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Tax Policy and the Dynamic Demand for Domestic and Foreign Capital by Multinational Corporations

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Abstract

The extent to which domestic and foreign operations of multinational corporations (MNCs) are related has important implications for the analysis of investment demand and its responsiveness to tax policy. We estimate the structural parameters of a model in which domestic and foreign investment demand interact in two important ways. First, the MNC's production technology allows the marginal products of domestic and foreign capital to be interdependent. Second, the marginal adjustment costs of investment in one location may be affected by investment in other locations. We estimate the model using firm-level panel data from Canadian MNCs that invest solely in the United States. Our estimates support the view that production and adjustment cost technologies are related. We find that domestic and foreign capital are greater than unit elastic substitutes and that investment in one location lowers the marginal adjustment costs of investment in the other location. We use our parameter estimates to simulate the effect of various tax policies on the growth of parent and affiliate capital stocks. The simulations demonstrate that allowing for interdependent capital demand across locations has important implications for the analysis of tax policy toward MNCs.

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1 Introduction

Recent empirical studies of foreign direct investment (FDI) have found strong tax effects on the pattern of investment over time and across countries (see the survey in Hines 1997).[1] Surprisingly, however, there has been little empirical work on the relationship between domestic and foreign capital demand at the firm level.[2] Such interdependency, if it exists, is important, since it means that national tax polices affect MNCs differently than purely domestic firms and suggests a role for policy coordination among countries. We consider a model in which the link between domestic and foreign operations is technological. This allows us to estimate the parameters of the technology and use them to study the effects of different features of home and host country tax policy on the investment patterns of MNCs.

In our theoretical model the domestic and foreign investment decisions of MNCs are linked in two ways. First, the output of the parent and its affiliates are functions of a production technology in which the marginal products of domestic and foreign capital are related. Second, adjustment costs of domestic and foreign investments are functions of both parent and affiliate investment and capital stocks. Thus factor demands interact through both the production and adjustment cost technologies. This means that both domestic and foreign tax parameters can affect the demand for capital in each location.

We use firm-level panel data on Canadian MNCs with US foreign affiliates to estimate our model. We choose to analyze these MNCs because Canada effectively exempts income from US affiliates from home country taxation. This feature of the Canadian tax system allows us to highlight how technological as opposed to institutional interrelations affect firm behavior. Moreover, it simplifies the incorporation of tax rules into our theoretical and empirical models.

[1] Most of the evidence on the effect of taxes on FDI comes from studies of either US MNCs or foreign firms investing in the US.

[2] One exception is Stevens and Lipsey (1992), in which the domestic and foreign operations of MNCs are linked through a financial constraint. Their reduced form estimates suggest that domestic and foreign investment are interdependent. A drawback of their analysis is that their dataset consists of proprietary information for only seven MNCs.

Our empirical approach involves estimating a system of interrelated Euler equations for parent and affiliate capital demand. We estimate both "own" production and adjustment cost parameters and "cross" ones resulting from interrelated technologies. The cross effect in the production technology determines the degree of substitutability between domestic and foreign capital. The cross effect in the adjustment cost technology indicates how adjustment costs are related. If the cross term is negative, the marginal adjustment costs of parent (affiliate) investment are decreased by affiliate (parent) investment. This may result from positive spillovers within the MNC that reflect, for example, the benefits of shared information. In contrast, a positive cross term may be due to negative spillovers within the MNC that reflect, for example, the costs of reorganizing and coordinating production across operations while integrating new capital.

We use our structural parameter estimates to calculate the elasticity of substitution between domestic and foreign capital, and the marginal adjustment costs of investment. We find that parent and affiliate capital are greater than unit elastic substitutes which suggests that changes in tax policy can have significant reallocative effects. Our estimate of the "cross" adjustment cost parameter is negative and statistically significant. This negative cross term significantly decreases our estimates of the marginal adjustment costs of both domestic and foreign investment.

Our simulation analysis explores the implications of incorporating interdependent capital demand into models used for policy analysis. Consider the effect of introducing an investment tax credit (ITC) on the steady state allocation of capital in a model in which the marginal products of capital across locations are unrelated. This domestic tax change will have no effect on investment abroad (unless there is another link between the parent and affiliate, such as a financial constraint). However, if capital demands are related, the tax change at home will have an impact on investment abroad. For example, our simulation results show that the introduction of a Canadian ITC leads to a substantial increase in the steady state capital stock of Canadian parent firms *and* a substantial decrease in the capital stock of US affiliates, relative to the baseline steady states.

Our simulations of the growth rates of capital show that the dynamic response to tax changes is different from what might be expected from a steady state analysis alone.

For example, when the Canadian ITC is increased both Canadian and US investment increase relative to the baseline at first, in spite of the fact that the eventual US steady state capital stock is lower. This dynamic result is due to the complementarity of domestic and foreign investment in the adjustment cost technology. According to our estimates, growth in one type of capital leads to an acceleration in the growth of the other type of capital. This means that even though the eventual steady state US capital stock is lower when the Canadian ITC is increased, US investment in the first years of the transition is higher because of the presence of complementary adjustment costs.

The paper is organized as follows. Section 2 introduces our theoretical model. Section 3 discusses the dataset. Section 4 presents our estimation strategy and results. Section 5 describes our simulation results and the final section concludes.

2 Model

We model the domestic and foreign investment decisions of an MNC with a single foreign affiliate.[3] Our formulation is based on Auerbach's (1989) model of the investment decisions of purely domestic corporations. We begin by defining the production technology of the MNC. We assume that the MNC produces output, Y, using a concave production function, $F(\cdot)$. The quasi-fixed factors of production are beginning-of-period domestic and foreign capital, K_{dt} and K_{ft}, where t indexes time, and d and f index the domestic parent and foreign affiliate. The variable factors of production are domestic and foreign labor, L_{dt} and L_{ft}. Inputs that are spatially separate are included in a single production technology:

$$Y_t = F(K_{dt}, K_{ft}, L_{dt}, L_{ft}). \tag{1}$$

This functional form allows the marginal products of domestic and foreign capital to be related. In our simulations, we contrast the results of our policy experiments with a special case in which marginal products of factors across locations are unrelated: $Y_t = F(K_{dt}, L_{dt}) + F(K_{ft}, L_{ft})$.

[3] The model could be extended to multiple foreign affiliates within the same foreign country through aggregation and to multiple affiliates in different foreign countries. In our empirical work, we use data in which all foreign affiliates in one country have been aggregated into a single entity.

We assume that investment in domestic and foreign capital is subject to adjustment costs that take the following quadratic form in net investment and capital:[4]

$$\begin{aligned} C(I_{dt}, I_{ft}, K_{dt}, K_{ft}) = \quad & \tfrac{\alpha_{dd}}{2}\left(\tfrac{I_{dt}}{K_{dt}} - \delta\right)^2 K_{dt} + \tfrac{\alpha_{ff}}{2}\left(\tfrac{I_{ft}}{K_{ft}} - \delta\right)^2 K_{ft} \\ & + \tfrac{\alpha_{df}}{4}\left[\left(\tfrac{I_{dt}}{K_{dt}} - \delta\right)\sqrt{K_{dt}} + \left(\tfrac{I_{ft}}{K_{ft}} - \delta\right)\sqrt{K_{ft}}\right]^2 \\ & + \tfrac{\alpha_{fd}}{4}\left[\left(\tfrac{I_{dt}}{K_{dt}} - \delta\right)\sqrt{K_{dt}} + \left(\tfrac{I_{ft}}{K_{ft}} - \delta\right)\sqrt{K_{ft}}\right]^2, \end{aligned} \tag{2}$$

where δ is the rate of economic depreciation which we assume is identical in all locations. We further assume that the interrelated adjustment costs are symmetric, i.e., $\alpha_{df} = \alpha_{fd}$.[5]

Given our adjustment cost function, the marginal adjustment costs for domestic and foreign investment are, respectively:

$$\begin{aligned} \frac{\partial C}{\partial I_{dt}} &= \left(\alpha_{dd} + \alpha_{df}\right)\left(\frac{I_{dt}}{K_{dt}} - \delta\right) + \alpha_{df}\sqrt{\frac{K_{ft}}{K_{dt}}}\left(\frac{I_{ft}}{K_{ft}} - \delta\right), \\ \frac{\partial C}{\partial I_{ft}} &= \left(\alpha_{ff} + \alpha_{df}\right)\left(\frac{I_{ft}}{K_{ft}} - \delta\right) + \alpha_{df}\sqrt{\frac{K_{dt}}{K_{ft}}}\left(\frac{I_{dt}}{K_{dt}} - \delta\right). \end{aligned} \tag{3}$$

This specification allows investment in one location to impact the marginal adjustment costs of investment in the alternate location.[6] If α_{df} is positive, increasing investment abroad, while simultaneously investing at home, increases the marginal adjustment

[4] Alternatively we could postulate that adjustment costs are on gross investment by setting $\delta = 0$ in equation (2) (see, e.g., Gould 1968; Treadway 1969; Abel 1985; Pindyck 1982; for a recent survey of adjustment costs see, Hammermesh and Pfann 1996). We found that estimates of this model were rejected in favor of one with adjustment costs on net investment (see appendix B).

[5] To ensure convexity of the adjustment cost function we must restrict the domain of α_{df}. The condition for convexity is:

$$\alpha_{df} > -\frac{\alpha_{dd}\alpha_{ff}}{(\alpha_{dd} + \alpha_{ff})}.$$

Consistent with the literature, we assume that both "own" adjustment cost terms (α_{dd} and α_{ff}) are positive. We confirm that convexity holds in our empirical work.

[6] To see this consider the derivative of the marginal adjustment cost of investment in one location with respect to investment in another location:

$$\frac{\partial^2 C}{\partial I_{dt}\partial I_{ft}} = \frac{\alpha_{df}}{\sqrt{K_{dt}K_{ft}}}.$$

costs of investment at home. As discussed in the introduction, this increase in marginal adjustment costs could be the result of a worldwide production process in which it is costly to coordinate some aspects of operations at home and abroad. A negative value for α_{df} could result if investment in one location generates positive spillovers (internal to the MNC) that decrease marginal adjustment costs of investment in other locations. This would be the case, for example, if adjustment costs were reduced by learning-by-doing.

Investment and capital are related by the usual capital stock accounting identities:

$$\begin{aligned} I_{dt} &= \dot{K}_d + \delta K_{dt}, \\ I_{ft} &= \dot{K}_f + \delta K_{ft}. \end{aligned} \tag{4}$$

The MNC makes investment decisions at home and abroad at time t to maximize the expected present discounted value of future profits:

$$V_t = \int_t^\infty \mathrm{e}^{-r(s-t)} \Pi_s ds, \tag{5}$$

where r is the nominal after-tax required rate of return on capital and Π_s is the MNC's global net revenue (i.e. net cash flow) after home and host country taxes.[7] We make two simplifying assumptions concerning the global net revenue function. First, the foreign affiliate repatriates all of its profits each year.[8] Second, the home country exempts foreign source income from home country taxation.[9] Using these assumptions we can express global net revenue in period t, Π_t, as the sum of after-tax domestic and foreign net revenue:

$$\Pi_t = \Pi_{dt} + (1 - \omega_t)\Pi_{ft}, \tag{6}$$

[7] We ignore shareholder level taxes on dividends and capital gains for simplicity. We have also ignored the deductibility of interest payments on debt finance by implicitly assuming that debt and equity are perfect substitutes and therefore that the MNC is financed entirely by equity. Allowing the MNC to choose between raising funds for the parent and affiliate over a more realistic set of alternatives (such as home country and local debt) is an important but difficult extension that we would like to address in future work.

[8] This assumption makes sense in our model since there is no alternative use for after-tax profits. A richer but considerably more complex model would allow after-tax profits to be invested in the world capital market or in other affiliates, for example.

[9] Our empirical work uses data from Canadian MNCs. Although Canada taxes the worldwide income of residents, dividends repatriated from US affiliates are effectively exempt from Canadian taxation through tax treaties with the US. Many other countries effectively exempt foreign source income from domestic taxation, including Australia, France, Germany, the Netherlands, and Switzerland.

where ω_t is the foreign country withholding tax rate on dividend payments.

