The Effects of Taxation on U.S. Multinationals and Their Canadian Affiliates

Jason G. Cummins
New York University

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Prepared for the
Technical Committee on Business Taxation

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Abstract

I develop an empirical approach that provides a general framework for studying the behavior of multinational corporations (MNCs). The approach begins with a dynamic structural model of the multinational firm. The model treats the MNC's factors of production in different countries as separate inputs into a general production technology and incorporates unobservable firm-specific productivity shocks and local demand shocks. The semiparametric econometric procedure I develop to estimate the model relies on the exit rule and input demand functions generated by the solution to the firm's stochastic dynamic decision problem to consistently estimate the parameters of the firm's production technology. I then estimate the technology parameters using a new firm-level panel dataset on U.S. MNCs and their Canadian affiliates.

I find that U.S. MNCs are able to substitute factor inputs between the parent and their Canadian affiliates rather easily, except parent and Canadian affiliate labour where the evidence is mixed. The elasticity estimates suggest three findings. First, outsourcing may be an important contributor to the U.S. wage gap between more-skilled and less-skilled workers, not because Canadian labour displaces the domestic parent's labour, but because Canadian capital does. Second, in contrast to a large empirical literature that finds fixed capital is immobile at the macroeconomic level, my results show that U.S. and Canadian fixed capital are relatively easy substitutes at the firm level. This implies that capital income taxes on MNCs are largely shifted and result in substantial efficiency costs. Specifically, an increase in capital taxation that leads to a 10-percent increase in the relative price of domestic capital would lead to at least a 10-percent decrease in the steady-state ratio of U.S. to Canadian capital. This level of substitution suggests that each country may face increasing pressure on corporate tax revenues, as companies shift production to the lower tax country. Third, taken as a whole, the estimates suggest that business taxation results in substantial efficiency losses. Thus when national governments formulate tax policy, they should specially tailor it to differences in countries' characteristics and taxation policies.

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> After producing 20 million sticks of chewing gum a day at the same California plant for more than 40 years, one might assume that Wm. Wrigley Jr. Co. was stuck on Santa Cruz. Wrong.
>
> Last week the Chicago-based gum Goliath announced it would shut its Santa Cruz plant, eliminating 311 local jobs over the next year. It will make up the slack at its two other U.S. factories. Wrigley separately announced that on Monday it will break ground on a new $25-million factory in St. Petersburg (Russia, not Florida).
>
> The company says the economics of producing in Santa Cruz no longer made sense. With slower growth in the West and faster production and wrapping machinery, the local plant has been operating at less than 60-percent capacity. Increasing production would have...[been] too costly.
>
> San Francisco Chronicle, April 30, 1996.

Multinational corporations (MNCs), such as Wrigley, are continually evaluating where and how to allocate factors of production like capital and labour to service domestic and international markets. This process is inherently dynamic. Firm decisions – like closing old plants, opening new ones, and changing production and investment in existing plants – are made in response to changes in local prices and demand, and to productivity. National governments face the problem of how to best design tax policy under these circumstances. Optimal tax theory says that tax policy should minimize efficiency loss, which depends on the degree to which MNCs can substitute among inputs located in different countries. If domestic and foreign inputs can be substituted for one another fairly easily by the firm, then taxes on MNCs in one jurisdiction can lead the firm to relocate production. This protects the relatively mobile factors of production from taxation, but shifts the incidence to the relatively immobile factors, resulting in substantial efficiency costs.

The key issue, then, is how easy it is to substitute among inputs in different countries. The theoretical literature on open economy capital-income taxation offers little guidance on this. In fact, the standard assumptions are that fixed capital is internationally mobile, labour is immobile, and countries are price takers in the world market for capital. Under these assumptions, optimal tax theory suggests that there should be no capital-income taxation at all, because it will prompt MNCs to move abroad in response to even the smallest tax increase. However, all developed countries impose capital-income taxes. An explanation for this observation may simply be that capital is immobile internationally.

The empirical literature on capital mobility begins with Feldstein and Horioka (1980), who first documented that there is a nearly one-for-one correlation between changes in domestic aggregate fixed investment and national saving. In other words, countries with low savings rates apparently do not make up for the low savings by acquiring capital from abroad. One explanation is that domestic investment is essentially constrained by domestic savings; that is, investors do not borrow from abroad. Many subsequent studies have demonstrated the robustness of this finding by replicating, extending and refining it. The weight of empirical evidence continues to suggest that capital-investment decisions depend on domestic fundamentals. This seems to contradict the empirical evidence that international interest rates are closely linked (see, for example, Obstfeld 1986; Frankel 1993). However, despite years of research, the literature has not neared a consensus on an explanation of this seeming contradiction (see, for example, the survey in Obstfeld 1993).

While the institutional structure of capital-income taxation and the existing empirical literature support the view that fixed capital and labour are immobile among countries, Wrigley is just one example of a large and growing number of MNCs that have succeeded in locating capital and labour in different places and moving them among many different countries. The popular press and policy-makers in the United States and other industrialized countries frequently argue that MNCs move fixed capital and jobs abroad (Ross Perot's "giant sucking sound") in order to take advantage of lower wages, lower costs of capital and less stringent regulations.

How can the view that capital is immobile be justified given this casual empiricism? The standard approach is of limited assistance, since it defines the firm as a plant that produces one good in one location. Multi-plant firms are either excluded from the analysis or production decisions among the plants are assumed to be independent (island plants). In this setup, multinationals can only gain access to a foreign market by producing in it. Since production depends only on the anticipated output demand in the host country, domestic and foreign-investment decisions are separable. As a result, when national governments formulate capital-income tax policy, they have little incentive to take account of the characteristics and policies of other countries. Alternatively, if MNCs overcome trade barriers gradually (e.g. due to regulation or asymmetric information), they may gain significant production and tax benefits by, for example, substituting foreign for domestic capital. If so, mobile investment could significantly erode any country's ability to impose capital-income taxes. As a result, when national governments formulate capital-income taxation policy, they would have to tailor policy to differences in countries' characteristics and taxation policies. Evaluation of these opposing viewpoints depends on MNCs' ability to substitute among inputs at home and abroad. Existing empirical research cannot address this important question, because it has focussed on reduced-form correlations of aggregate variables (see, for example, Feldstein 1983, 1995; Dooley, Frankel and Mathieson 1987; Tesar 1991; Stevens and Lipsey 1992; Ghosh 1995).

In this paper, I present a dynamic structural model of the multinational firm that allows me to directly estimate the degree of substitutability among MNCs' factor inputs. The key feature of the model is its generality. The firm's stochastic dynamic decision problem treats factors in different countries as different inputs to production. When firms choose these inputs, they observe both their firm-specific productivity and a demand shock, but the applied researcher observes neither. Productivity is allowed to be a serially correlated state variable in the firm's decision problem, and the demand shock is observed each period in both the source and host countries. I do not explicitly solve the firm's decision problem. Instead, I use the exit rule and input demand functions generated by the solution to estimate the parameters of the firm's production technology. The exit rule is used to correct for selection bias in the data, and input demand functions are inverted so that the unobservable variables are expressed in terms of the observables. The advantage of this approach is that I consistently estimate the technological relationship among output and inputs without trying to directly solve the firm's dynamic decision problem in the presence of serially correlated unobservables.

Unobservable (to the econometrician) serially correlated state variables complicate estimation in two ways. First, more variable inputs are more highly correlated with the current realization of the productivity shock; and second, input demands are endogenous because they are determined in part by the firm's expectations about the realizations of the productivity shock when those inputs will be used (in other words, inputs in place will be correlated with the current realization of the productivity shock, and this will generate a simultaneous equation bias). Hence, standard econometric techniques provide biased estimates of the input demand and production parameters.

In order to obtain unbiased parameter estimates of the key structural parameters, I extend the estimation procedure developed by Pakes (1994) and Olley and Pakes (1996). I estimate the model using a new firm-level panel dataset constructed from several sources, which provide information on country-specific domestic and foreign capital, labour and sales for more than 100 U.S. multinationals and their Canadian subsidiaries for the period 1980 through 1994, as well as the relevant price and tax variables.

The estimates of the technology parameters of U.S. MNCs and their Canadian affiliates shed considerable new light on the behaviour of these firms in particular, and on international fixed capital and labour flows. For the first time in the literature, I present estimates of firm-level substitutability of domestic and foreign capital, and provide new evidence on the own- and cross-elasticities of substitution of domestic and foreign labour for other inputs. The estimates provide a structural basis for evaluating different tax-policy proposals, and for assessing the numerous proposed explanations for the nearly one-for-one correlation of domestic aggregate fixed investment and national saving.

The paper is organized as follows. Section 1 describes the theoretical model. Section 2 presents the econometric procedure in detail. Section 3 describes the dataset. Section 4 discusses the estimation results, and the final section presents conclusions.

1. Theoretical Model

The model has four key features needed to study MNCs. First, it is dynamic and explicitly incorporates firm-specific productivity and local-demand shocks. Second, it allows for non-randomly missing data and firm exit.[1] Third, it combines the firm's dynamic decision problem with a general production technology with a constant, but not necessarily unitary, elasticity of substitution between factors. Finally, it includes multiple capital stocks and labour inputs indexed by the country in which the firm locates production.

I assume the MNC produces output Y using vectors of capital **K** and labour **L** inputs, indexed by country of location (with domestic labour and capital defined as L^d and K^d, respectively, and foreign labour and capital defined $L^f = \Sigma L_n$ and $K^f = \Sigma K_n$ where n is the number of foreign countries for which the firm reports operations). Labour is costlessly adjustable, and the cost of capital is **p**, also indexed by country of location.

