A_s^{1-\beta})^{\frac{\sigma-1}{\sigma}}$$
$$-\sum_{s=t}^{\infty}\lambda_s\left[W_{s+1}^K-(1+(\alpha_s r_s^{DD}+(1-\alpha_s)r_s^{DF}))W_s^K-(1-\tau^{pit})\varpi_s L_s+T_s+PZ_s Z_s\right]$$
(B7)

differentiating with respect to the decision variables (Z and α) yields the first order conditions for optimality:

$$\beta(1+\omega)^{t-s}(Z_s^{\beta}A_s^{1-\beta})^{\frac{\sigma-1}{\sigma}} = \lambda_s PZ_s Z_s \qquad \text{(B8)}$$

$$(1-\beta)(1+\omega)^{t-s}(Z_s^{\beta}A_s^{1-\beta})^{\frac{\sigma-1}{\sigma}}A_s^{-1}\frac{\partial A_s}{\partial\alpha_s} = \lambda_s(r_s^{DF}-r_s^{DD})W_s^K \qquad \text{(B9)}$$

Differentiating with respect to the state variable, W_{s+1}^K, yields:

$$-\lambda_s+(1+r_{s+1}^D)\lambda_{s+1}=0 \qquad \text{(B10)}$$

Define Λ, the present value of the marginal utility of wealth, as

$$\Lambda_s = \frac{\lambda_s}{(1+\omega)^{t-s}}$$

Using (B11), re-write (B8), (B9), and (B10) in their final form as:

$$\beta(Z_s^{\beta}A_s^{1-\beta})^{\frac{\sigma-1}{\sigma}} = \Lambda_s PZ_s Z_s \qquad \text{(B8')}$$

$$(1-\beta)(Z_s^{\beta}A_s^{1-\beta})^{\frac{\sigma-1}{\sigma}}A_s^{-1}\frac{\partial A_s}{\partial\alpha_s} = \Lambda_s(r_s^{DF}-r_s^{DD})W_s^K \qquad \text{(B9')}$$

$$\frac{\Lambda_{s+1}}{\Lambda_s} = \frac{(1+\omega)}{(1+r^D_{s+1})} \qquad \text{(B10')}$$

Once all Λ are known Z and α can be identified from (B8') and (B9').

2.2 Consumption and Leisure decision

Once the agent has determined his paths for portfolio shares and full consumption, he faces an intratemporal decision between goods consumption and leisure consumption. The consumer chooses paths for consumption and leisure so as to maximize:

$$Z_s = \left(\varepsilon_c C_s^{\psi} + \varepsilon_l l_s^{\psi}\right)^{\frac{1}{\psi}} \qquad \text{(B11)}$$

subject to:

$$PZ_s Z_s = PC_s C_s + (1-\tau^{pit})\varpi_s l_s \qquad \text{(B12)}$$

and $\psi = \dfrac{\nu - 1}{\nu}$ (B13)

C is the overall consumption basket
PC is the price of the consumption basket
l is leisure
ϖ is the wage rate (same as above)
ε_c and ε_l are the CES parameters for consumption and leisure, respectively
ν is the elasticity of substitution between consumption and leisure

Differentiating the Lagrangian with respect to the choice variables yields the two first order conditions for optimality:

$$C_s = \varepsilon_c^{\nu}\left(\frac{PZ_s}{PC_s}\right)^{\nu} Z_s \qquad \text{(B14)}$$

$$l_s = \varepsilon_l^{\nu}\left(\frac{PZ_s}{(1-\tau^{pit})\varpi_s}\right)^{\nu} Z_s \qquad \text{(B15)}$$

Subbing (B14) and (B15) into (B12) yields the equation for the price of full consumption:

$$PZ_s^{1-\nu} = \varepsilon_c^{\nu} PC_s^{1-\nu} + \varepsilon_l^{\nu}((1-\tau^{pit})\varpi)^{1-\nu} \qquad \text{(B16)}$$

The above establishes the level of leisure (and, given the fixed nature of the time endowment, the level of labour supply) and aggregate consumption. In our model, there is a one-to-one correspondence between commodities and sectors. That is, each sector in the economy is assumed to produce one commodity type. However, a foreign economy with the same sectors also produces those commodities. The consumer differentiates between commodities from different countries and allocates aggregate consumption among output from various sectors and countries. Our allocation method is all but identical to that of Lavoie et al. (1999)[18].