The after-tax net revenue in each location is composed of gross revenues less factor payments. Since factor and output prices may differ across locations, after-tax profits at home and abroad depend on the portion of global output produced in each location. Let a_t be the portion of output produced abroad.[10] Then we can write the net revenue functions for the parent and foreign affiliate, respectively,

$$\begin{aligned}
\Pi_{dt} = \quad & (1-\tau_{dt})\{(1-a_t)g_{dt}[F(\cdot)-C(\cdot)]-w_{dt}L_{dt}\} \\
& -(1-k_{dt})p_{dt}I_{dt}-\tau_{dt}\int_{-\infty}^{t}p_{du}I_{du}D_d(t,t-u)du, \\
\Pi_{ft} = \quad & (1-\tau_{ft})\{a_t\, g_{ft}[F(\cdot)-C(\cdot)]-w_{ft}L_{ft}\} \\
& -(1-k_{ft})p_{ft}I_{ft}-\tau_{ft}\int_{-\infty}^{t}p_{fu}I_{fu}D_f(t,t-u)du,
\end{aligned} \tag{7}$$

where τ is the statutory corporate income tax rate; k is the investment tax credit; $D(t,t-u)$ is the depreciation allowance (assumed constant over time) per dollar of date u capital expenditure;[11] and g, w, and p are the prices of output, variable inputs, and investment, respectively.

We substitute equations (6) and (7) into equation (5) and rearrange to yield the net present value of the MNC's profits:

$$\begin{aligned}
V_t = \quad & \int_t^{\infty} \mathrm{e}^{-r(s-t)}\Big\{A_s\Big[F(K_{ds},K_{fs},L_{ds},L_{fs})-C(I_{ds},I_{fs},K_{ds},K_{fs})\Big]+B_{ds}+B_{fs} \\
& -p_{ds}I_{ds}\Gamma_{ds}-p_{fs}I_{fs}\Gamma_{fs}-(1-\tau_{ds})w_{ds}L_{ds}-(1-\tau_{fs})w_{fs}L_{fs}\Big\}ds,
\end{aligned} \tag{8}$$

where A_s is the weighted-average of after-tax returns to a unit of production:

$$A_s = (1-a_s)(1-\tau_{ds})g_{ds}+a_s\,(1-\tau_{fs})(1-\omega_s)g_{fs}.$$

[10] The portion of output produced in each market is, in fact, an endogenous function of past investment, input and output prices, interest rates, and tax parameters both at home and abroad. In appendix C we extend the model in a simple way to to endogenize a and study how our simulation results are affected.

[11] In our empirical work we take into account that Canada has a fixed capital tax and reduces the tax depreciation basis by the full portion of the investment tax credit claimed. Thus, we multiply the domestic deprecation allowances by $(1-k_{du})$.

The term Γ_s is one minus the present value of the net tax benefit of one dollar of date s investment:

$$\begin{aligned}\Gamma_{ds} &= 1 - k_{ds} - \int_s^\infty \mathrm{e}^{-r(u-s)}\tau_{du}D_d(u,u-s)du,\\ \Gamma_{fs} &= 1 - k_{fs} - \int_s^\infty \mathrm{e}^{-r(u-s)}\tau_{fu}D_f(u,u-s)du.\end{aligned} \tag{9}$$

The term B_s summarizes the value of depreciation allowances on investments at home and abroad predetermined at date s:

$$\begin{aligned}B_{ds} &= \tau_{ds}\int_{-\infty}^s p_{du}I_{du}D_d(s,s-u)du,\\ B_{fs} &= \tau_{fs}\int_{-\infty}^s p_{fu}I_{fu}D_f(s,s-u)du.\end{aligned} \tag{10}$$

We define domestic and foreign marginal q to be the ratio of the marginal after-tax cost of investment, including adjustment costs, to its market price:

$$q_{dt} = \frac{A_t(\partial C/\partial I_d)_t + p_{dt}\Gamma_{dt}}{p_{dt}}, \tag{11}$$

and

$$q_{ft} = \frac{A_t(\partial C/\partial I_f)_t + p_{ft}\Gamma_{ft}}{p_{ft}}. \tag{12}$$

Notice that in the steady state marginal adjustment costs are zero ($I_d/K_d = \delta$ and $I_f/K_f = \delta$) and therefore $q_d = \Gamma_d$ and $q_f = \Gamma_f$.

Equations (11) and (12) show how adding interrelated adjustment costs complicates the analysis of investment demand. In the usual formulation in which adjustment costs are functions only of "own" investment and capital, these expressions can be inverted to obtain an estimable relationship between the investment-capital ratio and marginal q.[12] In our model this approach is generally infeasible since there is no closed form

[12] Letting $\alpha_{df} = 0$ and $a = 0$ in equation (11) and rearranging terms gives the familiar relationship between the investment-capital ratio and marginal q:

$$\left(\frac{I}{K}\right)_{dt} = \delta + \frac{1}{\alpha_{dd}}\frac{p_{dt}(q_{dt}-\Gamma_{dt})}{g_{dt}(1-\tau_{dt})}.$$

solution for the domestic and foreign investment-capital ratios (except in the special case when $\alpha_{df} = 0$).[13]

The Euler equation for the optimal path of the domestic capital stock is (the one for foreign capital is symmetric):

$$A\left[F_{K_d} + \frac{1}{2}\left(\frac{I_d}{K_d}\right)\left(\frac{\partial C}{\partial I_d}\right)\right] = p_d q_d\left(r + \delta - \frac{\dot{q_d}}{q_d} - \frac{\dot{p_d}}{p_d}\right). \tag{13}$$

This equation equates the after-tax marginal product of domestic capital net of adjustment costs (LHS) to the domestic marginal cost of capital (RHS). In the steady state this equation is the familiar cost of capital adjusted for interrelated production, which we denote as c_d:

$$F_{K_d} = c_d = \frac{p_d(r + \delta)\Gamma_d}{A} \tag{14}$$

At this point, we can use the Euler equation for domestic capital (13) and the symmetric one for foreign capital along with the capital stock accounting identities in equation (4) to find a system of first order differential equations in K_d, K_f, q_d, q_f. We begin by deriving those for K_d and K_f. We rearrange equations (11) and (12) to obtain the first-order differential equations governing the domestic and foreign capital stocks in terms of K_d, K_f, q_d, and q_f:

$$\frac{\dot{K_d}}{K_d} = \frac{(\alpha_{ff} + \alpha_{df})(q_d - \Gamma_d)p_d - \alpha_{df}(q_f - \Gamma_f)p_f\sqrt{\frac{K_f}{K_d}}}{A(\alpha_{dd}\alpha_{ff} + \alpha_{dd}\alpha_{df} + \alpha_{ff}\alpha_{df})} \tag{15}$$

and

$$\frac{\dot{K_f}}{K_f} = \frac{(\alpha_{dd} + \alpha_{df})(q_f - \Gamma_f)p_f - \alpha_{df}(q_d - \Gamma_d)p_d\sqrt{\frac{K_d}{K_f}}}{A(\alpha_{ff}\alpha_{dd} + \alpha_{ff}\alpha_{df} + \alpha_{dd}\alpha_{df})}. \tag{16}$$

[13] Auerbach and Hines (1987) develop a model with adjustment costs on equipment, structures, and total investment that resembles our formulation. They interpret the elasticity of the equipment investment-capital ratio with respect to q as the inverse sum of the marginal adjustment costs associated with equipment and total investment, or using our notation $\left(\alpha_{dd} + \alpha_{df}\right)^{-1}$, where α_{dd} is their adjustment cost parameter on equipment and α_{df} is their joint adjustment cost parameter. A problem with this interpretation is that it requires investment-capital ratios for equipment and structures to be equal.

The remaining two differential equations (for $\dot{q}_d$ and $\dot{q}_f$) are obtained by rearranging the Euler equations. We rewrite equation (13) using equation (4) so that $\dot{q}_d$ is expressed in terms of K_d, K_f, q_d, and q_f:

$$\begin{aligned}\dot{q}_d = \quad & q_d(\rho_d + \delta) - \frac{A}{p_d} F_{K_d} \\ & -\frac{1}{2}\left[\frac{(\alpha_{ff} + \alpha_{df})(q_d - \Gamma_d)p_d - \alpha_{df}(q_f - \Gamma_f)p_f\sqrt{\frac{K_f}{K_d}}}{A(\alpha_{dd}\alpha_{ff} + \alpha_{dd}\alpha_{df} + \alpha_{ff}\alpha_{df})} + \delta\right](q_d - \Gamma_d),\end{aligned} \tag{17}$$

and since $\dot{q}_f$ is symmetric to $\dot{q}_d$:

$$\begin{aligned}\dot{q}_f = \quad & q_f(\rho_f + \delta) - \frac{A}{p_f} F_{K_f} \\ & -\frac{1}{2}\left[\frac{(\alpha_{dd} + \alpha_{df})(q_f - \Gamma_f)p_f - \alpha_{df}(q_d - \Gamma_d)p_d\sqrt{\frac{K_d}{K_f}}}{A(\alpha_{ff}\alpha_{dd} + \alpha_{ff}\alpha_{df} + \alpha_{dd}\alpha_{df})} + \delta\right](q_f - \Gamma_f),\end{aligned} \tag{18}$$

where $\rho_d = r - \dot{p}_d/p_d$ and $\rho_f = r - \dot{p}_f/p_f$. This leaves us with a four equation system in K_d, K_f, q_d, and q_f.

There are two basic ways to analyze this system. First, one may consider an analytic solution by examining the behavior of the system near a steady state equilibrium, where the local behavior of K_d, K_f, q_d, and q_f is approximated by equations (15), (16), (17), and (18) linearized around the steady state (see, e.g., Auerbach 1989; Judd 1985). This approach gives explicit analytical expressions that summarize the effects of tax changes on q and investment. These expressions can then be used as regression equations to estimate the effect of taxes on investment (see Auerbach and Hassett 1992). Unfortunately, as Auerbach (1989) points out, a model with multiple interrelated capital stocks is too complicated to analyze in this framework.[14]

A second method uses numerical simulations (see, e.g., Auerbach and Hines 1987). This approach characterizes the sensitivity of investment and q to changes in tax policy and the parameters that govern the production and adjustment cost technologies. In section 5 we use simulation analysis to study how changes in tax parameters affect steady state capital stocks. However, instead of calibrating the model to a variety of

[14]The complexity added by considering multiple capital stocks is also discussed in footnote 18 of Auerbach and Hassett (1992).

different parameter values, we use firm-level panel data to estimate the structural parameters from the Euler equations derived above. In this way the calibration of the simulation model is consistent with the empirical estimates of its structural parameters.[15] Before presenting our estimation procedure we briefly discuss our dataset.

3 Data

We estimate the discrete time version of our Euler equations using a firm-level panel dataset constructed from several sources. As mentioned in the introduction, we are interested in studying the investment behavior of Canadian MNCs with US affiliates. Since our theoretical model considers firms that invest abroad in only one location, we constrain our sample to parents that have affiliates abroad in the US only. We obtain information on the domestic operations of our Canadian MNCs from Compustat supplemented by Global Vantage (for a detailed description see, respectively, Cummins, Hassett, and Hubbard 1994; Cummins, Harris, and Hassett 1995). The data on US affiliates are from the Compustat Geographic Segment file (for a detailed description see Cummins and Hubbard 1995).

The Geographic Segment file reports only a limited set of information on the foreign operations of MNCs: capital expenditures, tangible fixed assets, operating income, depreciation, and sales. The data are recorded for seven years at a time. We combine three seven-year panels to obtain a dataset extending from 1980 to 1995.[16] About 130 Canadian MNCs (with foreign operations located only in the US) have complete data for at least one year.

One problem with the Geographic Segment file is that, although the data are audited, companies have more than the usual latitude in what they include in the data. For example, excise taxes might be included in sales, or intangibles might be included in fixed assets. We attempt to mitigate these problems by isolating discrepancies from data footnotes. Nevertheless, it must be acknowledged that data errors are more likely

[15] This type of analysis of investment demand dates at least to Summers (1981) who estimated the adjustment cost parameter of a q model using US time-series data and used it to simulate the effects of various tax changes on the dynamics and steady state values of the US capital stock.

[16] Due to differences in accounting reporting requirements prior to 1980, we begin the panel in 1980.

in the Geographic Segment file than in Compustat. However, there is no reason to suspect that any one variable is more mismeasured for some firms than for others.