There are three log-additively separable structural disturbances in the model. First, the firm (but not the econometrician) observes a non-negative mean-one multiplicative index of its productivity ω against which it optimizes. The variable ω is a stochastic disturbance to the firm's production process with a known distribution that is serially correlated over time, and independently and identically distributed (iid) across firms. This setup is general enough so that an alternative formulation could allow each firm to have a distinct ω indexed by country, provided that the different productivity shocks enter the production technology log-additively. Second, the firm (but not the econometrician) observes a non-negative mean-one multiplicative vector of demand shocks η, indexed by year and country, against which it optimizes. The variable η is a stochastic disturbance to the firm's production process with a known distribution that is iid over time and across countries. Finally, I introduce a non-negative multiplicative mean-one random disturbance ε to represent measurement error.[2] The firm's production function is thus defined

[1] It would be an interesting extension to model both entry and exit jointly. However, this task is left for future research because the data do not detail the characteristics of the firms' actual and potential locations.

[2] Alternatively, one can think of ε as optimization error, which allows the firm’s first-order conditions to only be satisfied in expectation (from the perspective of the econometrician), or as a shock to productivity realized after input decisions that are iid over time and across firms.

$Y = F(\mathbf{K}, \mathbf{L}, \omega, \eta, \varepsilon | \alpha)$, where α is a parameter vector describing the technical coefficients of production. The goal of the econometric procedure is to estimate this parameter vector.

I assume the firm produces a homogeneous product with general production technology that can be approximated by a translog function. I assume the translog because it is a flexible functional form that provides a second-order approximation to any arbitrary continuous twice-differentiable production function, and it allows for non-unitary substitutability between inputs. Finally, I assume that profitability differences across firms result from Hicks-neutral technical change (HNTC).[3]

Since I study production, I model total output as a composite function of all of the MNCs' inputs, domestic *and* foreign. This means that inputs that are separated spatially are included in a single production technology. This general composite formulation nests the standard approach that treats domestic and foreign production processes independently (island plants). Recall that the standard approach represents factor inputs that are separated spatially by altogether separate production functions. In my general framework, the hypothesis that spatially separated processes are separable is testable. The composite production technology could approximate a function that is the sum of two spatially separable production processes – and one could find empirically using my approach that the input cross effects are zero, as would be the case if local production's sole purpose is to meet local demand. Thus, the framework does not impose or preclude any level of input substitutability.

While the test statistics overwhelmingly reject the restrictions imposed by the standard approach, I do not adopt this approach to the exclusion of alternatives. I also examine spatial separability by specifying separate production functions for each country, where sales in each country are solely a function of inputs in that country. Estimates of these models yield highly implausible and unstable parameter estimates.

If the standard view is rejected, then an alternative is the general model, where MNCs can increase input demand in markets where factor prices have declined and decrease it in markets

[3] In future research, I plan to consider how the estimates would be affected by relaxing the assumptions of HNTC.

where factor prices have risen, but they do not necessarily fully replace production in one market with production in another whenever factor prices vary. The composite production technology may reflect comparative advantage, as might be the case if firms perform some fraction of production in one country and the remaining in another. In this view, substitution reflects the transfer of production tasks among countries as factor prices change. Alternatively, if the firm's plants are self-contained, then inputs may be spatially correlated because firms change production (or at least want to maintain the option to do so) in a given country when factor prices, productivity, demand or exchange rates change.

The firm begins each period *t* by deciding whether to exit or continue operations for another period.[4] If the firm exits, it receives some liquidation value Ψ. If not, the firm chooses labour input and realizes profits, conditional on the beginning-of-period values of the state variables, capital $\mathbf{K}$, the cost of capital $\mathbf{p}$, firm efficiency ω, and demand conditions η. Let the profit function be $\pi_t(K_t, \mathbf{p}_t, \eta_t, \omega_t)$ ($\pi_K > 0$, $\pi_{KK} < 0$). As in Ericson and Pakes (1995) the profit function also depends on market structure – as does the value function presented below. Since the market structure is assumed identical across firms in a given period but not between periods, without loss of generality, it is omitted from the notation and the profit (and value) function are instead indexed by time.

The cost of capital is observable to both the firm and the econometrician. Demand evolves according to an exogenous process that is iid across time and countries. Productivity ω evolves according to an exogenous Markov process. The distribution of ω_{t+1} is given by the family of functions

$$f_\omega = \left\{ f(.|\omega), \omega \in \Omega \right\}. \tag{1}$$

At the end of the period, the firm chooses a vector of investment $\mathbf{I}$ and the capital stock $\mathbf{K}$ depreciates at a fixed geometric rate δ, so the capital stock next period is:

$$\mathbf{K}_{t+1} = \mathbf{K}_t(1-\delta) + \mathbf{I}_t. \tag{2}$$

[4] The firm index *i* is suppressed for notational convenience.

The firm is assumed to be risk-neutral and to maximize the expected present discounted value of future net profits. The Bellman equation for the firm is thus:

$$V_t(\mathbf{K}_t,\mathbf{p}_t,\eta_t,\omega_t) = \max\left\{\psi, \sup_{\mathbf{I}_t}\{\pi_t(\mathbf{K}_t,\mathbf{p}_t,\eta_t,\omega_t) - C(\mathbf{I}_t,\mathbf{K}_t) \tag{3}$$

$$+\beta_t E\left[V_{t+1}(\mathbf{K}_{t+1},\mathbf{p}_{t+1},\eta_{t+1},\omega_{t+1}) \mid \Theta_t\right]\right\}$$

where E is the expectations operator; β_t is the time t discount factor; $C(I_t,K_t)$ is the real cost of adjusting the capital stock ($C_{\mathbf{I}} > 0$, $C_{\mathbf{II}} > 0$, $C_{\mathbf{K}} < 0$, $C_{\mathbf{KK}} < 0$) and Θ_t is the time t information set. Equation (3) says that the firm compares its liquidation value to the expected discounted revenue for continuing operations for another period. If the values of the state variables make continuing operations profitable compared to liquidation, the firm chooses an optimal level of gross investment.

The general solution to this value function is very complicated to evaluate. But the exit rule and investment demand function generated by the solution can be used to obtain econometric estimates of the structural parameters of the firm's production technology. Define the indicator function ι_t for entry and exit as:

$$\iota_t = \begin{cases} 1 \text{ if } s_t \geq \underline{\omega}_t(\mathbf{K}_t,\mathbf{p}_t) \\ 0 \text{ otherwise,} \end{cases} \tag{4}$$

where $s_t = \omega_t + \eta_t$ is unobservable; and $\underline{\omega}$ is the critical value determining exit. Note that since $V(K_t,\mathbf{p}_t,\eta_t,\omega_t)$ is increasing in $\mathbf{K}$, $\underline{\omega}_t(\mathbf{K}_t,\mathbf{p}_t)$ is decreasing in $\mathbf{K}$.

Define the investment demand function as:

$$\mathbf{I}_t = \mathbf{I}_t(\mathbf{K}_t,\mathbf{p}_t,\eta_t,\omega_t). \tag{5}$$

Assume $\mathbf{I}_\omega(\mathbf{K}_t,\mathbf{p}_t,\eta_t,\omega_t) > 0$. The critical value in the exit rule $\underline{\omega}_t$ and the investment demand function $\mathbf{I}_t$ are functions of time because they are determined as part of the equilibrium market structure.

Using the assumptions $E(\eta_t \eta_{t-1}) = 1$ and $E(\eta_t \mid \mathbf{K}_t, \mathbf{p}_t, \omega_t) = 1$, equation (5) can be rewritten without the demand shock η_t:

$$\mathbf{I}_t = \mathbf{I}(\mathbf{K}_t, \mathbf{p}_t, \omega_t). \tag{6}$$

Equation (6) says that investment demand is unaffected by the demand shock because, by assumption, η_t provides no information about future demand conditions or the fundamentals that affect the marginal revenue product of capital. Demand shocks then only affect the vector of labour input since it is the costlessly variable factor.

Given the assumptions of HNTC and log-additive separability of the stochastic disturbances to production, the translog function I use to approximate the general production technology is expressed as:

$$\begin{aligned} y_t = {} & \alpha_0 + \alpha_1 l_t^d + \alpha_2 l_t^f + \alpha_3 k_t^d + \alpha_4 k_t^f \\ & + \tfrac{1}{2}\left[\alpha_{11} l_t^d l_t^d + \alpha_{22} l_t^f l_t^f + \alpha_{33} k_t^d k_t^d + \alpha_{44} k_t^f k_t^f\right] \\ & + \alpha_{12} l_t^d l_t^f + \alpha_{13} l_t^d k_t^d + \alpha_{14} l_t^d k_t^f + \alpha_{23} l_t^f k_t^d + \alpha_{24} l_t^f k_t^f + \alpha_{34} k_t^d k_t^f \\ & + \eta_t + \omega_t + \varepsilon_t, \end{aligned} \tag{7}$$

where lower-case letters represent the logarithms of variables (including η, ω and ε).

2. Econometric Estimation

In this section I describe the econometric procedure, beginning with an overview. The standard approach in the empirical industrial organization literature is to estimate the system of factor-share equations derived from the cost function dual to the production function. This approach would not take advantage of the rich firm-level variation in my panel data, since some of the price data are only available by country. As an alternative, I employ a newly developed three-step econometric procedure that accounts for the well-known biases resulting from estimation of production functions.

The first step is a semiparametric estimator of equation (7) that uses a non-parametric series estimator to obtain parametric coefficient estimates on the labour inputs. Since the distribution of the unobserved state variable ω is truncated by exit, the second and third steps implement a semiparametric version of a sample selection model. The second step estimates the selection mechanism.[5] The third step uses nonlinear least squares to fit a nonparametric series to the selection correction and the estimated productivity index and obtain parametric estimates of the remaining structural parameters.