2.3 Consumption allocation across goods from various sectors

The domestic consumer allocates his aggregate consumption expenditures (previously determined) between goods from each sector (these goods, however, are themselves composites of foreign and domestic commodities from each sector, see (2.4) below). He is assumed to maximize a Cobb-Douglas composite of the various goods[19]:

$$C = \prod_i c_i^{\theta_i} \tag{B17}$$

subject to

$$PC \cdot C = \sum_i Pc_i c_i \tag{B18}$$

c_i is consumption of good *i*
Pc_i is the price of good *i*
θ_i is the share parameter of good *i*

The first order condition for good *i* is:

$$c_i = \theta_i \frac{PC \cdot C}{Pc_i} \tag{B19}$$

Subbing (B19) into (B17), and subsequently, (B17) into (B18) one obtains the equation for the aggregate price *PC*:

$$PC = \prod_i \left(\frac{Pc_i}{\theta_i}\right)^{\theta_i} \tag{B20}$$

2.4 Geographical origins of commodities for consumption

The domestic consumer considers commodities produced by a given sector in different countries as imperfect substitutes. He allocates consumption expenditures on the various goods (previously determined in (2.3)) between commodities from each country. As in Armington (1969) preferences with respect to geographic origin are represented by a CES. The consumer maximizes:

[18] Detailed calculations for the derivations in (2.3) and (2.4) are given in their paper.
[19] At this point, since all choices are intratemporal, the time subscript, *s*, is dropped to simplify the notation.

$$c_i = \left(\delta_{i,D} c_{i,D}^{\frac{\mu_i - 1}{\mu_i}} + \delta_{i,F} c_{i,F}^{\frac{\mu_i - 1}{\mu_i}} \right)^{\frac{\mu_i}{\mu_i - 1}} \quad \text{(B21)}$$

subject to:

$$Pc_i c_i = (1+\tau_i^{OUT}) p_{i,D} c_{i,D} + (1+\tau_i^{TAR})(1+\tau_i^{OUT}) p_{i,F} c_{i,F} \quad \text{(B22)}$$

$c_{i,D}$ is consumption of commodity *i* produced in the domestic country
$c_{i,F}$ is consumption of commodity *i* produced in the foreign country
$p_{i,D}$ is the price of commodity *i* produced in the domestic country
$p_{i,F}$ is the price of commodity *i* produced in the foreign country in domestic currency
$\delta_{i,D}$ is the consumption share parameter for commodity *i* from the domestic country
$\delta_{i,F}$ is the consumption share parameter for commodity *i* from the foreign country
μ_i is the Armington elasticity of substitution for consumption between $c_{i,D}$ and $c_{i,F}$
τ^{OUT} indirect tax on commodity *i* purchased for consumption
τ^{TAR} tariff rate on commodity *i* from the foreign country

The first order conditions for $c_{i,D}$ and $c_{i,F}$ are:

$$c_{i,D} = \delta_{i,D}^{\mu_i} \left(\frac{Pc_i}{(1+\tau_i^{OUT}) p_{i,D}} \right)^{\mu_i} c_i \quad \text{(B23)}$$

$$c_{i,F} = \delta_{i,F}^{\mu_i} \left(\frac{Pc_i}{(1+\tau_i^{OUT})(1+\tau_i^{TAR}) p_{i,F}} \right)^{\mu_i} c_i \quad \text{(B24)}$$

Substituting (B19) into (B23) and (B24) yields the domestic consumer's demand functions for commodities produced by sector *i* in both the domestic and foreign country. These are functions of prices alone.

$$c_{i,D} = \delta_{i,D}^{\mu_i} \left(\frac{Pc_i}{(1+\tau_i^{OUT}) p_{i,D}} \right)^{\mu_i} \theta_i \frac{PC \cdot C}{Pc_i} \quad \text{(B23')}$$

$$c_{i,F} = \delta_{i,F}^{\mu_i} \left(\frac{Pc_i}{(1+\tau_i^{OUT})(1+\tau_i^{TAR}) p_{i,F}} \right)^{\mu_i} \theta_i \frac{PC \cdot C}{Pc_i} \quad \text{(B24')}$$

Furthermore, combining (B23) and (B24) with (B22) gives the explicit form for the aggregate price Pc_i:

$$Pc_i^{1-\mu_i} = \delta_{i,D}^{\mu_i} ((1+\tau_i^{OUT}) p_{i,D})^{1-\mu_i} + \delta_{i,F}^{\mu_i} ((1+\tau_i^{OUT})(1+\tau_i^{TAR}) p_{i,F})^{1-\mu_i} \quad \text{(B25)}$$

3. Aggregation for the representative investment good and material input

As illustrated in figure 1, the representative investment good and the intermediate input is made up of commodities from various sectors and countries. The composition of the investment good is determined in a fashion identical to that described in sections 2.3 and 2.4 of this appendix. Once aggregate investment has been determined (see section 1), allocation across commodities from various sectors and countries derives from the maximization of the nested Cobb-Douglas-CES composite functions. The same is true for the intermediate good bundle. The only nuance is that the representative investment good is homogenous (i.e. all sectors purchase the same representative capital good) while different sectors will have different intermediate input bundles.

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