In the Geographic Segment data the Canadian parent and affiliate's data are both reported in US dollars. We assume that firms accurately translate Canadian dollars into US dollars in each year using the current exchange rate — as they are required to do under accounting regulations. Then we divide the variables by the US price deflator to form the real series. Leamer (1988) concludes that this method performs well relative to others in constructing comparable investment and capital stock series. To the extent that there is mismeasurement due to exchange rate fluctuations we believe that it is unlikely that the qualitative empirical results would be affected because we include year effects in our regressions to capture such macro shocks.

Summary statistics on the data used in our estimation are given in tables 1 through 3.[17] Table 1 reports the number of Canadian MNCs for which we have complete data and the mean, median, and standard deviations of the variables we use. We also report the user costs of capital in Canada and the US since they are used as instruments. These user costs are calculated from equation (13) assuming no adjustment costs and a model in which the marginal products of capital are functions of only own-country capital:

$$\widehat{F_{K_{dt}}} = \widehat{c_{dt}} = \frac{p_{dt}\Gamma_{dt}\left[\rho_{dt} + \delta - \left(\frac{\Delta\Gamma_{d,t+1}}{\Gamma_{dt}}\right)\right]}{g_{dt}(1-\tau_{dt})}. \tag{19}$$

Tables 2 and 3 contain the components of the user costs for the Canadian parent firms and their US affiliates, respectively. We do not report the depreciation allowances used in our calculations because they are calculated on a two-digit SIC code industry basis.

[17] A detailed description of how the variables are constructed is contained in appendix A.

4 Estimation and Empirical Results

4.1 Estimation Methodology

To estimate the structural parameters of the model, we rewrite the Euler equations for firm i (equation (13) and its symmetric foreign counterpart), in discrete time, respectively,

$$\begin{aligned} \mathrm{E}_t\left\{\beta_{t+1}\left[\frac{\partial \Pi_{i,t+1}}{\partial K_{id,t+1}} - (1-\delta)\frac{\partial \Pi_{i,t+1}}{\partial I_{id,t+1}}\right]\right\} &= -\left(\frac{\partial \Pi_{it}}{\partial I_{idt}}\right) \\ \mathrm{E}_t\left\{\beta_{t+1}\left[\frac{\partial \Pi_{i,t+1}}{\partial K_{if,t+1}} - (1-\delta)\frac{\partial \Pi_{i,t+1}}{\partial I_{if,t+1}}\right]\right\} &= -\left(\frac{\partial \Pi_{it}}{\partial I_{ift}}\right), \end{aligned} \tag{20}$$

where $\beta_{t+1} = (1+\rho_{t+1})^{-1}$.[18]

We impose rational expectations to eliminate the expectations operators in equations (20). This allows us to substitute observed values of the variables for their expectations. We allow for expectational errors, $\nu_{id,t+1}$ and $\nu_{if,t+1}$, that are the sum of a firm-specific, a time-specific, and a stochastic component:

$$\begin{aligned} \nu_{id,t+1} &= u_i + v_{t+1} + \epsilon_{id,t+1} \qquad \text{where} \quad \mathrm{E}_t(\nu_{id,t+1}) = 0, \quad \mathrm{E}_t(\nu^2_{id,t+1}) = \sigma^2, \\ \nu_{if,t+1} &= u_i + v_{t+1} + \epsilon_{if,t+1} \qquad \text{where} \quad \mathrm{E}_t(\nu_{if,t+1}) = 0, \quad \mathrm{E}_t(\nu^2_{if,t+1}) = \sigma^2. \end{aligned} \tag{21}$$

The firm index i distinguishes variables that vary cross-sectionally by firm from those that vary by country (indexes d and f) and by time (index t). The first error component u_i is a firm-specific effect accounting for unobserved heterogeneity. It is assumed to be constant over time and identical for the domestic parent and foreign affiliate. The second error component v_{t+1} is a time-specific effect capturing macroeconomic effects common to Canada and the US.[19] Finally, the third error component is a stochastic

[18] There is a large literature on estimating dynamic factor demand models using Euler equations (for applications using time-series data see, e.g., Pindyck and Rotemberg 1983a; Pindyck and Rotemberg 1983b; Shapiro 1986; for an application using firm-level panel data see, e.g., Wolfson 1993; for a very sophisticated recent theoretical and empirical application see, e.g. Prucha and Nadiri 1996). In many respects the study most closely related to our empirical approach is Bernstein and Nadiri (1988) which develops a general theoretical model of dynamic factor demand that incorporates rich tax effects.

[19] More generally the time-specific effect could be specified in terms of shocks to each country, $v_{d,t+1}$ and $v_{f,t+1}$. However, we found that this richer specification did not affect our qualitative empirical results, so we opted for the more parsimonious specification.

disturbance that represents idiosyncratic optimization errors by the domestic parent and its foreign affiliates.

Substituting expressions for $\frac{\partial \Pi_i}{\partial K_{id}}$ and $\frac{\partial \Pi_i}{\partial I_{id}}$ into equation (20) and adopting this error structure yields the following Euler equation for the domestic parent:

$$\begin{aligned}
&\beta_{t+1}\left(\tfrac{A_{t+1}}{A_t}\right)\Bigg\{\tfrac{\partial F_{i,t+1}}{\partial K_{id,t+1}}+\tfrac{\alpha_{dd}}{2}\left(\tfrac{I_{id,t+1}}{K_{id,t+1}}-\delta\right)^2 \\
&+\tfrac{\alpha_{df}}{2}\left[\left(\tfrac{I_{id,t+1}}{K_{id,t+1}}-\delta\right)^2+\sqrt{\tfrac{K_{if,t+1}}{K_{id,t+1}}}\left(\tfrac{I_{id,t+1}}{K_{id,t+1}}-\delta\right)\left(\tfrac{I_{if,t+1}}{K_{if,t+1}}-\delta\right)\right] \\
&+(1-\delta)\Bigg[(\alpha_{dd}+\alpha_{df})\left(\tfrac{I_{id,t+1}}{K_{id,t+1}}-\delta\right)+\alpha_{df}\sqrt{\tfrac{K_{if,t+1}}{K_{id,t+1}}}\left(\tfrac{I_{if,t+1}}{K_{if,t+1}}-\delta\right)+p_{d,t+1}\left(\tfrac{\Gamma_{id,t+1}}{A_{t+1}}\right)\Bigg]\Bigg\} \\
&-(\alpha_{dd}+\alpha_{df})\left(\tfrac{I_{idt}}{K_{idt}}-\delta\right)-\alpha_{df}\sqrt{\tfrac{K_{ift}}{K_{idt}}}\left(\tfrac{I_{ift}}{K_{ift}}-\delta\right)-p_{dt}\left(\tfrac{\Gamma_{idt}}{A_t}\right)=u_i+v_{t+1}+\epsilon_{id,t+1}.
\end{aligned} \tag{22}$$

The foreign affiliate's discrete time Euler equation is symmetric. Note that equation (22) simplifies to a standard Euler equation for domestic capital when production and adjustment costs are unrelated (see, e.g., Hubbard and Kashyap 1992 and for an application to US foreign affiliates see, Cummins and Hubbard 1995).[20] The two Euler equations (one foreign and one domestic) we estimate simultaneously then follow directly. The equations are first differenced to remove the firm-specific error term and time dummies are introduced as regressors for v_{t+1} in each period. The equations are estimated by the generalized method of moments (GMM). The GMM estimator accommodates conditional heteroskedasticity of unknown form in the error terms $\epsilon_{id,t+1}$ and $\epsilon_{if,t+1}$.

When the error terms are serially uncorrelated, lagged endogenous variables are valid instruments for the endogenous variables in the Euler equations. However, first differencing introduces a first-order moving average error that necessitates using instruments dated at $t-2$ and before. If the model is misspecified the error terms may

[20] While there is a large literature on formulating and estimating models with interrelated adjustment costs, dating to the seminal study by Nadiri and Rosen 1969, to our knowledge there are no studies that have estimated interrelated adjustment costs using firm-level panel data (for applications using time series data see, e.g., Epstein and Yatchew 1985; Shapiro 1986; Holly and Smith 1989; for an application using two-digit industry data see, e.g., Rossana 1990). In addition, since our model describes MNCs we study adjustment costs across locations whereas the previous literature focused on adjustment costs among different factors of production.

be serially correlated of higher order, in which case even instruments dated at $t-2$ and before may be invalid. Hence it is important to test for the presence of this higher-order serial correlation. In our empirical results we report the Sargan statistic which is a test of the joint null hypothesis that the model is correctly specified and that the instruments are valid (for further theoretical details see, e.g., Arellano and Bond 1991; Blundell, Bond, Devereux, and Schiantarelli 1992).[21] Unfortunately, it is not possible to test either hypothesis separately. So considerable caution should be exercised in interpreting why the null is rejected — the instruments may be invalid or, more seriously, the model may be misspecified, or both.

Before presenting our parameter estimates, we discuss some additional details of the estimation procedure. We assume the firm's production technology can be approximated by a translog function. We chose the translog because it is a flexible functional form that provides a second-order approximation to any arbitrary continuous twice-differentiable production function and allows for non-unitary substitutability between inputs. The functional form is:[22]

$$\begin{aligned} y_{it} &= \phi_{L_{dt}} l_{idt} + \phi_{L_{ft}} l_{ift} + \phi_{K_d} k_{idt} + \phi_{K_f} k_{ift} \\ &+ \frac{1}{2}\left(\phi_{L_dL_d} l_{idt}^2 + \phi_{L_fL_f} l_{ift}^2 + \phi_{K_dK_d} k_{idt}^2 + \phi_{K_fK_f} k_{ift}^2\right) \\ &+ \phi_{L_dL_f} l_{idt} l_{ift} + \phi_{L_dK_d} l_{idt} k_{idt} + \phi_{L_dK_f} l_{idt} k_{ift} + \phi_{L_fK_d} l_{ift} k_{idt} + \phi_{L_fK_f} l_{ift} k_{ift} \\ &+ \phi_{K_dK_f} k_{idt} k_{ift}, \end{aligned} \tag{23}$$

where lowercase letters represent the logarithms of variables.

[21] Formally, the Sargan statistic is a test that the overidentifying restrictions are asymptotically distributed $\chi^2_{(n-p)}$, where n is the number of instruments and p is the number of parameters.

[22] We assume that there is no productivity shock in the production function for expositional simplicity. Alternatively we could introduce a productivity shock — even one that was serially-correlated of arbitrary degree — if it entered the production function log-additively. Under that assumption the shock drops out of the estimated Euler equations. Hence it need not be considered explicitly if the focus is on estimating Euler equations.

MNCs are not required to report data on employees or labor costs by geographic location. As a result, we must assume that domestic and foreign labor inputs are log-additively separable from capital (i.e. $\phi_{L_dK_d} = \phi_{L_dK_f} = \phi_{L_fK_d} = \phi_{L_fK_f} = 0$).[23] Then the marginal products of domestic and foreign capital do not depend on domestic or foreign labor inputs:

$$\begin{aligned}\frac{\partial F_{i,t+1}}{\partial K_{id,t+1}} &= \frac{Y_{i,t+1}}{K_{id,t+1}}\left(\phi_{K_d} + \phi_{K_dK_d}k_{id,t+1} + \phi_{K_dK_f}k_{if,t+1}\right)\\ \frac{\partial F_{i,t+1}}{\partial K_{if,t+1}} &= \frac{Y_{i,t+1}}{K_{if,t+1}}\left(\phi_{K_f} + \phi_{K_fK_f}k_{if,t+1} + \phi_{K_dK_f}k_{id,t+1}\right).\end{aligned} \tag{24}$$

These expressions are substituted into our estimation equation (22) and its symmetric foreign counterpart.[24]

4.2 Estimation Results

Our estimation results are contained in tables 4 through 6.[25] Table 4 contains the parameter estimates of our model.[26] We report estimates for a baseline and extended instrument set for the full sample and for a manufacturing subsample. We defined the manufacturing subsample to include SIC 20-39. The majority of firms that are not in the manufacturing sample are in resource extraction (SIC 10-14) and transportation and communications (SIC 40-48).[27]

[23] This restricts the flexibility of the translog functional form. In particular, in the case we consider, in order for the production technology to be well-behaved domestic and foreign capital cannot be complements. Nevertheless our formulation still places no restrictions on the degree of substitutability between domestic and foreign capital.