There are two problems in consistently estimating equation (7). First, simultaneous equation bias results from the correlation of inputs in place with current ω. This occurs because current input choices are a function of expected future realizations of the unobserved (from the perspective of the econometrician) serially correlated state variable ω. Any econometric procedure that fails to account for the endogeneity will yield upwardly biased estimates of the input coefficients. The bias will be most severe for the more variable inputs $\mathbf{L}$, because they are more highly correlated with current realizations of ω. Moreover, the variable inputs are potentially correlated with η as well.

[5] In addition to true exit, the dataset likely contains non-randomly missing data since firms can choose how they report their accounting data. The econometric approach potentially offers a way to control for this type of selection as well. See section 3 for a discussion.

Second, selection bias results from the fact that exit truncates the observed distribution of *s* as a function of the production inputs. This generates an omitted variable:

$$\mathrm{E}\left[s_t | \mathbf{k}_t, \mathbf{l}_t, \omega_{t-1}, \iota_t = 1\right]$$

in the conditional expectation:

$$\mathrm{E}\left[y_t | \mathbf{k}_t, \mathbf{l}_t, \omega_{t-1}, \iota_t = 1\right].$$

If $\underline{\omega}_t(\mathbf{k},\mathbf{p})$ is decreasing in **k**, firms with larger capital stocks would expect larger future profits for any given *s*, so they would continue in operation for lower realizations of *s*, selection bias will cause the conditional expectation of s_t to be decreasing in **k**. Any econometric procedure that fails to account for this omitted variable will yield downwardly biased estimates of the capital coefficients.

I adapt the procedure Olley and Pakes (1996) introduced to address the two problems discussed above. The derivation builds on theirs with three extensions: I consider a more general production technology; allow for vectors of capital and labour inputs; and generalize the selection mechanism. The procedure provides consistent estimates of the coefficients of equation (7) by expressing the unobservable state variable in terms of the observable variables and the unobservable η in terms of year and country effects. Provided $\mathbf{i}_t > 0$, equation (6), the investment demand function, is invertable for the observables ($\mathbf{i}_t$,$\mathbf{k}_t$,$\mathbf{p}_t$) and can be expressed as:

$$\omega_t = \mathrm{g}_t(\mathbf{i}_t, \mathbf{k}_t, \mathbf{p}_t). \tag{8}$$

Substitute equation (8) into equation (7) to yield:

$$\begin{aligned} y_t = {} & \alpha_1 l_t^d + \alpha_2 l_t^f + \tfrac{1}{2}\left[\alpha_{11} l_t^d l_t^d + \alpha_{22} l_t^f l_t^f\right] \\ & + \alpha_{12} l_t^d l_t^f + \alpha_{13} l_t^d k_t^d + \alpha_{14} l_t^d k_t^f + \alpha_{23} l_t^f k_t^d + \alpha_{24} l_t^f k_t^f \\ & + h_t(\mathbf{i}_t, \mathbf{k}_t) + \eta_t + \varepsilon_t . \end{aligned} \tag{9}$$

where

$$h_t(\mathbf{i}_t, \mathbf{k}_t) = \alpha_0 + \alpha_3 k_t^d + \alpha_4 k_t^f$$
$$+ \frac{1}{2}\left[\alpha_{33} k_t^d k_t^d + \alpha_{44} k_t^f k_t^f\right] + \alpha_{34} k_t^d k_t^f + g_t(\mathbf{i}_t, \mathbf{k}_t, \mathbf{p}_t). \qquad (10)$$

In the first step, I estimate equation (9) semiparametrically by projecting y_t on the functions of domestic and foreign labour inputs, year and country indicator variables with interactions as regressors for $\boldsymbol{\eta}_t$, and a fourth-order polynomial series in ($\mathbf{i}_t$,$\mathbf{k}_t$,$\mathbf{p}_t$) as regressors for h_t. This step provides consistent estimates of the coefficients on labour inputs (see Olley and Pakes 1996, Robinson 1988 and Newey 1995 for additional details).

The second step estimates the selection mechanism for the model where the probability of survival is:

$$\begin{aligned} \mathrm{P}\left[\iota_{t+1} = 1 | \underline{\omega}_{t+1}(\mathbf{k}_{t+1}, \mathbf{p}_{t+1}), \Theta_t\right] &= \mathrm{P}\left[s_{t+1} \geq \underline{\omega}_{t+1}(\mathbf{k}_{t+1}, \mathbf{p}_{t+1}) | \underline{\omega}_{t+1}(\mathbf{k}_{t+1}, \mathbf{p}_{t+1}), \omega_t\right] \\ &= f_t\left[\underline{\omega}_{t+1}(\mathbf{k}_{t+1}, \mathbf{p}_{t+1}), \omega_t\right] \\ &= f_t(\mathbf{i}_t, \mathbf{k}_t, \mathbf{p}_t) \\ &\equiv P_t. \end{aligned} \qquad (11)$$

where P is the probability operator and *P* is the selection probability or, using the language of Rosenbaum and Rubin (1993), the propensity score. The second equality follows from equation (1) and the third follows from equations (2) and (8). I estimate this probability using a fourth-order polynomial series in ($\mathbf{i}_t$,$\mathbf{k}_t$,$\mathbf{p}_t$) as regressors.

For the final step, consider the expectation of y_{t+1}, given the estimates in the first step and conditional on survival:

$$
\begin{aligned}
&\mathrm{E}\Big[y_{t+1} - \hat{\alpha}_1 l^d_{t+1} - \hat{\alpha}_2 l^f_{t+1} - \tfrac{1}{2}\left[\hat{\alpha}_{11} l^d_{t+1} l^d_{t+1} - \hat{\alpha}_{22} l^f_{t+1} l^f_{t+1}\right] - \hat{\alpha}_{12} l^d_{t+1} l^f_{t+1} \\
&- \hat{\alpha}_{13} l^d_{t+1} k^d_{t+1} - \hat{\alpha}_{14} l^d_{t+1} k^f_{t+1} - \hat{\alpha}_{23} l^f_{t+1} k^d_{t+1} - \hat{\alpha}_{24} l^f_{t+1} k^f_{t+1} \,|\, \mathbf{k}_{t+1}, \iota_{t+1} = 1\Big] \\
&= \alpha_0 + \alpha_3 k^d_{t+1} + \alpha_4 k^f_{t+1} + \tfrac{1}{2}\left[\alpha_{33} k^d_{t+1} k^d_{t+1} + \alpha_{44} k^f_{t+1} k^f_{t+1}\right] + \alpha_{34} k^d_{t+1} k^f_{t+1} \qquad (12) \\
&\quad + \varepsilon_{t+1} + E\left[s_{t+1} \,|\, \omega_t, \iota_{t+1} = 1\right] \\
&= \alpha_0 + \alpha_3 k^d_{t+1} + \alpha_4 k^f_{t+1} + \tfrac{1}{2}\left[\alpha_{33} k^d_{t+1} k^d_{t+1} + \alpha_{44} k^f_{t+1} k^f_{t+1}\right] + \alpha_{34} k^d_{t+1} k^f_{t+1} \\
&\quad + \varepsilon_{t+1} + \int_{\underline{\omega}_{t+1}} \omega_{t+1} \frac{f(d\omega_{t+1}|\omega_t)}{\int_{\underline{\omega}_{t+1}} f(d\omega_{t+1}|\omega_t)} \\
&= \alpha_0 + \alpha_3 k^d_{t+1} + \alpha_4 k^f_{t+1} + \tfrac{1}{2}\left[\alpha_{33} k^d_{t+1} k^d_{t+1} + \alpha_{44} k^f_{t+1} k^f_{t+1}\right] + \alpha_{34} k^d_{t+1} k^f_{t+1} \\
&\quad + \varepsilon_{t+1} + k(\underline{\omega}_{t+1}, \omega_t).
\end{aligned}
$$

The last term in equation (12) expresses the selection bias in terms of two unobservable indexes $\underline{\omega}_{t+1}$ and ω_t. In order to control for the bias, the unobservables must be re-expressed in terms of observables. The selection equation in (11) can be inverted to express $\underline{\omega}_{t+1}$ as a function of P_t and ω_t. For fixed parameter values, h_t in (10) can be rearranged to express ω_t as a function of observables:

$$\omega_t = h_t(\mathbf{i}_t, \mathbf{k}_t) - \alpha_3 k^d_t - \alpha_4 k^f_t - \tfrac{1}{2}\left[\alpha_{33} k^d_t k^d_t - \alpha_{44} k^f_t k^f_t\right] - \alpha_{34} k^d_t k^f_t . \qquad (13)$$

Using these two results:

$$
\begin{aligned}
& k(\underline{\omega}_{t+1}, \omega_t) = \\
& k\Big\{ f^{-1}\Big[P_t, h_t - \alpha_3 k_t^d - \alpha_4 k_t^f - \tfrac{1}{2}\Big(\alpha_{33} k_t^d k_t^d - \alpha_{44} k_t^f k_t^f\Big) - \alpha_{34} k_t^d k_t^f \Big], \\
& h_t - \alpha_3 k_t^d - \alpha_4 k_t^f - \tfrac{1}{2}\Big(\alpha_{33} k_t^d k_t^d - \alpha_{44} k_t^f k_t^f\Big) - \alpha_{34} k_t^d k_t^f \Big\} \\
& \equiv k_t(P_t, g_t).
\end{aligned} \tag{14}
$$

The equation estimated in the last step is derived by substituting equation (14) into (12):

$$
\begin{aligned}
& y_{t+1} - \hat{\alpha}_1 l_{t+1}^d - \hat{\alpha}_2 l_{t+1}^f - \tfrac{1}{2}\Big[\hat{\alpha}_{11} l_{t+1}^d l_{t+1}^d - \hat{\alpha}_{22} l_{t+1}^f l_{t+1}^f\Big] - \hat{\alpha}_{12} l_{t+1}^d l_{t+1}^f \\
& - \hat{\alpha}_{13} l_{t+1}^d k_{t+1}^d + \hat{\alpha}_{14} l_{t+1}^d k_{t+1}^f - \hat{\alpha}_{23} l_{t+1}^f k_{t+1}^d - \hat{\alpha}_{24} l_{t+1}^f k_{t+1}^f \Big]
\end{aligned} \tag{15}
$$

$$
\begin{aligned}
& = \alpha_0 + \alpha_3 k_{t+1}^d + \alpha_4 k_{t+1}^f + \tfrac{1}{2}\Big[\alpha_{33} k_{t+1}^d k_{t+1}^d + \alpha_{44} k_{t+1}^f k_{t+1}^f\Big] + \alpha_{34} k_{t+1}^d k_{t+1}^f \\
& \quad + \Sigma_{i=0}^{4} \Sigma_{j=0}^{4-i} \gamma_{ij} \hat{P}_t^i \hat{g}_t^j + \varepsilon_{t+1} + \nu_{t+1}.
\end{aligned}
$$

where $v_{t+1} = s_{t+1} - E[s_{t+1} \mid \omega_t, \iota_{t+1} = 1]$ is the innovation in s_{t+1}.

In order to clarify the relationship among v_{t+1} and the factor inputs, recall that domestic and foreign capital stocks are known at the beginning of the period because they are assumed to be quasi-fixed and v_{t+1} is mean independent of all variables known at the beginning of the period. Thus, v_{t+1} is mean independent of the period t+1 domestic and foreign capital stocks. But domestic and foreign labour demand can adjust in response to realizations in v_{t+1} since they are assumed to be variable inputs. This endogeneity of variable inputs is why it is necessary to use a semiparametric estimator in the first stage.

Nonlinear least squares is used to estimate equation (15). This is also a semiparametric estimator that uses a fourth-order polynomial series in (P_t, g_t) as regressors to nonparametrically approximate k in equation (14). In the results presented, I will refer to the results from the three-step procedure generically as the "semiparametric" estimator.

3. Data

I estimate the model using a new firm-level panel dataset constructed from several sources. The dataset reports firm capital expenditures, tangible fixed assets, depreciation, operating income, employees and sales by country, as well as the relevant price and tax variables for the period 1980 through 1994. The multinational firms' domestic data are from Compustat supplemented by Global Vantage (for a detailed description see Cummins and Hubbard 1995). The foreign affiliates' data are from the Compustat Geographic Segment file. I describe this dataset in some detail for two reasons. First, it is relatively unfamiliar. Second, there is more than the usual latitude in data reporting requirements, which may result in non-randomly missing data and additional measurement error.

Approximately 6,500 companies (of which about 1,000 are non-U.S.-incorporated) report data on their foreign operations, segregated by geographic area. Both U.S.- and foreign-incorporated firms report capital expenditures, tangible fixed assets, operating income, depreciation and sales. Up to four geographic regions are reported for seven years at a time. I combine three seven-year panels to obtain a dataset extending from 1980 to 1994. There is no requirement by either the Financial Accounting Standards Board (FASB) or the Securities and Exchange Commission (SEC) regarding the groupings for geographic areas. As a result, the degree of specificity between company reports varies. For example, consider two companies operating in the same countries. Company A might report four different geographic areas: France, Germany, Canada and Asia, while Company B reports two: France and Europe, and "other foreign."

The accounting literature stresses that considerable caution should be exercised in making inferences about data reported for regions and for groups of countries (see, for example, Pointer and Doupnik 1993). No conclusions about their relative importance can be made from the data. Consider Company B again. Since it aggregates Brazil into South America, there is no way to separate its foreign operations into specific countries, or to separate its South American operations from those in the United States. Fortunately, about 15 percent of the firms in the sample separately report activities in the United States and in at least one other country (what is called the "country sample"). The sample chosen consists of the U.S. parents and their Canadian subsidiaries in the country sample.

Since firms may choose the level of aggregation at which to report their geographic segment data, those that report by country are perhaps materially different from those that report more coarsely. In other words, the smaller country-specific sample is not necessarily a random sample of the larger one, as a result of "reporting exit," as contrasted with true exit. Studies in the accounting literature have found some evidence in support of reporting selection – even though the focus of the accounting research is not explicitly on selection. Balakrishnan, Harris and Sen (1990), for example, show that the geographical composition of firms' activities are statistically and economically significant predictors of future earnings and equity valuations. The overall evidence suggests that firms may face differential trade-offs between the benefit of revealing more information to the financial markets and the cost of revealing too much detail to competitors. This competitive disadvantage may be relatively more severe when firms that are required to report geographic segment data by the FASB compete against firms that need not, usually because they are foreign incorporated firms that do not file according to U.S. Generally Accepted Accounting Principles (GAAP).

It is likely, then, that firms choose whether to report country-specific geographic-segment data based on expectations about the financial and product market structure. The model offers a way to potentially control for this type of selection using the same approach as that used to control for the bias generated by true exit. In the model, current profits are a function of the firm's own state variables, capital **K**, prices **p** and productivity ω, and a vector of the state variables of the other firms in the market. The latter, (following Ericson and Pakes 1995), is a counting measure that lists the vector of state variables of all the firm's active competitors – which is referred to as the market structure. The market structure then consists of a list of tuples of state variables for all of the active firms. Just as selection bias results from the fact that exit truncates the observed distribution of s as a function of the production inputs, bias also results from reporting choices that truncate the observed distribution of s as function of production inputs and equilibrium market structure. Since the market structure is identical across firms in a given period, the selection probability presented in equation (11) for true exit is also applicable for reporting exit. It follows that the derivation of equation (14) is applicable for reporting exit as well. Thus, when I estimate the selection probability $\hat{P}_t$ and use it together with the estimate of the productivity shock $\hat{\omega}_t$ to correct for selection bias resulting from true exit, this procedure can also correct for bias resulting from reporting exit.

There are two primary reasons to focus on the country sample. First, both the cost of capital and local demand conditions are important determinants of firm behaviour that cannot be constructed at higher levels of aggregation. While better measures of the cost of capital and demand effects could theoretically be constructed at an even more disaggregated level (e.g. the cost of capital could incorporate sub-federal tax policies), the data to do so are unavailable. Second, it is possible to isolate individual countries in the sample and analyse how firm behaviour differs among countries. This is the strategy pursued in this paper, where I concentrate on U.S. parents and their Canadian foreign affiliates.

There are two important general limitations of the geographic segment data. First, firms 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. I attempt to mitigate these problems by isolating discrepancies from data footnotes. Nevertheless, it must be emphasized that care is required in constructing variables from these data and data errors are more likely.

A second issue is that geographic segment data are reported in U.S. dollars so currency fluctuations could misrepresent the value of the foreign affiliate's data. In particular, the foreign investment variable is generated from changes in the foreign capital stock, which may reflect revaluation of the dollar rather than any real investment activity. However, the qualitative empirical results are unlikely to be sensitive to this problem, since the year used to control for local demand shocks could also control for the kind of country-specific measurement error caused by exchange rate revaluations. Nevertheless, as a check on the severity of this problem, I convert the U.S. dollar data into foreign currency equivalents and then construct the investment variables. In order to do this conversion, it is necessary to determine when geographic segment data are converted to dollars. For the purposes of Statement of Financial Accounting Standards No. 14 –

Financial Reporting of Segments in a Business Enterprise (SFAS 14), firms typically convert the data when balance sheets are prepared at fiscal year-end, so I construct the foreign currency equivalent variables using the exchange rate prevailing in the month of the firm's fiscal year end. The qualitative results using these data were similar to those reported below.

The sample selection rules are better understood by knowing the genesis of the data. Geographic segment disclosures are mandated by SFAS 14, which was issued in 1976. SFAS 14 was designed to provide information useful for evaluating the nature of the firm's investment and production decisions but to allow discretion in defining reportable segments and in employing coarse definitions. SFAS 14 requires firms to disclose information about foreign sales, income, and fixed assets if foreign operations account for 10 percent or more of a firm's revenue or assets. The directive became effective for companies with fiscal years ending after December 15, 1976. Two notes should be made about data extending to 1976. Segment data through fiscal years ending in 1979 contain many classification adjustments consistent with a learning process. Moreover, there appears to be little gain from extending samples before 1979 because of the paucity of data. As a result of these considerations, I begin the sample in 1980.

There is another more subtle issue in sample selection. In order to properly understand the effect of taxes on investment, the "new investment" component must be separated from the "mergers and acquisitions" component. This is a potentially serious problem in these data, since reporting requirements are broad and data definitions are coarse. In previous research, Cummins and Hubbard (1995) found that this problem is not a significant one. But I take two additional steps in the data construction to minimize any potential contamination. First, as is typical in the investment literature, I delete major capital stock changes to eliminate clear discontinuities in the identity of the firm. Second, the geographic segment file provides a footnote if the data reflect the results of a merger or acquisition. I also delete firms recording this footnote.

The variables used in the econometric estimation are constructed as follows. Total output is defined as the sum of each foreign affiliate's reported net sales for its geographic segment as well as its 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 gross stock of tangible fixed assets using the perpetual inventory method (with the first data year used as the initialization). The depreciation rate used for the parent and the affiliates is assumed identical and constructed using the approach in Cummins, Hassett and Hubbard (1995).

Labour input is defined as total employees.[6] I use an auxiliary dataset to construct the parents' and affiliates' labour input from total employees. The U.S. Bureau of Economic Analysis (BEA) reports parent employment by industry and foreign affiliate employment by country and industry in its annual survey, U.S. Direct Investment Abroad: Operations of U.S. Parent Companies and their Foreign Affiliates (for a detailed description of the data, see U.S. Department of Commerce 1995). Using these data, I construct the percent of total employment accounted for by the parent and its affiliates by industry. I then match these industry weights to the firm-level data, and construct parent and affiliate employees as the respective weight multiplied by total employees. The BEA's industry classification fails to correspond exactly to the firm-level SIC industry codes. Rather, it corresponds to a three-digit SIC code, or in some cases, to a two- or four-digit code. Parent and affiliate employees are constructed using the most disaggregated BEA weight available. In most cases, this will be a good approximation of parent and affiliate employment, since the survey from which the weights are constructed includes the MNCs in the firm-level data.