[24] The use of sales data for output necessitates an adjustment to our estimating equations. Worldwide sales is the sum of domestic and foreign sales which are determined by domestic and foreign prices, respectively. In our data, however, domestic and foreign sales are given in US dollars. To correct for this, when we estimate the model we remove output prices, g_{dt} and g_{ft}, from our weighted-average term A_t.

[25] In appendix B we discuss how robust our findings are to alternative specifications.

[26] Before beginning our estimation procedure, we identified observations that we determined were outliers. We deleted observations for which the ratio of domestic or foreign investment to beginning-of-period capital is greater than the 99th percentile of the distribution or less than the 1st percentile. We also deleted observations for which the domestic and foreign capital stocks were less than $1 million in 1987 dollars. We chose a cutoff like this to delete very small MNCs and those that maintain only a marketing or "test trial" operation in the US. Our results are robust to other similar rules for deleting outliers. Our qualitative results are insensitive to outliers in other variables.

[27] Our qualitative results are robust to including these sectors along with the manufacturing sector in a larger subsample.

Our instrument sets contain use lagged endogenous variables ($\frac{I_d}{K_d}$, $\frac{I_f}{K_f}$, k_d, k_f, $\frac{Y}{K_{dt}}$, $\frac{Y}{K_{ft}}$), interactions of lagged endogenous variables, and an intercept (INT). In the baseline instrument set we use period $t-3$ instruments; in our extended instrument set we use period $t-2$ and $t-3$ instruments and costs of capital ($\hat{c_d}$, $\hat{c_f}$, $\hat{c_d}\hat{c_f}$). Because we use instruments dated as far back as $t-3$ we are left with observations for only 65 different firms for the full sample results and for 33 different firms for the manufacturing results.

Our estimates of the parameters of the production technology are reported in the first three rows of table 4.[28] In unconstrained estimation we failed to reject the hypothesis that the higher order terms of the translog were not symmetric so we imposed symmetry ($\phi_{K_dK_d} = \phi_{K_fK_f} = -\phi_{K_dK_f}$) to conserve on the number of estimated parameters and for comparability with the literature (see, e.g., Berndt and Christensen 1973).[29]

The parameter estimates of the production function are nearly identical using either the baseline or extended instrument set. The parameter estimates of ϕ_{K_d} are similar to ϕ_{K_f} indicating that the marginal products of domestic and foreign capital are similar holding constant $\phi_{K_dK_f}$ (see equation (24)). The parameter estimates of the higher order terms of the production technology ($\phi_{K_dK_d}$, $\phi_{K_fK_f}$, $\phi_{K_dK_f}$) are statistically significant from zero which is a test of whether the elasticity of substitution between them is non-unitary (see table 6 for the elasticities).

The parameter estimates of the adjustment cost technology are reported in rows four through six of table 4. All of the "own" adjustment cost parameter estimates are statistically significant at the five percent level or better using either the baseline or extended instrument set. All of the "cross" adjustment cost parameter estimates, α_{df}, are negative and statistically significant at the five percent level or better (with

[28] To ensure that the production function is monotonically increasing and strictly quasi-concave, as is required by theory, we verified that the fitted values of the share equations (marginal products) were positive and that the matrix of substitution elasticities was negative semidefinite at each observation (see Lau 1978). We deleted the observations that violated these conditions, constituting about five percent of the sample. This ensures that our estimated translog functions are monotonic and strictly quasi-concave in the neighborhood covered by our dataset. The qualitative results, however, were unaffected when we did not delete these observations.

[29] The unconstrained estimates from column (1) of table 4, with standard errors in parentheses, are: $\phi_{K_dK_d} = 0.043\,(0.010)$, $\phi_{K_dK_f} = -0.039\,(0.013)$, $\phi_{K_fK_f} = 0.049\,(0.010)$. The other parameters were also qualitatively unaffected. The results of unconstrained estimation were qualitatively similar for the specifications reported in columns (2)–(4).

the exception of the estimate in column (4) which is statistically significant at the 10 percent level).

The Wald statistics reported in table 4 are tests of the joint null hypothesis that production and adjustment cost technologies are unrelated (i.e. a joint test of $\phi_{K_d K_f} = \alpha_{df} = 0$). The null is rejected with p-values of 0.00 for both samples and both instrument sets. This suggests that our model with interrelated production and adjustment cost technologies fits the data better than one where those parameters are equal to zero.

The Sargan tests reported below the Wald tests indicate that the joint null hypothesis that the model is correctly specified and that the instruments are valid is not rejected in columns (1) and (4). This means that the strong assumptions made to estimate the model are not rejected. In columns (2) and (3) the joint null is rejected but this is not cause for concern about model misspecification since the parameter estimates are qualitatively identical to their counterparts in columns (1) and (4).

Since previous studies have not allowed for our "cross" adjustment cost parameter there are no estimates against which to gauge our own. However, we can compare the magnitude of our marginal adjustment costs to those from previous studies. We use the estimates of the adjustment cost parameters in table 4 to calculate the marginal adjustment costs of both foreign and domestic investment using equation (3). Table 5 presents calculations of these marginal adjustment costs using the sample means of the ratios of domestic and foreign investment to beginning-of-period capital. The first row is the "own" marginal adjustment cost without taking into account the "cross" effect. The second row is the "cross" effect and the third is "total" marginal adjustment cost. For the full sample estimates from column one of table 4, the marginal adjustment cost of adding one dollar of domestic capital is about \$0.03; for foreign capital it is about \$0.06. These costs would be higher (\$0.13 and \$0.20) if adding capital in one location had no effect on adjustment costs in the other location. Our estimates of marginal adjustment costs for the manufacturing sector are similarly sized for domestic investment and smaller for foreign investment. These marginal adjustment costs are among the smallest in the literature (for a review of studies see Chirinko 1993 and Hassett and Hubbard 1997). Thus the dynamic response of investment to policy changes will be relatively rapid.

Table 6 presents the price (PES_{K_i,K_j}) and Morishima (MES_{K_i,K_j}) elasticities of substitution between factors K_i and K_j.[30] The elasticities of input substitution are calculated using the full and manufacturing samples' parameter estimates in columns one and two in table 4 at the full sample means in table 1. There are two main findings. First, domestic and foreign capital are relatively strong substitutes (defined as greater than unit elastic substitutes). Second, the own elasticities are also relatively large. These findings are consistent with the results in Cummins (1996) which studies US MNCs and their Canadian foreign affiliates. The finding that domestic and foreign capital are relatively strong substitutes in the worldwide production function suggests that changes in tax policy in the US or Canada may lead to substantial changes in the steady state allocation of capital across locations. We investigate this implication of our parameter estimates in the next section.

In the bottom row of table 6 we report the shares of domestic and foreign capital in gross output. For the full sample containing all industries, the shares of domestic and foreign capital are 0.116 and 0.076, respectively, indicating a total capital share of 0.192. For the manufacturing sample the shares of domestic and foreign capital are 0.088 and 0.092, respectively, indicating a total capital share of 0.180. These factor shares are somewhat smaller than capital's total share in national income which typically ranges from 0.25 to 0.30.

5 Simulations

In this section, we use the structural parameter estimates from our model to simulate the effect of tax changes on domestic and US capital stocks of a representative Canadian MNC. We generate each set of simulations under the assumption that in 1995 the representative firm is on the path to the steady state and will converge in 50 years. We use the structural parameter estimates from column one of table 4 along with average

[30] The Morishima elasticity of substitution is the log derivative of an input quantity ratio (taken from the compensated input demands) in the ith coordinate direction. The elasticities are related in the following way:

$$PES_{K_i,K_j} = \frac{\partial \ln K_i}{\partial \ln p_j}$$

$$MES_{K_i,K_j} = PES_{K_j,K_i} - PES_{K_i,K_i}$$

where K_i is the ith factor input and p_j is the jth factor price.

(across all firms) values of Γ_d, Γ_f, and a_t for 1995 (reported in table 7). All tax parameters in our baseline simulations are from 1995 (and are reported in tables 2 and 3). The discount rate is set equal to 3 percent and economic depreciation for both types of capital is 10 percent. In our simulations in which tax parameters change, we assume that firms have perfect foresight — in other words, they correctly anticipate the tax changes we impose.[31] We also assume that before-tax interest rates are unresponsive to changes in tax rates.

Given the structural parameters and the 1995 exogenous parameters discussed above, we can solve equations (15), (16), (17), and (18) for the steady state. Once we have the steady state, we solve for the transition path as a two point boundary value problem using the multiple shooting algorithm with initial conditions given by the 1995 parameter values and the steady state values as end restrictions.[32] In our tax experiments, we change either the corporate tax rate or the ITC and solve for the new steady states and transition paths.

5.1 Steady State Analysis

The steady state results are presented in the two panels of table 7. The numbers in parentheses are the percentage change (divided by 100) due to each tax policy experiment from the baseline case in each panel. The results in the top panel are from a model in which technologies are not related: in these simulations the parent and affiliate have separate translog production functions, so that the marginal products of capital are functions of only own-country output and capital:

$$\widehat{F_{K_d}} = \frac{Y_d}{K_d}\left(\phi_{K_d} + \phi_{K_dK_d}k_d\right) \quad \text{and} \quad \widehat{F_{K_f}} = \frac{Y_f}{K_f}\left(\phi_{K_f} + \phi_{K_fK_f}k_f\right). \tag{25}$$

[31] One possible extension would be to relax the assumption of perfect foresight and incorporate uncertainty over the after-tax price of capital to the model (see, e.g., Bizer and Judd 1989). However, doing so would significantly complicate both the model and potentially the numerical solution method (see, e.g., McGrattan 1996).

[32] The Matlab programs we use for the simulations are available from the authors upon request.

Notice that in this formulation only own-country variables enter the steady state cost of capital formulas:

$$\widehat{c_d} = \frac{p_d \Gamma_d \,(r+\delta)}{g_d(1-\tau_d)} \quad \text{and} \quad \widehat{c_f} = \frac{p_f \Gamma_f \,(r+\delta)}{g_f(1-\tau_f)}. \tag{26}$$

In our first policy experiment we lower the Canadian corporate tax rate by 5 percentage points while leaving the present value of tax allowances (Γ_d) unchanged. Tax reforms usually lead to changes in both tax rates and investment incentives. However, to illustrate that these two kinds of changes have different allocative effects in our model we analyze them separately. The second row of table 7 shows that the corporate tax cut leads to a 17.3 percent increase in the steady state capital stock in Canada but has no effect on the steady state capital stock in the US. As a result, decreasing the Canadian rate by 11 percent (0.05/0.45) leads to an 8 percent increase in the ratio of Canadian to total capital in the steady state.

We also experiment with reinstating the Canadian investment tax credit at 10 percent. Regardless of whether production or adjustment costs are related, a change in investment incentives will only impact the cost of capital in the country in which the change takes place. In the "unrelated technology" model we find that implementing a 10 percent investment tax credit leads to a 33 percent increase in steady state capital in Canada and a 14 percent increase in the ratio of Canadian to total capital in the steady state. As we will see in the bottom panel, however, allowing interaction between investment demands alters this result — even though the cost of capital in the US is unchanged when Canadian investment incentives change, US investment can be affected.

The bottom panel demonstrates how our results change when we simulate the steady state of the model in section 2 using our parameter estimate of $\phi_{K_d K_f}$. We perform the same two tax experiments from the top panel along with analogous ones in which US tax parameters are changed.

In contrast to the results in the top panel, lowering the Canadian corporate tax rate by 5 percentage points affects the costs of capital both at home and abroad. To see

why recall the Euler equations for domestic and foreign capital in the steady state:

$$
\begin{aligned}
F_{K_d} = c_d &= \frac{p_d(r+\delta)\Gamma_d}{(1-a)(1-\tau_d)g_d + a\,(1-\tau_f)(1-\omega)g_f}, \\
F_{K_f} = c_f &= \frac{p_f(r+\delta)\Gamma_f}{(1-a)(1-\tau_d)g_d + a\,(1-\tau_f)(1-\omega)g_f}.
\end{aligned}
\tag{27}
$$

These equations show that investment responds to a weighted average of marginal statutory tax rates at home and abroad when production is interrelated. As a result, changes in corporate tax rates in one country affect steady state capital stocks in both countries. In addition, since the policy change has no impact on the tax value of investment incentives, capital stocks fall by the same percentage in both countries. This is a result of our assumption that the division of output across countries, a, is unaffected by changes in capital stocks in either country. If a were instead determined endogenously, the relative cost of capital would be affected by the decrease in the Canadian tax rate. However, the result that both steady states are altered by the tax changes holds whether a is determined inside or outside the model.