Home and host country tax variables (federal and sub-federal corporate income tax rates, investment tax credits, depreciation allowances, and withholding tax rates on repatriated dividends) are updated and expanded from Cummins, Hassett and Hubbard (1995).[7] The prices of capital and output goods are, respectively, the property, plant and equipment (PPE) deflator and GDP deflator of the home or host country.

Tables 1 and 2 summarize the data on U.S. parents and their Canadian affiliates. The first table reports selected aggregate data for the MNCs in the sample. Column two shows how many U.S. MNCs are in the sample. While this number varies from year-to-year, the sample size is generally growing over the period, except in 1993 and 1994 when the number reporting actually declined.

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6 Another measure using wage cost results in too many missing observations to be empirically useful.
7 Ken McKenzie supplied some of the Canadian tax parameters.

The remaining columns present aggregate U.S. parent and Canadian affiliate sales, tangible fixed assets and employees. The sample aggregates account for a large fraction (greater than half for each variable) of those reported in the BEA's annual survey of U.S. direct investment abroad (*Survey of Current Business*, various issues). Thus while the sample does not contain all the U.S. parents and their Canadian affiliates, it nonetheless contains the largest U.S. MNCs, and by that measure is representative.

Table 2 reports summary statistics (bi-yearly) for the sample variables. The sample variables are MNCs sales (Y), parent and affiliate capital (K^d and K^f, respectively) and parent and affiliate labour (L^d and L^f, respectively). Included are the mean, medians, quartiles and minimums and maximums of the variables used in the estimating equations. The number of MNCs declines significantly from 1, for three reasons. First, firms reporting zeros for any of the variables were deleted. Second, the construction of the replacement value of the capital stock eliminated firms. Finally, to focus on the relationship between U.S. parents and their Canadian affiliates, firms reporting data for affiliates in countries in addition to Canada were not included. Aggregating the non-Canadian affiliates with the Canadian ones potentially contaminates the analysis, however, results are robust to including those MNCs that report in more than just their Canadian affiliates. The total number of observations for which there is complete data is 757, which represents more than 100 firms.

The first quartile of the sample variables shows that the sample contains a large number of relatively small MNCs. For example, there are several MNCs that have a total labour force of less than five employees.[8] The upper quartile shows that the sample contains many of the largest U.S. MNCs (e.g. General Motors). The means and medians of the sample variables are similar to those of Compustat industrial file firms over the same period.

[8] The MNCs with small numbers of employees were overwhelmingly concentrated in the computer software and specialty instruments industries.

4. Empirical Results

Table 3 presents the parameter estimates of the spatially separable and general production technology models using ordinary least squares and the semiparametric estimator. The first and second columns report the estimates for the spatially separable production technologies. The parameter estimates of these models appear severely misspecified in comparison to the other estimates. Estimates of the factor shares indicate decreasing returns to scale and unrealistically low estimates of the labour shares. Column three reports the baseline estimates of the general joint production model, without correcting for endogeneity and selection bias.

Column 4 reports estimates of equations (9) and (15). The parameter estimate of α_{Ld} in equation (9) from the first step of the semiparametric estimator is 0.413; the estimate of α_{Lf} is 0.350. Both parameter estimates are statistically significant. The parameter estimate of α_{LfLf} is -0.204, the largest in absolute magnitude of the cross-terms, and is statistically significant. The parameter estimates of α_{Kd} and α_{Kf} are, respectively, 0.174 and 0.095. Both estimates are statistically significant. The parameter estimate of $\alpha_{Kd\ Kf}$ is -0.071 and is statistically significant. The magnitude and signs of production function parameter estimates are not sufficient to gauge substitution possibilities between inputs.

Column 5 reports estimates of the semiparametric model imposing the restriction that capital and labour inputs are linearly separable. I will use these estimates below to further analyse the estimated elasticities of substitution.

Applied production analysis usually reports Allen elasticities of substitution (AES). When there are more than two inputs, however, the AES – which is the constant-output cross-price elasticity of demand between goods *i* and *j* divided by the share of the *j*th input in total cost – is quantitatively meaningless and qualitatively uninformative relative to the price elasticities of demand (PES), the Morishima (MES) and shadow elasticities of substitution (SES) (see Blackorby and Russell 1981, 1989; McFadden 1963; Mundlak 1968).

The Morishima elasticity of substitution is the log derivative of an input quantity ratio (taken from the compensated demands) in the *i*th co-ordinate direction. It provides a correct measure of the ease of substitution or curvature of the production function, and is – in a frictionless world – a sufficient statistic for assessing the effects of changes in price or quantity ratios on relative factor shares. It is defined as

$$MES_{ij} = PES_{ji} - PES_{ii}. \tag{16}$$

where subscripts indicate inputs. The SES are the factor share weighted average of the MES.

The MES elasticity has two important features. First, it is asymmetric, $MES_{ij} \neq MES_{ji}$. This is because the derivative is taken in the co-ordinate direction. That is, MES_{ij} is calculated by assuming that the price ratio is changed because of a change in p_i, whereas MES_{ji} is calculated by varying the ratio via p_j. To illustrate an extreme case of this asymmetry, assume $PES_{ji} < 0$ and that $|PES_{ii}| > |PES_{ji}| > |PES_{jj}|$. Then $MES_{ij} > 0$ but $MES_{ji} < 0$: inputs i and j are substitutes by the former and compliments by the latter. Second, inputs can be AES compliments and MES substitutes. Thus drawing inferences from the AES is potentially misleading.

Since the production function is accompanied by adjustment costs, and these have not been estimated, one should interpret these elasticities with caution. The reported elasticities measure the change in the ratio of the desired steady-state or "target frictionless" domestic and foreign capital stocks with respect to a change in the ratio of the factor prices in each country. If adjustment costs are very high, this information might not be informative for assessing the effects of transitory policy, or of short-run effects of permanent policies. In related work, however, Altshuler and Cummins (1996) estimated adjustment costs joint with a translog production function for Canadian MNCs with affiliates in the United States, and found that the marginal adjustment costs are relatively small, about five percent of the cost of the investment for manufacturing.

The elasticities of input substitution are calculated from the parameter estimates of the semiparametric unrestricted translog in Table 3 at the full sample means and the 1994 means in Table 2. Tables 4 through 7 present the AES, PES, MES and SES for all the inputs. Summarizing all the tables, there are four main findings about cross-country substitutability. First, domestic and foreign labour are complements, although the degree of complementarity has declined to nearly zero by 1994. Second, domestic labour and foreign capital are relatively strong substitutes. Third, domestic capital and foreign labour are relatively easy substitutes. Finally, domestic and foreign capital are also strong substitutes.

There is an emerging body of literature on the ease of substitutability between domestic and foreign labour (see, for example, Lawrence and Slaughter 1993; Slaughter 1995). These estimates are consistent with other studies that have found that the two are complements. The results for capital contrast sharply with those from reduced-form estimates of correlations of aggregate variables typical of the macro/international literature on capital mobility. Those studies found that capital is largely immobile with implied elasticities of substitution near zero. However, as emphasized by several authors, positive domestic saving-investment correlations interpreted as evidence of capital immobility do not themselves provide evidence against mobility (for a review of these arguments see, for example, Obstfeld 1993). The elasticities of substitution support this interpretation of the previous empirical studies.

The AES and PES own elasticities of substitution are calculated as well.[9] Using the full sample means the own elasticities on domestic and foreign labour are quite small, and are relatively large on domestic and foreign capital (consistent with the fact that the labour shares are large relative to the capital shares). Using the 1994 sample means, the qualitative results are the same, except foreign labour has an own elasticity that is comparable to those on domestic and foreign capital.

The within-country factor substitutability is also reported in Tables 4 through 7. The AES and PES elasticities tell a different story from the MES and SES elasticities, so I concentrate on the latter two. Using either the full sample or 1994 sample means, the MES of domestic capital for domestic labour indicate substitutability (0.592 and 0.459, respectively), while the MES of domestic labour for domestic capital is about zero (-0.043 and -0.024, respectively). Recalling the discussion of the MES, this means when the price of domestic capital increases, there is substitution to domestic labour, but when the price of domestic labour rises there is almost no effect on domestic capital. Using either the full sample or the 1994 sample means, the MES of foreign capital for foreign labour indicates complementarity (-1.161 and -1.291, respectively),

[9] The own elasticities are undefined using the MES and SES.

while the MES of foreign labour for foreign capital is about zero (0.092 and -0.086, respectively). This means that when the price of foreign capital increases, both foreign capital and foreign labour decrease, but when the price of foreign labour increases, foreign capital is almost unaffected. Since the SES are share-weighted averages of the MES, the SES of domestic labour for domestic capital indicate some substitutability, and the SES of foreign labour for foreign capital indicates some complementarity.

The elasticities can be further analysed by decomposing them into two effects. First, a change in the input price ratio causes technical substitution between the inputs along the old isoquant. This is called the gross elasticity of substitution. Second, a change causes an expansion effect along the new expansion path associated with new input prices. Pedagogically, these two effects are analogous to consumption substitution and income effects, respectively.