As another corporate tax rate experiment, we decrease the US rate by the same percentage as the Canadian rate in the previous experiment (from 0.35 to 0.31). Since both the percentage of output produced and its price are higher in the US in 1995 than in Canada, a change in the US rate will have a larger impact on the cost of capital formulas than the same percentage change in the Canadian rate. In fact, the simulations show that lowering the US rate instead of the Canadian rate leads to a slightly larger increase in steady state capital stocks (5.8% versus 5.1%).[33]

More dramatic than the results on changing the statutory tax rates are the impact of changes in investment tax incentives at home on the steady state capital abroad. Again refer to equation (27) above and consider a reinstatement of the Canadian ITC. At first glance, changes in the components of Γ_d seem to affect only domestic investment decisions. However, while lowering Γ_d makes domestic capital relatively less expensive, both capital stocks adjust to the new "price ratio" between domestic and foreign capital since the marginal benefits of investment are related. This contrasts with the results

[33] Alternatively, if the percent of output produced abroad were lower (say 25%, as in the experiments discussed in appendix B), the steady state capital stocks would be slightly lower when we decrease the US corporate rate by the same percentage as the Canadian rate.

in the top panel where only the domestic capital stock responds to the increase in the Canadian investment tax credit since the marginal product of foreign investment is unaffected by changes in the Canadian capital stock. Comparing the identical experiments in the two panels we see that a reinstatement of the Canadian ITC at 10 percent leads to about the same increase in total capital in the steady state (between 16 and 17 percent). However, the Canadian share of capital is almost 25 percent greater due to the decrease in the US capital stock in the steady state. The last row shows that reinstating the US ITC yields similar results.

5.2 Dynamic Analysis

In tables 8 and 9 we present the dynamic effects of the policy experiments considered in table 7. The tables show the growth rates of domestic and foreign capital and the domestic and foreign marginal q for the first ten years of the transition path to the steady state.[34]

We begin by discussing table 8 in which the parent and affiliate have production and adjustment cost technologies that are functions of only own-country parameters. The first four columns of the table present the baseline case (defined in the first row of the top panel of table 7); the next four columns the case in which we lower the Canadian corporate tax rate by five percentage points (defined in the second row of the top panel of table 7); and the last four columns the case in which the Canadian ITC is reinstated at ten percent (defined in the third row of the top panel in table 7). The entire path of the growth rates to the steady state are shown in figure 1.

The domestic corporate tax decrease and the reinstatement of the ITC cause substantial responses in domestic investment relative to the baseline. In the first year, for example, the corporate tax decrease results in about 26% more domestic investment (0.043 versus 0.034) and the ITC increase results in about 50% more domestic investment (0.051 versus 0.034).

[34]To compare the results for the different models we calibrate the simulations so that the interrelated baseline steady state in table 9 — corresponding to the first row of the bottom panel in table 7 — is reached in 50 years. It is necessary to establish this benchmark to compare the unrelated and interrelated technology cases because in the unrelated case adjustment costs are larger so the simulations take longer than 50 years to converge.

The results for the interrelated model are given in table 9 and the entire path of growth rates to the steady state are shown in figure 2. These simulations use the estimates of the cross production and adjustment cost parameters in column one of table 4 and the parameter values from the bottom panel of table 7. In these simulations the initial capital stocks are assumed to be equal.[35]

Compared to the unrelated case in table 8, adjustment to the steady state is faster when domestic and foreign investment are investment complements ($\alpha_{df} < 0$).[36] When the domestic corporate tax is reduced, domestic investment increases by less than when production technologies are unrelated but, in this case, there is also a response in foreign investment of about the same size. For example, in the first year domestic and foreign investment are about 7% (0.112 versus 0.120) and 10% (0.073 versus 0.08) greater than baseline investment, respectively.

When the domestic ITC is increased both domestic and foreign investment increase, which is not what one would expect from the steady state results in table 7. For example, in the first year domestic and foreign investment are about 23% (0.112 versus 0.138) and 3% (0.073 versus 0.075) greater than baseline investment, respectively. In fact, foreign investment is greater than baseline investment for the first five years of the transition path to the steady state. This may seem puzzling at first since the foreign steady state capital stock decreases by 18%. The explanation comes from the complementarity of domestic and foreign investment in the adjustment cost function ($\alpha_{df} < 0$). If the interrelated adjustment cost parameter is negative, growth in one type of capital leads to an acceleration in the growth of the other type of capital (see equations (15) and (16)). This means that even though the eventual *steady state* foreign capital stock is lower when the domestic ITC is increased, foreign investment in the first years of the transition is higher. The result that the dynamic response to tax changes is different from what might be expected from a steady state analysis suggests the importance of estimating both production and adjustment cost functions' parameters.[37]

[35] We discuss the sensitivity of the results to alternative assumptions about the relative size of the initial domestic and foreign capital stocks in appendix B.

[36] If foreign and domestic investment were investment substitutes ($\alpha_{df} > 0$) domestic (foreign) capital growth dampens foreign (domestic) capital growth on the steady state path, so adjustment to the steady state would be slower than in the unrelated case.

[37] Obviously, if adjustment costs affect the steady state capital stock, as in, e.g., Auerbach (1989), we would want to have estimates of them. But in our model adjustment costs have no effect on the steady state so the reason to estimate them is for the dynamic analysis solely.

6 Conclusion and Caveats

The estimates from our model of the multinational firm offer some preliminary answers to basic questions in the international tax literature: how and to what degree are foreign and domestic operations of MNCs related? According to our estimates, it is relatively easy for Canadian MNCs in our sample to substitute US for Canadian capital in the production process. We also find that adjustment costs of US and Canadian investment are negatively related — increases in host (home) country investment decrease the adjustment costs of investment in the home (host) country. Our simulations demonstrate the importance of including interrelated production and adjustment technologies in models designed to evaluate the impact of changes in tax policy on MNC behavior.

There are many issues our analysis either does not attempt to address or cannot address. Our model studies only the investment decisions of Canadian MNCs and therefore cannot capture how tax law changes in Canada could alter the composition and magnitude of either purely domestic firms' investment or inward FDI. As a result, a study such as ours will not reveal the impact of outbound FDI on aggregate domestic investment.[38] Because the model is partial equilibrium, we have ignored any impact of tax changes on interest rates which in turn may affect the relative return of foreign and domestic capital. We have also abstracted from financing decisions and important issues about the market structure such as how and when entry and exit decisions are made and when or why trade, licensing, or mergers and acquisitions might be preferred to direct investment. Finally, because of data limitations we have ignored how capital and labor interact in the MNC. We plan to address some of these issues in extensions to this research.

[38] As Feldstein (1995) explains, "(w)hen firms increase their overseas investment, the funds that they might otherwise have used in the United States might instead finance greater domestic investment by others, leaving both the aggregate capital outflow and the level of domestic investment unchanged. Alternatively, the process of outbound FDI might increase the aggregate net capital outflow and therefore reduce total domestic investment. Resolving the policy debate .... requires resolving this macroeconomic general equilibrium issue (pages 45-46)."

A Dataset Construction

We constructed the variables for econometric estimation as follows. Output is equal to total sales defined as the sum of reported net sales in the Geographic Segment and the parent's domestic reported net sales. Net investment is the change in the net stock of tangible fixed assets. The replacement value of the parent's and affiliate's capital stock (hereafter capital stock) is constructed from the net stock of tangible fixed assets using the perpetual inventory method (with the first data year used as the initialization). The sales and investment variables are divided by the beginning-of-period capital stock. The depreciation rate of parent and affiliate capital is assumed identical and calculated using the approach in Cummins, Hassett, and Hubbard (1995). The after-tax discount factor is set equal to 0.97, the sample mean of the parent's discount rate.[39]

Canadian and US tax variables are supplied by Ken McKenzie and updated and expanded from Cummins, Hassett, and Hubbard (1995), respectively. The price of capital and output goods are, respectively, the property, plant and equipment deflator (PPE) and the GDP deflator of the US. The capital stock and investment variables are deflated by the US nonresidental fixed investment deflator and the other variables are deflated by the US GDP deflator. These price deflators are obtained from Citibase.

B Robustness of Empirical and Simulation Results

In this appendix we report how our conclusions are affected by a number of alternative specifications. For the estimation results we examined changes in: data construction; instrument sets; how the parameters are identified; and alternative functional forms. For the simulation results we examined changes in some of the parameter values.

B.1 Robustness of Empirical Results

We examined the robustness of our results to some of our assumptions about the data including: (1) constructing alternative depreciation measures using the rates for one-digit SIC codes that were constructed by Hulten and Wykoff (1981); (2) allowing

[39] In appendix B we present additional empirical results examining robustness to alternative specifications of the deprecation rate and the discount factor.

the discount factor (β_{t+1}) to vary over time and also estimating it as a parameter; (3) using different rules for deleting outliers. The qualitative results were insensitive to using alternative depreciation rates, time-varying discount rates, and different rules for deleting outliers. When we treated the discount factor as a parameter we found in many specifications that its estimate exceeded unity. However, the estimate was not always statistically significant from unity.

We experimented with many different variables in the instrument sets. We found that including some variables led to rejections of the Sargan test and economically unreasonable parameter estimates. For example, including period $t-2$ costs of capital always led to rejections of the null, most likely because the period $t-2$ costs of capital contain period $t-1$ information in $\Delta\Gamma_{d,t+1}$ (see equation (19)). When we used alternative instrument sets that did not lead to rejections of the null our qualitative results were similar to those reported in table 4.

A potential criticism of our structural model is that the production and adjustment cost parameters are identified by an accelerator effect introduced by $\frac{Y_{it}}{K_{idt}}$ and $\frac{Y_{it}}{K_{ift}}$ in the marginal products of capital. To examine this possibility we shut down the variance in these variables by setting them equal to their sample means. We found that the precision of the estimates was decreased but that they were usually still statistically significant from zero at the five percent level or better. More importantly, the qualitative results were unaffected. Thus our estimates are not capturing an accelerator effect.

A similar potential criticism is that the adjustment cost parameters are not identified, as theory suggests they should be, by the after-tax price of capital. To examine this possibility we performed two experiments: the first eliminates taxes, the "no tax" model; and the second eliminates prices by setting them equal to unity, the "no price" model. The "no tax" model sets corporate taxes equal to zero and the ITC, k, equal to zero in equation (22) and its symmetric foreign counterpart (i.e. in periods t and $t+1$, we set $A = g_d$ and $p_d\Gamma_d/A = p_d/g_d$ in the domestic Euler equation and $A = g_f$ and $p_f\Gamma_f/A = p_f/g_f$ in the foreign Euler equation. The "no price" model sets corporate taxes equal to zero and the after-tax price of capital relative to the price of output equal to unity in equation (22) and its symmetric foreign counterpart (i.e. in periods t and $t+1$, we set $A = 1$, $p_d\Gamma_d/A = 1$, and $p_f\Gamma_f/A = 1$). In both experiments we found

that the parameter estimates of the adjustment cost function violated convexity (see equation (3)) and were statistically significant from zero at the one percent level. In addition, both sets of parameter estimates implied *negative* marginal adjustment costs. In both these specifications the Sargan test was rejected. Thus in both specifications we can reject the joint null that the model is correctly specified and that the instruments are valid. Unfortunately, this is not solely a test of the "no tax" or "no price" models. However, the result that the adjustment cost parameters violate convexity in both specifications suggests that both taxes and factor prices have an important role in identifying the model.[40]

We examined whether alternative functional forms for adjustment costs affected our results. Specifically, we assumed an adjustment cost function on net investment with the feature that adjustment costs affect the steady state capital stock. The estimates of this model produced total marginal adjustment costs, elasticities of substitution, and factor shares similar to those in tables 5 and 6. We also experimented with an adjustment cost function on gross investment by setting $\delta = 0$ in equation (2). It proved impossible to find an instrument set that did not reject the Sargan test so we interpreted the resulting estimates with great skepticism: While the production function parameter estimates were economically reasonable and statistically significant, the parameter estimates of the adjustment cost function varied widely and were typically statistically insignificant.