Consider a firm producing output Y with production function $F(X)$, where $X = \{x_1, x_2, \ldots, x_n\}$,

$$Y = F(\boldsymbol{X}) = F(x_1, x_2, \ldots, x_n).$$

Let the set $N = \{1,2,\ldots,n\}$ be partitioned into S subsets $\{N_1, N_2, \ldots, N_S\}$ and $\{x\}$ into S bundles $\{x^{(1)}, x^{(2)}, \ldots, x^{(S)}\}$ so that $x_i \in x^{(s)}$ if $i \in N_s$. Homothetic weak separability with respect to the partition is necessary and sufficient for the production function to be represented:

$$Y = F\left[f_1(x^{(1)}), f_2(x^{(2)}), \ldots, fs(x^{(S)})\right],$$

where $f_s(x^{(s)})$ is a positive strictly quasi-concave homothetic production sub-function of only the elements in N_s . Assume $Y = F(f_1(K^d, K^f), f_2(L^d, L^f))$, and total capital K^T is the output of the production subfunction $K^T = f_1\,(K^d, K^f\,)$ and total labour is defined analogously $L^T = f_2(L^d, L^f)$.

An example illustrates the importance of considering both of these effects. Figure 1 depicts a representative firm using K_1 units of total capital and L_1 units of total labour at a pair of initial input price P_K and P_L (represented by the line AA). Figures 2 and 3 show that at the initial prices of domestic and foreign capital P_{Kd} and P_{Kf}, respectively, the firm produces K_1 using K_1^d and K_1^f (represented by the line BB). Similarly, Figure 4 shows that at the initial prices of domestic and foreign labour P_{Ld} and P_{Lf}, respectively, the firm produces L_1 using L_1^d and L_1^f (represented by line CC).

Now consider the effects of introducing an investment incentive in the domestic market that decreases P_{Kd}. First, holding fixed the output of the total capital subfunction K_1 the isocost cost line shifts as P_{Kd} falls, causing the demand for domestic capital to increase from K_1^d to K_2^d and the demand for foreign capital to decrease from K_1^f to K_2^f (represented by line DD in Figures 2 and 3). These are gross substitution effects. Second, holding fixed the output of the total production function, the decrease in P_{Kd} lowers total price P_K. The total isocost line in Figure 1 shifts to EE, causing the demand for total capital to increase from K_1 to K_2 and the demand for total labour to decrease from L_1 to L_2. This results in an expansion of the K isoquant from K_1 to K_2 or DD to FF in Figure 2 and to FF' in Figure 3, increasing the demand for both domestic and foreign capital to K_3^d and K_3^f, respectively. These are the expansion effects. For domestic capital, the gross substitution effect (K_1^d to K_2^d) and the expansion effect (K_2^d to K_3^d) have the same sign, but for foreign capital, the effects are opposite. The gross substitution effect decreases demand for K^f and the expansion effect increases demand. The net elasticity of substitution is the sum of these two effects. It is an empirical question which effect dominates. If the expansion effect dominates, domestic and foreign capital are gross substitutes but net complements. Figure 2 shows the case when the scale elasticity is large relative to the gross elasticity of substitution, and Figure 3 shows the opposite case.

Using the restricted semiparametric model parameter estimates in Table 3, I can decompose the net price elasticities between capital inputs. The effects are presented in Table 8. The estimates show that the scale elasticity is an order of magnitude smaller than the gross elasticities (the case depicted in Figure 3). Caution should be used in interpreting these results since linear separability of capital and labour is rejected in the unrestricted semiparametric parameter estimates in Table 3. Nevertheless the results suggest that the capital scale elasticities are relatively small compared to the gross elasticities.

5. Conclusion

I find that U.S. MNCs are able to substitute factor inputs between their domestic and Canadian affiliates rather easily, except domestic and foreign labour which are complements. The elasticity estimates imply that an increase in capital taxation that leads to a 10-percent increase in the relative price of domestic capital would lead to at least a 10-percent decrease in the steady-state ratio of domestic to foreign capital. This level of substitution suggests that countries may face increasing pressure on corporate tax revenues, as companies shift production to the lowest tax countries. Taken as a whole, the estimates provide a basis for evaluating the degree to which MNCs can shift taxes to other factors of production, and the size of the efficiency costs that result.

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TABLE 1

Selected Aggregate Data for Sample U.S. Parents and Canadians Affiliates

Year	Number of MNCs	Sales		Tangible Fixed Assets		Employees	
		Parent	Affiliate	Parent	Affiliate	Parent	Affiliate
1980	214	488469.916	177118.090	232022.204	103185.668	4596494	206424
1981	212	493271.742	164172.021	231414.584	96835.188	4491420	200627
1982	229	428270.746	143762.655	220611.070	85992.644	3832755	161381
1983	240	442160.173	132025.256	242950.939	84602.634	3938132	167290
1984	263	508080.890	135456.517	290011.727	94171.903	4604607	187560
1985	279	551132.827	152510.548	359733.977	123293.581	4996321	232643
1986	290	539537.799	139090.866	337160.649	120908.018	4826889	235940
1987	318	554303.438	158227.986	369627.945	144189.805	4834209	229216
1988	361	599767.400	181200.882	553391.637	183062.712	4983200	263551
1989	392	636517.947	186106.698	638717.439	204417.147	5394083	225421
1990	408	630476.540	206988.791	635150.633	240476.929	5284975	249919
1991	420	609743.647	203981.398	637135.186	231592.782	5357815	219697
1992	423	434466.049	132111.375	345183.193	127366.465	3552111	166144
1993	397	373952.334	74247.844	350187.410	100983.595	2868053	131900
1994	337	343881.326	64267.192	332347.618	97233.968	2378522	113085

Variables are in millions of 1987 U.S. dollars, except employees, which is in units.

TABLE 2
Summary Statistics for Sample Variables (Bi-yearly)

Year	Number of MNCs	Variable	Mean	Min	Q1	Median	Q3	Max
1980	27	Y	1227.24	2.302	17.83	47.79	293.29	20000.70
		K^d	414.90	2.046	7.00	46.05	154.11	6804.35
		K^f	38.69	0.014	4.01	9.10	35.65	467.52
		L^d	10583.41	4.000	97.00	295.00	1646.00	212445.00
		L^f	2234.82	1.000	12.00	73.00	442.00	43555.00
1982	25	Y	1168.28	0.568	13.42	39.76	275.53	20186.48
		K^d	392.52	0.624	6.84	30.52	101.34	6311.32
		K^f	30.68	0.607	3.48	6.38	18.65	346.87
		L^d	10501.40	4.000	104.00	262.00	1710.00	199167.00
		L^f	2222.72	1.000	19.00	96.00	409.00	40833.00
1984	41	Y	1004.46	6.081	37.71	104.37	440.87	23357.38
		K^d	491.43	1.085	15.58	66.84	229.78	7568.34
		K^f	50.69	0.289	3.10	7.48	29.61	479.33
		L^d	9217.78	20.000	150.00	751.00	2472.00	244073.00
		L^f	1811.49	6.000	46.00	199.00	674.00	45927.00
1986	44	Y	535.68	6.668	29.65	142.13	468.07	8083.84
		K^d	263.56	0.605	23.80	92.63	193.51	1890.12
		K^f	42.18	0.502	3.64	9.32	24.88	436.83
		L^d	5152.32	12.000	169.50	1311.00	3449.50	65842.00
		L^f	1209.82	4.000	55.00	374.50	844.50	15658.00
1988	59	Y	795.47	0.371	20.43	101.29	647.86	13107.65
		K^d	337.63	0.029	15.19	54.19	280.57	2035.27
		K^f	60.35	0.098	3.13	13.74	39.27	561.70
		L^d	5980.10	7.000	134.00	894.00	3637.00	87130.00
		L^f	1410.59	3.000	41.00	225.00	1032.00	20069.00
1990	72	Y	742.08	0.510	22.90	87.40	524.46	13133.42
		K^d	324.50	0.366	11.52	38.05	240.03	2432.84
		K^f	67.46	0.039	2.22	8.32	42.26	641.33
		L^d	4990.15	6.000	121.00	462.50	2382.50	91668.00
		L^f	1256.61	2.000	41.00	192.50	891.50	22832.00
1992	74	Y	1144.17	0.689	45.31	209.73	860.90	12531.55
		K^d	480.95	0.476	34.88	121.14	690.58	2382.76
		K^f	87.33	0.030	3.64	13.98	108.35	872.54
		L^d	5672.97	9.000	214.00	894.50	3362.00	99885.00
		L^f	919.49	4.000	57.00	224.50	904.00	7910.00
1994	55	Y	847.48	0.799	29.32	134.30	523.34	12393.21
		K^d	509.18	3.556	22.57	101.88	493.45	5219.50
		K^f	75.71	0.004	4.60	10.11	69.38	714.73
		L^d	4284.49	21.000	135.00	801.00	2538.00	89357.00
		L^f	1149.87	15.000	41.00	194.00	758.00	20643.00
Full Sample	757	Y	863.30	0.006	24.68	110.83	474.11	23357.38
		K^d	392.00	0.029	16.52	65.83	289.08	7568.34
		K^f	62.66	0.004	3.30	10.29	38.57	872.54
		L^d	6047.14	2.000	150.00	772.00	2783.00	244073.00
		L^f	405.18	1.000	40.00	223.00	788.00	45927.00

Variables are defined in the text. Variables are in millions of 1987 U.S. dollars, except employees, which is in units.