Finally, we examined whether functional forms that result in separate Euler equations for domestic and foreign investment decisions yield reasonable results. Specifically, we assumed that in equation (22): (1) production is Cobb-Douglas in only own-country capital; (2) adjustment costs are unrelated; (3) A_t is a function of only own-country variables. In both the domestic and foreign Euler equations, estimates of the production function parameters were sometimes statistically insignificant and implied capital shares that were unrealistically small (less than 0.05 for both domestic and foreign capital). The adjustment cost parameter estimates implied marginal adjustment costs on domestic or foreign capital about equal to those reported in the "own" row of table 5.

[40] We follow Shapiro (1986) in conducting the latter two robustness tests of shutting down the variance in output and eliminating taxes and factor prices from the model.

B.2 Robustness of Simulation Results

We studied whether our steady state results were sensitive to changes in the MNC's percentage of foreign sales (a). Not surprisingly, as the percent of foreign sales decreases the impact of lowering the Canadian corporate tax rate increases in percentage terms. Since a is lower, the impact of a change in τ_d is higher. The weighted average term, A, falls by about 7 percent (from 0.691 to 0.737) when a equals 0.25, compared to only about 4 percent (from 0.715 to 0.742) when a equals 0.55 as in table 7.

In the dynamic analysis we had to make an assumption about the relative size of the initial domestic and foreign capital stocks because it affects the transition paths in the interrelated model. To illustrate the effects of different initial capital stocks we experimented with several different sets of them. In general, when the initial foreign capital stock is smaller (greater) than the domestic capital stock, the marginal product of foreign capital is higher (lower) and, consequently, foreign investment is greater (less). For example, when we assumed that the initial domestic capital stock was twice as large as the foreign capital stock we found that foreign investment was greater than domestic investment in the baseline case and when the domestic corporate tax is reduced (compared to when the capital stocks were initially equal as in table 9). However, when the domestic ITC is increased the effect of the larger foreign marginal product of capital is dominated by the price effect. In terms of figure 2 this effect can be seen as leftward shift in the domestic transition path. If less mature Canadian MNCs have lower initial US capital stocks this means that we expect their US affiliate's investment response to be larger than for mature Canadian MNCs.

C Capital Demand with Endogenous Production

C.1 Model

Instead of letting a be exogenous, assume it is a function of beginning-of-period domestic and foreign capital K_{dt} and K_{ft}:

$$a_t = \frac{K_{ft}}{K_{dt} + K_{ft}}, \qquad 1 - a_t = \frac{K_{dt}}{K_{dt} + K_{ft}}. \tag{28}$$

This means that a_t is not a function of current investment.

Then A_t, which was the weighted average of the after tax returns to a unit of production, is now written:

$$A_t = \frac{\kappa_{dt}K_{dt} + \kappa_{ft}K_{ft}}{K_{dt} + K_{ft}}, \tag{29}$$

where $\kappa_{dt} = (1 - \tau_{dt})g_{dt}$; and $\kappa_{ft} = (1 - \tau_{ft})(1 - \omega_t)g_{ft}$. This implies:

$$\frac{\partial A_t}{\partial K_{dt}} = \frac{(\kappa_{dt} - \kappa_{ft})K_{ft}}{(K_{dt} + K_{ft})^2}, \qquad \frac{\partial A_t}{\partial K_{ft}} = \frac{(\kappa_{ft} - \kappa_{dt})K_{dt}}{(K_{dt} + K_{ft})^2}. \tag{30}$$

The MNC makes investment decisions at home and abroad at time t to maximize the expected present discounted value of future profits:

$$\begin{aligned} V_t = \quad & \int_t^\infty \mathrm{e}^{-r(s-t)}\Big[A_s\Big[F(K_{ds}, K_{fs}, L_{ds}, L_{fs}) - C(I_{ds}, I_{fs}, K_{ds}, K_{fs})\Big] - L_s \\ & - p_{ds}(1 - k_{ds})I_{ds} - \tau_{ds}\int_{-\infty}^{t} p_{du}I_{du}D_d(t, t-u)du \\ & - p_{fs}(1 - k_{fs})I_{fs} - \tau_{fs}\int_{-\infty}^{t} p_{fu}I_{fu}D_f(t, t-u)du\Big]ds. \end{aligned} \tag{31}$$

where $D_d(t, t-u)$ is the depreciation allowance at home per dollar of date u capital expenditure.

The Euler equation for the optimal path of the domestic capital stock is (the one for foreign capital is symmetric):

$$A\left[F_{K_d} + \frac{1}{2}\left(\frac{I_d}{K_d}\right)\left(\frac{\partial C}{\partial I_d}\right)\right] + \left(\frac{\partial A}{\partial K_d}\right)[F(\cdot) - C(\cdot)] = p_d q_d\left(r + \delta - \frac{\dot{q_d}}{q_d} - \frac{\dot{p_d}}{p_d}\right). \tag{32}$$

This equation is the same as in the text with the addition of the term on the LHS in $\frac{\partial A}{\partial K_d}$ which modifies the after-tax marginal product of domestic capital to incorporate the revenue effect from an additional unit of capital stock at home.

The differential equations in $\dot{K_d}$ and $\dot{K_f}$ are the same as in the text. However, the differential equations for $\dot{q_d}$ and $\dot{q_f}$ are different:

$$\dot{q_d} = \quad -\frac{A}{p_d}F_{K_d} - \frac{1}{2}\left(\frac{\dot{K_d}}{K_d} + \delta\right)(q_d - \Gamma_d) + q_d(\rho_d + \delta) - \frac{1}{p_d}\left(\frac{\partial A}{\partial K_d}\right)[F(\cdot) - C(\cdot)] \tag{33}$$

and since $\dot{q}_f$ is symmetric to $\dot{q}_d$:

$$\dot{q}_f = -\frac{A}{p_f}F_{K_f} - \frac{1}{2}\left(\frac{\dot{K}_f}{K_f} + \delta\right)(q_f - \Gamma_f) + q_f(\rho_f + \delta) - \frac{1}{p_f}\left(\frac{\partial A}{\partial K_f}\right)[F(\cdot) - C(\cdot)]. \tag{34}$$

In the steady state the domestic and foreign costs of capital are:

$$\begin{aligned}
\widehat{F_{K_d}} = \widehat{c_d} &= \frac{p_d(r+\delta)\Gamma_d - \dfrac{\partial A}{\partial K_d}[F(\cdot) - C(\cdot)]}{(1-a)(1-\tau_d)g_d + a\,(1-\tau_f)(1-\omega)g_f}, \\
\widehat{F_{K_f}} = \widehat{c_f} &= \frac{p_f(r+\delta)\Gamma_f - \dfrac{\partial A}{\partial K_f}[F(\cdot) - C(\cdot)]}{(1-a)(1-\tau_d)g_d + a\,(1-\tau_f)(1-\omega)g_f}.
\end{aligned} \tag{35}$$

Rewriting equation (35) in terms of the ratios of the domestic and foreign costs of capital, we have:

$$\frac{\widehat{F_{K_d}}}{\widehat{F_{K_f}}} = \frac{p_d(r+\delta)\Gamma_d - \dfrac{\partial A}{\partial K_d}[F(\cdot) - C(\cdot)]}{p_f(r+\delta)\Gamma_f + \dfrac{\partial A}{\partial K_d}\dfrac{K_d}{K_f}[F(\cdot) - C(\cdot)]}. \tag{36}$$

To understand the impact of $\frac{\partial A}{\partial K_d}$, first assume for simplicity that there are no withholding taxes and output prices at home and abroad are identical. Now consider a tax change that decreases τ_d. Regardless of whether τ_f is greater than or less than τ_d, the relative cost of capital at home decreases due to the new effect. This counteracts the increase in the cost of capital at home resulting from the decrease in the value of depreciation allowances.

C.2 Steady State Analysis

In this section we perform the same tax experiments considered in the bottom panel of table 7 (i.e. the case when production is interrelated) using the model with endogenous production. The discussion of the comparative statics in the model with endogenous production shows that $\frac{\partial A}{\partial K_d}$ is the key determinant of how the results will differ from those in table 7. Given the tax parameters, output prices, and withholding tax rate, κ_{dt} is

less than κ_{ft} in the baseline simulation. This indicates that the domestic cost of capital is greater than in the baseline in the bottom panel of table 7. However, decreases in the domestic tax rate will lower the domestic cost of capital and increase the domestic steady state capital stock. Hence, compared to the results in table 7, we expect the steady state share of domestic capital to be smaller and that it increases with domestic corporate tax decreases. Table 10 confirms this and presents the specific values from the experiments.

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Table 1: Means, Medians, and Standard Deviations of Sample Variables

Year	Number of MNCs	I_d/K_d	I_f/K_f	Y_d/K_d	Y_f/K_f	$\hat{c_d}$	$\hat{c_f}$
1981	21	0.237	0.247	4.296	5.271	0.413	0.412
		(0.235)	(0.193)	(1.857)	(3.118)	(0.413)	(0.419)
		[0.201]	[0.260]	[6.789]	[4.619]	[0.104]	[0.082]
1982	22	0.044	0.057	3.569	4.033	0.488	0.441
		(0.038)	(0.024)	(1.557)	(2.998)	(0.482)	(0.439)
		[0.110]	[0.111]	[5.287]	[3.659]	[0.104]	[0.062]
1983	19	0.141	0.111	4.122	4.839	0.332	0.308
		(0.134)	(0.128)	(1.883)	(2.894)	(0.315)	(0.303)
		[0.101]	[0.093]	[5.521]	[4.678]	[0.092]	[0.068]
1984	21	0.193	0.193	4.151	5.096	0.367	0.360
		(0.123)	(0.154)	(1.624)	(2.904)	(0.352)	(0.362)
		[0.302]	[0.277]	[5.815]	[5.921]	[0.089]	[0.058]
1985	24	0.049	0.178	3.764	5.186	0.416	0.305
		(0.072)	(0.122)	(1.606)	(3.099)	(0.390)	(0.292)
		[0.230]	[0.363]	[5.415]	[5.001]	[0.111]	[0.076]
1986	28	0.120	0.183	3.455	3.927	0.317	0.145
		(0.143)	(0.108)	(1.730)	(2.103)	(0.311)	(0.142)
		[0.201]	[0.332]	[4.725]	[3.868]	[0.094]	[0.066]
1987	30	0.235	0.289	3.518	3.419	0.234	0.150
		(0.235)	(0.185)	(1.404)	(2.241)	(0.189)	(0.124)
		[0.196]	[0.383]	[4.529]	[3.740]	[0.105]	[0.079]
1988	32	0.273	0.241	3.343	3.792	0.240	0.210
		(0.244)	(0.232)	(1.251)	(2.539)	(0.209)	(0.186)
		[0.247]	[0.281]	[4.756]	[3.633]	[0.095]	[0.082]
1989	39	0.205	0.153	2.993	3.578	0.297	0.306
		(0.146)	(0.134)	(1.472)	(2.539)	(0.283)	(0.287)
		[0.273]	[0.218]	[3.862]	[3.484]	[0.104]	[0.087]
1990	59	0.098	0.155	2.583	3.241	0.425	0.310
		(0.095)	(0.145)	(1.120)	(2.415)	(0.392)	(0.297)
		[0.244]	[0.223]	[3.864]	[3.089]	[0.110]	[0.084]
1991	58	0.072	0.098	2.247	2.636	0.329	0.287
		(0.097)	(0.111)	(1.159)	(1.646)	(0.301)	(0.270)
		[0.242]	[0.262]	[3.109]	[2.569]	[0.094]	[0.076]
1992	65	0.038	0.132	2.221	2.677	0.249	0.233
		(0.046)	(0.097)	(1.000)	(1.659)	(0.219)	(0.201)
		[0.186]	[0.232]	[3.709]	[2.496]	[0.089]	[0.086]
1993	52	0.128	0.253	2.509	2.912	0.192	0.178
		(0.083)	(0.172)	(1.180)	(1.305)	(0.181)	(0.163)
		[0.286]	[0.292]	[3.896]	[3.852]	[0.078]	[0.078]
1994	60	0.101	0.231	2.631	2.826	0.209	0.202
		(0.047)	(0.198)	(1.346)	(1.645)	(0.188)	(0.183)
		[0.263]	[0.242]	[3.714]	[2.977]	[0.082]	[0.075]
1995	52	0.177	0.223	2.855	1.889	0.224	0.205
		(0.146)	(0.196)	(1.501)	(1.493)	(0.209)	(0.192)
		[0.274]	[0.253]	[3.904]	[1.798]	[0.079]	[0.067]

Medians of variables are in parentheses below the means. Standard deviations of variables are in square brackets below the means. The ratios of domestic and foreign investment to beginning-of-period capital stock are I_d/K_d and I_f/K_f, respectively. The ratios of domestic and foreign gross output to beginning-of-period capital stock are Y_d/K_d and Y_f/K_f. The domestic and foreign costs of capital (without adjustment costs) are $\widehat{c_d}$ and $\widehat{c_f}$, respectively (see equation (19) in the text).

Table 2: Components of the User Cost of Capital: Canadian Parent

	Corporate Tax Rate							
	Federal		Provincial		Fixed Capital		Price of	Price of
Year	General	M&P	General	M&P	Tax Rate	ITC	Output	Investment
1980	0.38	0.32	0.14	0.13	0.003	0.07	69.700	87.897
1981	0.38	0.32	0.14	0.13	0.003	0.07	77.235	91.511
1982	0.38	0.32	0.14	0.13	0.003	0.07	83.938	98.004
1983	0.37	0.31	0.15	0.14	0.003	0.07	88.159	98.094
1984	0.36	0.30	0.15	0.14	0.003	0.07	90.909	99.037
1985	0.38	0.32	0.15	0.14	0.003	0.07	93.258	100.04
1986	0.38	0.32	0.16	0.15	0.003	0.07	95.493	99.285
1987	0.36	0.29	0.16	0.15	0.003	0.05	100.00	100.00
1988	0.29	0.27	0.16	0.15	0.003	0.03	104.63	101.02
1989	0.29	0.26	0.16	0.15	0.003	0.00	109.70	103.26
1990	0.29	0.25	0.16	0.15	0.003	0.00	113.12	104.64
1991	0.29	0.24	0.16	0.15	0.003	0.00	116.39	98.153
1992	0.29	0.24	0.16	0.15	0.003	0.00	117.83	94.678
1993	0.29	0.23	0.16	0.14	0.003	0.00	119.07	93.596
1994	0.29	0.22	0.16	0.14	0.003	0.00	119.79	94.331
1995	0.29	0.22	0.16	0.14	0.003	0.00	122.06	96.376

M&P is the corporate tax rate on manufacturing and processing income (SIC 20-39). We assume the provincial corporate tax rates are equal to those of Ontario. The Ontario M&P corporate tax rate applies to a broader range of industries than the federal rate. Corporate tax rates are rounded to the nearest percent. The sum of the federal and provincial corporate tax rates equals the total corporate tax rate τ_d. The fixed capital tax rate multiplied by $(1 - \tau_d)$ is added to Γ_d and thereby increases the Canadian cost of capital.

Table 3: Components of the User Cost of Capital: Canadian Parent's US Foreign Affiliate

	Corporate Tax Rate	Witholding Tax Rate	ITC	Price of Output	Price of Investment
1980	0.46	0.10	0.10	71.71	80.81
1981	0.46	0.10	0.10	78.86	90.11
1982	0.46	0.10	0.08	83.76	95.33
1983	0.46	0.10	0.08	87.16	95.09
1984	0.46	0.10	0.08	91.05	95.65
1985	0.46	0.10	0.08	94.37	96.59
1986	0.46	0.10	0.08	96.92	98.41
1987	0.40	0.10	0.00	100.0	100.0
1988	0.34	0.10	0.00	103.9	102.8
1989	0.34	0.10	0.00	108.5	105.2
1990	0.34	0.10	0.00	113.3	107.4
1991	0.34	0.10	0.00	117.6	108.1
1992	0.34	0.10	0.00	120.9	106.8
1993	0.35	0.10	0.00	123.5	104.1
1994	0.35	0.10	0.00	126.1	103.8
1995	0.35	0.10	0.00	128.2	101.6

Table 4: GMM Parameter Estimates of Domestic and Foreign Capital Euler Equations: Interrelated Production and Adjustment Cost Technologies

Parameter	Baseline Instrument Set		Extended Instrument Set	
	Full Sample (1)	Manufacturing Sample (2)	Full Sample (3)	Manufacturing Sample (4)
Production Function				
ϕ_{K_d}	0.096	0.087	0.092	0.088
	(0.012)	(0.010)	(0.006)	(0.008)
ϕ_{K_f}	0.096	0.093	0.103	0.092
	(0.014)	(0.011)	(0.006)	(0.008)
$\phi_{K_dK_d} = \phi_{K_fK_f} = -\phi_{K_dK_f}$	0.040	0.036	0.037	0.035
	(0.006)	(0.005)	(0.003)	(0.004)
Adjustment Cost Function				
α_{dd}	3.08	2.45	1.66	1.21
	(1.14)	(0.825)	(0.415)	(0.577)
α_{df}	-0.989	-1.05	-0.453	-0.369
	(0.361)	(0.333)	(0.153)	(0.203)
α_{ff}	2.33	3.15	0.833	1.27
	(0.846)	(1.06)	(0.319)	(0.580)
Year Effects	Yes	Yes	Yes	Yes
Moment Conditions (Instruments)	INT; $t-3$: I_d/K_d, I_f/K_f, I_dI_f/K_dK_f, k_d, k_f, k_dk_f, Y/K_d, Y/K_f, $Y^2/(K_dK_f)$		INT; $t-2$, $t-3$: I_d/K_d, I_f/K_f, I_dI_f/K_dK_f, k_d, k_f, k_dk_f, Y/K_d, Y/K_f, $Y^2/(K_dK_f)$; $t-3$: c_d, c_f, c_dc_f	
Wald statistic	48.32	68.60	149.1	72.40
p-value	(0.000)	(0.000)	(0.000)	(0.000)
Sargan statistic	21.99	33.70	120.9	48.21
p-value	(0.079)	(0.002)	(0.000)	(0.124)
Number of Observations	285	170	280	167

The parameter estimates are of the Euler equation system defined by equation (22) in the text and its symmetric foreign counterpart. Asymptotic standard errors are in parentheses. Standard errors and test statistics are robust to general time-series and cross-section heteroskedasticity. The Wald statistic is a test of the joint null hypothesis that production and adjustment cost technologies are unrelated (i.e. a joint test of $\phi_{K_dK_f} = \alpha_{df} = 0$). The Sargan statistic is a test of the overidentifying restrictions (the moment conditions are discussed in the text), asymptotically distributed $\chi^2_{(n-p)}$, where n is the number of moments and p is the number of parameters. The number of moments in columns (1) and (2) is 20 (10 multiplied by two equations), and the number in columns (3) and (4) is 44 (22 multiplied by two equations). The number of free parameters is six. The significance levels of the tests are in parentheses below the statistic.

Table 5: Estimated Marginal Adjustment Costs on the Cost of Investment

	Full Sample (1)		Manufacturing Sample (2)	
Source of Cost	Domestic	Foreign	Domestic	Foreign
Own	0.126	0.196	0.058	0.062
Cross	-0.099	-0.140	-0.040	-0.056
Total	0.027	0.055	0.027	0.007
	Full Sample (3)		Manufacturing Sample (4)	
Source of Cost	Domestic	Foreign	Domestic	Foreign
Own	0.090	0.224	0.045	0.103
Cross	-0.088	-0.133	-0.036	-0.048
Total	0.002	0.090	0.009	0.055

The marginal adjustment costs are calculated by substituting the adjustment cost parameter estimates in columns one through four in table 4 and the sample means of the variables into equation (3) in the text.

Table 6: Elasticities of Input Substitution from Euler Equation Translog Parameter Estimates

	Full Sample		Manufacturing Sample	
Input	Domestic Capital (K_d)	Foreign Capital (K_f)	Domestic Capital (K_d)	Foreign Capital (K_f)
		Price Elasticities ($PES_{K_iK_j}$)		
Domestic Capital (K_d)	-3.06	3.06	-2.55	2.55
Foreign Capital (K_f)	4.64	-4.64	2.46	-2.46
		Morishima Elasticities ($MES_{K_iK_j}$)		
Domestic Capital (K_d)	—	7.70	—	5.01
Foreign Capital (K_f)	7.70	—	5.01	—
Factor Share	0.116	0.076	0.088	0.092

Elasticities of input substitution and factor shares are calculated from the parameter estimates of the translog in columns one and two in table 4 at the full and manufacturing sample means, respectively.

Table 7: The Effects of Tax Reform on the Steady State Capital Stock in Canada and the US

Model	Specification	Parameter Values	Steady State Capital Stocks Canada (1)	US (2)	Total (1)+(2)	Canadian Share $\frac{(1)}{(1)+(2)}$
Unrelated Production Technologies	Baseline	$\Gamma_d = 0.690, \Gamma_f = 0.748,$ $\phi_{K_dK_f} = 0,$ $\phi_{K_dK_d} = \phi_{K_fK_f} = 0.040$	0.877	0.841	1.718	0.510
	Decrease τ_d by 0.05	$\tau_d = 0.40$	1.029 (0.173)	0.841 (0.000)	1.871 (0.089)	0.550 (0.078)
	Increase k_d by 0.10	$k_d = 0.10 \Rightarrow \Gamma_d = 0.590$	1.167 (0.331)	0.841 (0.000)	2.009 (0.169)	0.581 (0.139)
Interrelated Production Technologies	Baseline	$a = 0.55, A = 0.715,$ $\Gamma_d = 0.690, \Gamma_f = 0.748,$ $\phi_{K_dK_d} = \phi_{K_fK_f} = -\phi_{K_dK_f} = 0.040$	1.101	0.734	1.835	0.600
	Decrease τ_d by 0.05	$\tau_d = 0.40 \Rightarrow A = 0.742$	1.157 (0.051)	0.772 (0.051)	1.929 (0.051)	0.600 (0.000)
	Decrease τ_f by 0.04	$\tau_f = 0.31 \Rightarrow A = 0.746$	1.165 (0.058)	0.777 (0.058)	1.942 (0.058)	0.600 (0.000)
	Increase k_d by 0.10	$k_d = 0.10 \Rightarrow \Gamma_d = 0.590$	1.533 (0.392)	0.602 (-0.180)	2.136 (0.164)	0.718 (0.197)
	Increase k_f by 0.10	$k_f = 0.10 \Rightarrow \Gamma_f = 0.648$	0.981 (-0.109)	1.011 (0.377)	1.991 (0.085)	0.493 (-0.178)

The simulations use the full sample parameter estimates in column one of table 4: $\phi_{K_d} = 0.096$, $\phi_{K_f} = 0.096$. The numbers in parentheses are the percentage change due to each tax policy experiment from the baseline case in each panel.

Table 8: The Effects of Taxation on the Growth Rate of Capital and Marginal q: Unrelated Production and Adjustment Cost Technologies

	Baseline				Domestic Corporate Tax Decrease				Domestic ITC Increase			
	Growth Rate		Marginal q		Growth Rate		Marginal q		Growth Rate		Marginal q	
Year	Canada	US	Canada	US	Canada	US	Canada	US	Canada	US	Canada	US
1996	0.034	0.027	0.828	0.906	0.043	0.027	0.883	0.906	0.051	0.027	0.797	0.906
1997	0.031	0.026	0.820	0.897	0.040	0.026	0.870	0.897	0.047	0.026	0.783	0.897
1998	0.029	0.024	0.811	0.888	0.038	0.024	0.859	0.888	0.044	0.024	0.770	0.888
1999	0.028	0.023	0.804	0.880	0.035	0.023	0.848	0.880	0.041	0.023	0.759	0.880
2000	0.026	0.022	0.797	0.873	0.033	0.022	0.838	0.873	0.038	0.022	0.748	0.873
2001	0.024	0.020	0.790	0.866	0.031	0.020	0.829	0.866	0.036	0.020	0.738	0.866
2002	0.023	0.019	0.784	0.859	0.029	0.019	0.820	0.859	0.034	0.019	0.729	0.859
2003	0.021	0.018	0.778	0.853	0.027	0.018	0.812	0.853	0.032	0.018	0.720	0.853
2004	0.020	0.017	0.773	0.847	0.025	0.017	0.805	0.847	0.030	0.017	0.712	0.847
2005	0.019	0.016	0.768	0.842	0.024	0.016	0.798	0.842	0.028	0.016	0.705	0.842

The simulations use the data values corresponding to the tax experiments in the top panel of table 7 and the full sample parameter estimates in column one of table 4 with the "cross" parameters set equal to zero ($\phi_{K_d K_f} = 0$, $\alpha_{df} = 0$). The initial domestic capital stock is assumed to be equal to the foreign capital stock.