TABLE 3
Translog Production Function Parameter Estimates

	Ordinary Least Squares			Semiparametric	
Parameter	Domestic	Foreign	Joint	Unrestricted	Restricted
α_{L}^{d}	0.556	---	0.185	0.413	0.310
	(0.066)		(0.188)	(0.204)	(0.202)
α_{L}^{f}	---	0.160	0.342	0.350	0.279
		(0.069)	(0.167)	(0.177)	(0.185)
α_{K}^{d}	0.356	---	0.308	0.174	0.170
	(0.064)		(0.080)	(0.045)	(0.035)
α_{K}^{f}	---	0.424	0.073	0.095	0.254
		(0.055)	(0.063)	(0.037)	(0.041)
$\alpha_{L^dL^d}$	-0.042	---	0.148	0.101	0.182
	(0.022)		(0.091)	(0.103)	(0.091)
$\alpha_{L^fL^f}$	---	0.027	0.165	0.202	0.273
		(0.016)	(0.064)	(0.083)	(0.088)
$\alpha_{K^dK^d}$	-0.030	---	0.040	0.021	0.071
	(0.026)		(0.034)	(0.015)	(0.018)
$\alpha_{K^fK^f}$	---	-0.005	0.047	0.050	0.071
		(0.016)	(0.018)	(0.018)	(0.018)
$\alpha_{L^dK^d}$	0.049	---	-0.043	0.0009	---
	(0.022)		(0.074)	(0.045)	
$\alpha_{L^dK^f}$	---	---	0.074	0.107	---
			(0.039)	(0.039)	
$\alpha_{L^dL^f}$	---	---	-0.168	-0.204	-0.221
			(0.031)	(0.087)	(0.087)
$\alpha_{L^fK^d}$	---	---	0.061	0.070	---
			(0.035)	(0.038)	
$\alpha_{L^fK^f}$	---	0.032	-0.043	-0.061	---
		(0.013)	(0.028)	(0.034)	
$\alpha_{K^dK^f}$	---	---	-0.067	-0.114	-0.071
			(0.024)	(0.013)	(0.018)
Year Effects	Yes	Yes	Yes	Yes	Yes
Non-parametric Series:	No	No	No	Yes	Yes
First Stage				Polynomial in (**i**, **k**, **p**)	Polynomial in (**i**, **k**, **p**)
Second Stage				Polynomial in (**i**, **k**, **p**)	Polynomial in (**i**, **k**, **p**)
Third Stage				Polynomial in $(\hat{P}, \hat{g})$	Polynomial in $(\hat{P}, \hat{g})$
Wald Statistic	2.68	33.31	2.60	---	---
p-value	(0.102)	(0.000)	(0.107)		
Number of Observations	783	759	757	439	439

The parameter estimates in columns 1 through 3 are based on the translog production function defined by (7) in the text. The parameter estimates in columns 4 and 5 are based on the semiparametric procedure described in the text. The dependent variable is domestic sales for domestic production, foreign sales for foreign production, and total sales for joint production. Asymptotic standard errors are in parentheses. The Wald statistic is a test of constant returns to scale. The significance level of the test is in parentheses below the statistic.

TABLE 4
Allen Elasticities of Input Substitution (AES_{ij}) from the Semiparametric Unrestricted Translog Parameter Estimates

Full Sample Means

Input	Domestic Labour (L^d)	Foreign Labour (L^f)	Domestic Capital (K^d)	Foreign Capital (K^f)
Domestic Labour (L^d)	-0.064	-1.409	-0.202	3.551
Foreign Labour (L^f)	-1.409	-0.012	2.590	-5.675
Domestic Capital (K^d)	-0.202	2.590	-1.638	1.882
Foreign Capital (K^f)	3.551	-5.675	1.882	-6.512

1994 Sample Means

Input	Domestic Labour (L^d)	Foreign Labour (L^f)	Domestic Capital (K^d)	Foreign Capital (K^f)
Domestic Labour (L^d)	-0.432	0.024	-0.504	5.093
Foreign Labour (L^f)	0.024	-2.560	2.969	-7.906
Domestic Capital (K^d)	-0.504	2.969	-1.714	1.602
Foreign Capital (K^f)	5.093	-7.906	1.602	-6.585

Allen elasticities of input substitution are calculated from the parameter estimates of the semiparametric unrestricted translog in Table 3 at the full sample means and the 1994 means in Table 2.

TABLE 5
Price Elasticities of Input Demand (PES_{ij}) from the Semiparametric Unrestricted Translog Parameter Estimates

Full Sample Means

Input	Domestic Labour (L^d)	Foreign Labour (L^f)	Domestic Capital (K^d)	Foreign Capital (K^f)
Domestic Labour (L^d)	-0.020	-0.289	-0.083	0.392
Foreign Labour (L^f)	-0.439	-0.002	1.068	-0.627
Domestic Capital (K^d)	-0.063	0.531	-0.676	0.208
Foreign Capital (K^f)	1.106	-1.163	0.776	-0.719

1994 Sample Means

Input	Domestic Labour (L^d)	Foreign Labour (L^f)	Domestic Capital (K^d)	Foreign Capital (K^f)
Domestic Labour (L^d)	-0.147	0.006	-0.191	0.332
Foreign Labour (L^f)	0.008	-0.618	1.126	-0.516
Domestic Capital (K^d)	-0.171	0.717	-0.650	0.105
Foreign Capital (K^f)	1.732	-1.910	0.608	-0.430

Price elasticities of demand are calculated from the parameter estimates of the semiparametric unrestricted translog in Table 3 at the full sample means and the 1994 means in Table 2.

TABLE 6
Morishima Elasticities of Input Substitution (MES_{ij}) from the Semiparametric Unrestricted Translog Parameter Estimates

Full Sample Means

Input	Domestic Labour (L^d)	Foreign Labour (L^f)	Domestic Capital (K^d)	Foreign Capital (K^f)
Domestic Labour (L^d)	---	-0.419	-0.043	1.126
Foreign Labour (L^f)	-0.286	---	0.533	-1.161
Domestic Capital (K^d)	0.592	1.744	---	1.452
Foreign Capital (K^f)	1.111	0.092	0.927	---

1994 Sample Means

Input	Domestic Labour (L^d)	Foreign Labour (L^f)	Domestic Capital (K^d)	Foreign Capital (K^f)
Domestic Labour (L^d)	---	0.155	-0.024	1.879
Foreign Labour (L^f)	0.624	---	1.335	-1.291
Domestic Capital (K^d)	0.459	1.776	---	1.258
Foreign Capital (K^f)	0.762	-0.086	0.534	---

Morishima elasticities of input substitution are calculated from the parameter estimates of the semiparametric unrestricted translog in Table 3 at the full sample means and the 1994 means in Table 2.

TABLE 7
Shadow Elasticities of Input Substitution (SES_{ij}) from the Semiparametric Unrestricted Translog Parameter Estimates

Full Sample Means

Input	Domestic Labour (L^d)	Foreign Labour (L^f)	Domestic Capital (K^d)	Foreign Capital (K^f)
Domestic Labour (L^d)	---	-0.339	0.230	1.115
Foreign Labour (L^f)	-0.339	---	0.935	-0.346
Domestic Capital (K^d)	0.230	0.935	---	1.038
Foreign Capital (K^f)	1.115	-0.346	1.038	---

1994 Sample Means

Input	Domestic Labour (L^d)	Foreign Labour (L^f)	Domestic Capital (K^d)	Foreign Capital (K^f)
Domestic Labour (L^d)	---	0.429	0.204	0.942
Foreign Labour (L^f)	0.429	---	1.507	-0.343
Domestic Capital (K^d)	0.204	1.507	---	0.641
Foreign Capital (K^f)	0.942	-0.343	0.641	---

Shadow elasticities of input substitution are calculated from the parameter estimates of the semiparametric unrestricted translog in Table 3 at the full sample means and the 1994 means in Table 2.

TABLE 8
Gross, Scale, and Net Price Elasticities of Demand from the Semiparametric Restricted Translog Parameter Estimates

Full Sample Means

Net Price Elasticity	Gross Price Elasticity	Scale Elasticity	Value of Net Elasticity
$PES_{K^d K^d}$	-0.938	-0.059	-0.997
$PES_{K^d K^f}$	0.426	-0.033	0.394
$PES_{K^f K^f}$	0.774	-0.059	0.714
$PES_{K^f K^d}$	-1.285	-0.033	-1.318

1994 Sample Means

Net Price Elasticity	Gross Price Elasticity	Scale Elasticity	Value of Net Elasticity
$PES_{K^d K^d}$	-0.942	-0.058	-1.001
$PES_{K^d K^f}$	0.431	-0.033	0.398
$PES_{K^f K^f}$	0.760	-0.058	0.701
$PES_{K^f K^d}$	-1.270	-0.033	-1.303

The net price elasticity is the sum of the gross price and scale elasticities. The elasticities are calculated from the parameter estimates of the semiparametric restricted translog in Table 3 at the full sample means and the 1994 means in Table 2.

FIGURE 1
Master Production Function Isoquant

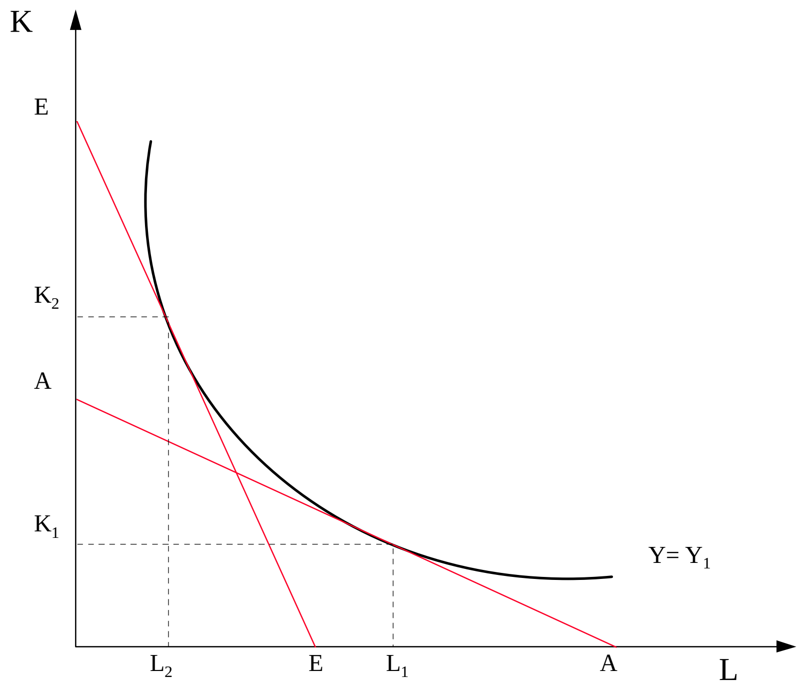


FIGURE 2
Capital Isoquant: Relatively Large Scale Elasticity

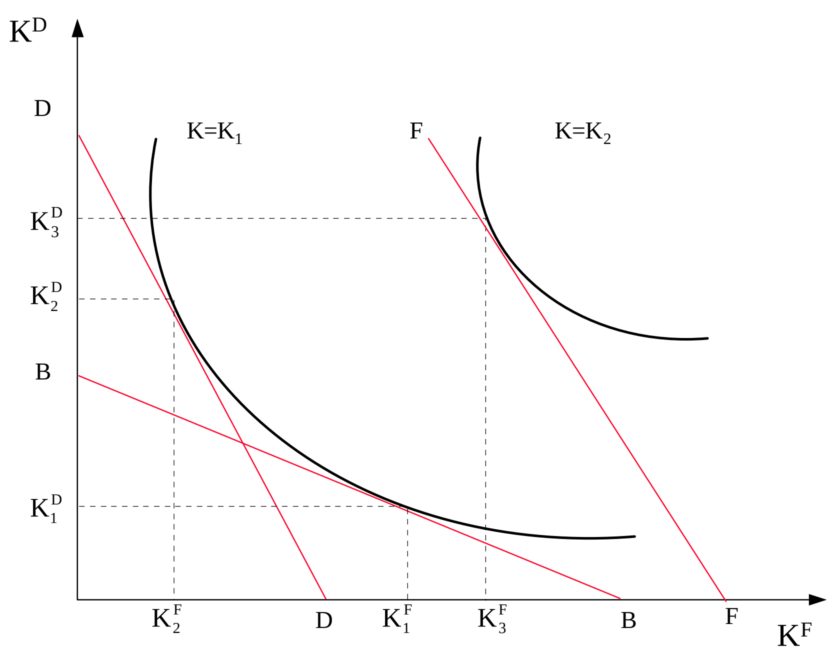


FIGURE 3
Capital Isoquant: Relatively Small Scale Elasticity

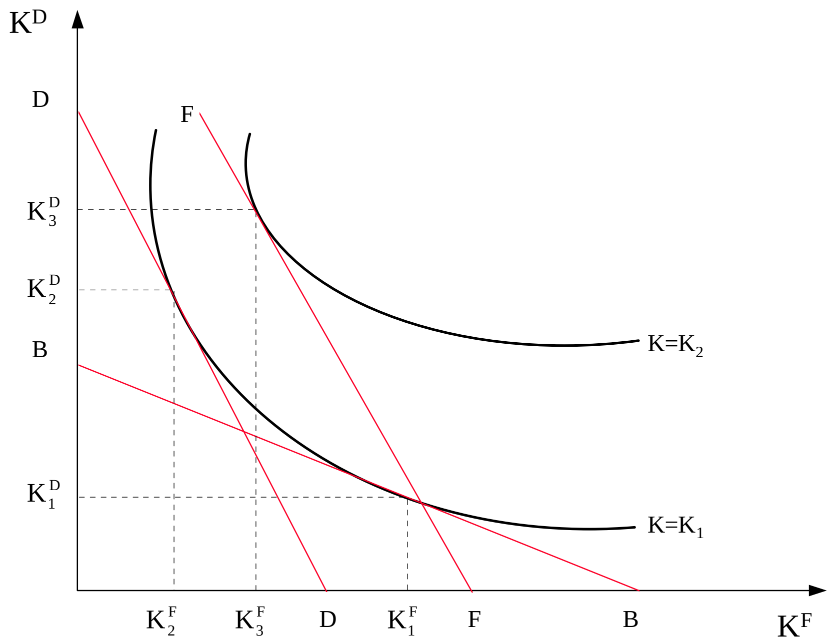
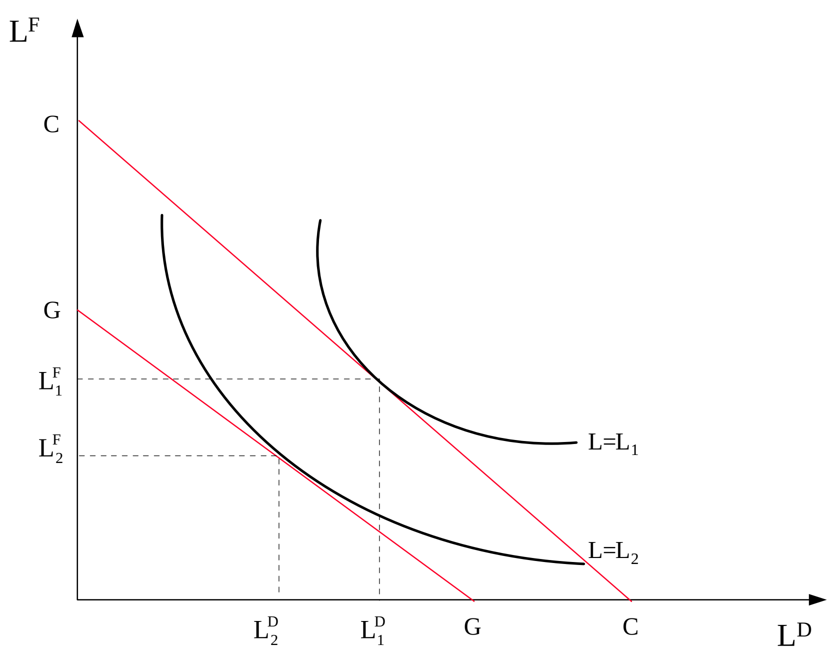


FIGURE 4
Labour Isoquant



Technical Committee on Business Taxation

The Technical Committee was established by the Minister of Finance, at the time of the March 1996 federal budget, to consider ways of:

- improving the business tax system to promote job creation and economic growth,
- simplifying the taxation of businesses to facilitate compliance and administration, and
- enhancing fairness to ensure that all businesses share the cost of providing government services.

The Technical Committee will report before the end of 1997; consultations with the public will follow the release of the report.

The Technical Committee is composed of a panel with legal, accounting and economic expertise in the tax field. The members are:

Mr. Robert Brown
Price Waterhouse
Toronto, Ontario

Mr. James Cowan
Stewart McKelvey Stirling Scales
Halifax, Nova Scotia

Mr. Wilfrid Lefebvre
Ogilvy Renault
Montreal, Quebec

Professor Nancy Olewiler
Department of Economics
Simon Fraser University
Burnaby, British Columbia

Mr. Stephen Richardson
Tory, Tory, Deslauriers & Binnington
Toronto, Ontario

Professor Bev Dahlby
Department of Economics
University of Alberta
Edmonton, Alberta

Mr. Allan Lanthier
Ernst & Young
Montreal, Quebec

Professor Jack Mintz (Chair)
Faculty of Management,
University of Toronto (on leave)
Clifford Clark Visiting Economist
Department of Finance
Ottawa, Ontario

Mr. Norm Promislow
Buchwald Asper Gallagher Henteleff
Winnipeg, Manitoba

The Technical Committee has commissioned a number of studies from outside experts to provide analysis of many of the issues being considered as part of its mandate. These studies are being released as working papers to make the analysis available for information and comment. The papers have received only limited evaluation; views expressed are those of the authors and do not necessarily reflect the views of the Technical Committee.

A list of completed research studies follows. They may be requested from:

Distribution Centre
Department of Finance
300 Laurier Avenue West
Ottawa, Ontario K1A 0G5
Telephone: (613) 995-2855
Facsimile: (613) 996-0518

They are also available on the Internet at http://www.fin.gc.ca/

Technical Committee on Business Taxation
Completed Research Studies

☐ **WORKING PAPER 96-1**
Comparison and Assessment of the Tax Treatment of Foreign-Source Income in Canada, Australia, France, Germany and the United States
Brian Arnold (Goodman Phillips & Vineberg)
Jinyan Li and *David Sandler* (University of Western Ontario)

☐ **WORKING PAPER 96-2**
Why Tax Corporations
Richard Bird (University of Toronto)

☐ **WORKING PAPER 96-3**
Tax Policy and Job Creation: Specific Employment Incentive Programs
Ben Cherniavsky (Technical Committee Research Analyst)

☑ **WORKING PAPER 96-4**
The Effects of Taxation on U.S. Multinationals and Their Canadian Affiliates
Jason Cummins (New York University)

☐ **WORKING PAPER 96-5**
The Integration of Corporate and Personal Taxes in Europe: The Role of Minimum Taxes on Dividend Payments
Michael Devereux (Keele University)

☐ **WORKING PAPER 96-6**
International Implications of U.S. Business Tax Reform
Andrew Lyon (University of Maryland)

☐ **WORKING PAPER 96-7**
The Economic Effects of Dividend Taxation
Ken McKenzie (University of Calgary)
Aileen Thompson (Carleton University)

☐ **WORKING PAPER 96-8**
Capital Tax Issues
Peter McQuillan and *Cal Cochrane* (KPMG Toronto)

☐ **WORKING PAPER 96-9**
Compliance Issues: Small Business and the Corporate Income Tax System
Robert Plamondon (Ottawa)

☐ **WORKING PAPER 96-10**
Study on Transfer Pricing
Robert Turner (Ernst & Young, Toronto)

☐ **WORKING PAPER 96-11**
The Interaction of Federal and Provincial Taxes on Businesses
Marianne Vigneault (Bishop's University)
Robin Boadway (Queen's University)

☐ **WORKING PAPER 96-12**
Taxation of Inbound Investment
Gordon Williamson (Arthur Andersen, Toronto)