Table 9: The Effects of Taxation on the Growth Rate of Capital and Marginal q: Interrelated Production and Adjustment Cost Technologies

	Baseline				Domestic Corporate Tax Decrease				Domestic ITC Increase			
	Growth Rate		Marginal q		Growth Rate		Marginal q		Growth Rate		Marginal q	
Year	Canada	US	Canada	US	Canada	US	Canada	US	Canada	US	Canada	US
1996	0.112	0.073	0.838	0.830	0.120	0.080	0.851	0.846	0.138	0.075	0.796	0.795
1997	0.093	0.061	0.815	0.813	0.099	0.066	0.826	0.826	0.115	0.062	0.767	0.778
1998	0.078	0.050	0.797	0.799	0.083	0.055	0.805	0.810	0.097	0.051	0.744	0.765
1999	0.065	0.042	0.782	0.788	0.070	0.046	0.789	0.798	0.082	0.042	0.725	0.755
2000	0.055	0.035	0.770	0.779	0.059	0.039	0.775	0.788	0.071	0.035	0.709	0.747
2001	0.047	0.030	0.760	0.772	0.050	0.033	0.764	0.780	0.061	0.029	0.696	0.740
2002	0.041	0.025	0.751	0.766	0.043	0.028	0.755	0.773	0.053	0.024	0.685	0.735
2003	0.035	0.021	0.744	0.761	0.037	0.024	0.747	0.767	0.046	0.020	0.676	0.730
2004	0.030	0.018	0.738	0.757	0.032	0.020	0.740	0.763	0.041	0.016	0.668	0.727
2005	0.026	0.015	0.733	0.754	0.028	0.017	0.735	0.759	0.036	0.013	0.661	0.724

The simulations use the data values corresponding to the tax experiments in the bottom panel of table 7 and the full sample parameter estimates in column one of table 4. The initial domestic capital stock is assumed to be equal to the foreign capital stock.

Table 10: The Effects of Tax Reform on the Steady State Capital Stock in Canada and the US when Production is Endogenous

Model	Specification	Parameter Values	Steady State Capital Stocks Canada (1)	US (2)	Total (1)+(2)	Canadian Share $\frac{(1)}{(1)+(2)}$
Unrelated Production Technologies	Baseline	$\Gamma_d = 0.690, \Gamma_f = 0.748,$ $\phi_{K_dK_f} = 0,$ $\phi_{K_dK_d} = \phi_{K_fK_f} = 0.040$	0.877	0.841	1.718	0.510
	Decrease τ_d by 0.05	$\tau_d = 0.40$	1.029 (0.173)	0.841 (0.000)	1.871 (0.089)	0.550 (0.078)
	Increase k_d by 0.10	$k_d = 0.10 \Rightarrow \Gamma_d = 0.590$	1.167 (0.331)	0.841 (0.000)	2.009 (0.169)	0.581 (0.139)
Interrelated Production Technologies	Baseline	$\Gamma_d = 0.690, \Gamma_f = 0.748,$ $\phi_{K_dK_d} = \phi_{K_fK_f} = -\phi_{K_dK_f} = 0.040$	0.804	1.677	2.480	0.324
	Decrease τ_d by 0.05	$\tau_d = 0.40$	1.294 (0.610)	1.360 (-0.189)	2.654 (0.070)	0.488 (0.506)
	Decrease τ_f by 0.04	$\tau_f = 0.31$	0.633 (-0.213)	1.978 (0.180)	2.611 (0.053)	0.223 (-0.312)
	Increase k_d by 0.10	$k_d = 0.10 \Rightarrow \Gamma_d = 0.590$	1.073 (0.335)	1.622 (-0.034)	2.696 (0.087)	0.398 (0.228)
	Increase k_f by 0.10	$k_f = 0.10 \Rightarrow \Gamma_f = 0.648$	0.753 (-0.063)	2.099 (0.252)	2.852 (0.150)	0.264 (-0.185)

The simulations use AC's full sample parameter estimates in column one of table 4:$\phi_{K_d} = 0.096$, $\phi_{K_f} = 0.096$. The numbers in parentheses are the percentage change due to each tax policy experiment from the baseline case in each panel.

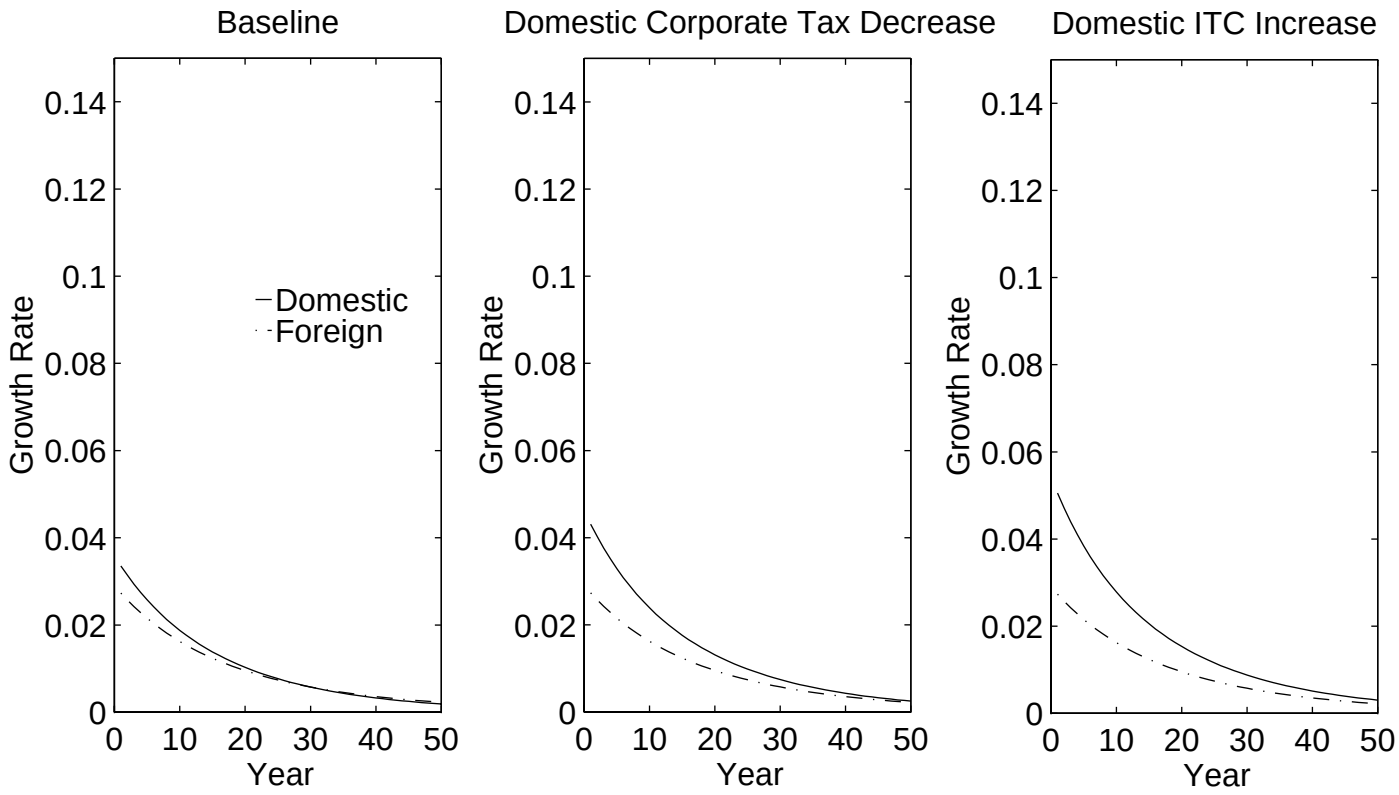

Figure 1: The Effects of Taxation on the Growth Rate of Capital: Unrelated Production and Adjustment Cost Technologies

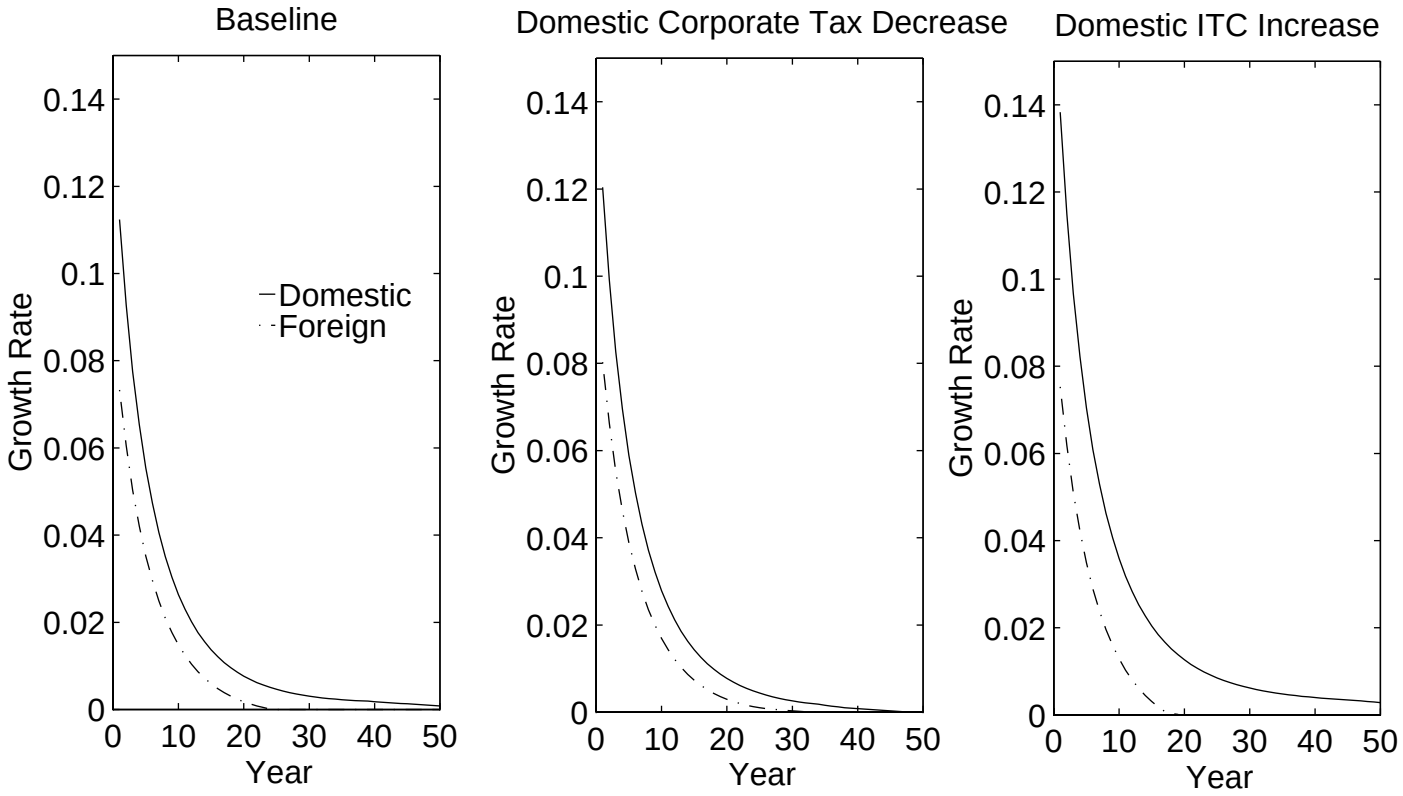

Figure 2: The Effects of Taxation on the Growth Rate of Capital: Interrelated Production and Adjustment Cost Technologies