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FOREIGN DIRECT INVESTMENT AND PRODUCTIVITY GROWTH: THE CANADIAN HOST-COUNTRY EXPERIENCE

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ABSTRACT

In this paper, we analyze the impact of technology transfers and spillovers from inward foreign direct investment (FDI) on the production cost and structure of Canadian industries. Specifically, we: (1) estimate the effects of inward FDI on the cost of production; and (2) examine the impact of FDI on the structure of production, i.e., the effects on demand for factors such as capital, labour, intermediate goods and R&D capital. In doing so, we control for domestic and international R&D spillovers. We find that inward FDI lowers production cost and increases productivity in most Canadian industries, and that it alters the structure of production as industries adjust their demand for factor inputs. Our estimates show that inward FDI is biased against the use of capital, labour and intermediate goods and somewhat biased toward the use of domestic R&D. We also find evidence of significant positive international R&D spillovers through trade flows. The results indicate that international R&D spillovers are biased against the use of physical capital, labour and intermediate goods, and biased toward the use of domestic R&D capital. The relationship between domestic R&D and international R&D spillovers suggests that domestic firms must invest in R&D to capture the benefits of R&D spillovers from abroad.

I. INTRODUCTION

The internationalization of production has been a major phenomenon in the modern day global economy. This is partly a result of the removal of many barriers to international capital movements and partly a result of the widespread use of the information technology which has made it possible for firms to integrate their worldwide production and investment activities. Most significant has been the dramatic growth in foreign direct investment (FDI) along with other transactions that support international production, including subcontracting, licensing, franchising and alliances.

Between 1970 and 1990, direct investment flows among OECD countries more than doubled as a share of GDP (from 0.5 to 1.2 percent). Similar trends are observed in Canada. Over the past ten years, the stock of inward FDI more than doubled in Canada, reaching 22.6 percent of GDP in 1996. The increased importance of FDI in the economy has renewed the debate on such policy issues as whether inward FDI affects employment, production and export growth in the host country, and whether outward FDI substitutes for exports and reduces capital investment and employment in the home country.[1] In this paper, we focus on the relationship between inward FDI and productivity in the host country.

The existing literature on FDI points to two major channels through which FDI improve the efficiency of production in the host country: technology transfers and spillover benefits to domestic firms (Blomström and Kokko, 1994; and Blomström, 1991). Technology transfers from foreign parent firms can take place through the addition of more productive capital stock and the adoption of product and process innovations, and through the R&D and innovative activities of these firms in the host economy. The inflow of new technology and working practices of foreign firms could create significant spillover benefits to domestic firms in the host country. These spillovers can occur in a number of ways. First, they can occur simply because of the public good characteristics of knowledge. Like all other types of knowledge, the firm-specific assets of multinational enterprises (MNEs) may escape from their owner's control and leak into competing domestic firms. Second, knowledge and technology could spillover from foreign firms to domestic firms through the training of labour and management, which will subsequently benefit local firms. Third, MNEs can stimulate improvements in quality and reliability of inputs by local suppliers. Fourth, domestic firms can 'learn by watching' (Balasubramanyam et al., 1996). Finally, inward FDI can also lead to increased competition and force less efficient domestic firms to innovate or to exit.

Previous Empirical Findings: FDI and Productivity in the Host-Country

A number of empirical studies have shown that inward FDI improves the productivity performance of host countries through technology transfer and spillover benefits. Borensztein et al. (1994) found that FDI outflows from the OECD countries are an important vehicle of technology transfer for developing countries and they appear to have contributed positively to GDP growth. Similarly, Caves (1996) and Dunning (1993) observed that FDI has contributed to productivity convergence among countries. Mansfield and Romeo (1980) found that technologies transferred to affiliates were consistently of later vintage than those sold to outsiders. A Canadian study by McFetridge (1987) also concluded that technology transfer lags tend to be shorter for intra-firm transfers than for other types of transfers.

Evidence also shows that there are significant spillover benefits from MNEs for competing local firms. Blomström and Wolff (1994) found that productivity of domestic firms in Mexico increased more rapidly, and the productivity gap from foreign subsidiaries narrowed, the higher the foreign subsidiaries' initial share and the larger the initial productivity gap. Based on a panel of 1,270 German manufacturing firms over the period 1984-88, Bertschek (1995) found that inward FDI had a positive and significant effect on product and process innovations of domestic firms. Similarly, Mansfield and Romeo (1980) found that innovative efforts by domestic firms in the United Kingdom were hastened in response to technology transfers from the U.S. multinationals to their subsidiaries in the United Kingdom.

The Canadian evidence on spillover benefits of inward FDI is somewhat mixed. Globerman (1979) found that labour productivity across Canadian-owned plants was positively related to the share of foreign ownership of an industry in 1972. However, studies by Saunders (1980) and Bernhardt (1981) questioned the existence of spillover benefits of FDI for domestic producers. Saunders (1980) found a negative relationship between the labour productivity of Canadian industries relative to U.S. industries and the share of foreign ownership for a sample of 3-digit industries in 1967. In contrast, Bernhardt (1981) found no relationship between the two variables in 1966 and a negative correlation in 1972.

In a recent study, Barrell and Pain (1997) analyze the impact of technology transfers and spillovers from foreign-owned firms on productivity growth. Their estimates for West Germany show that a 1 percent increase in the real inward FDI stock raises technical progress by 0.27 percent. For the United Kingdom the results provide an interesting sectoral contrast. In the manufacturing sector, inward FDI is found to have a significant effect on technical progress — a 1 percent rise in the FDI stock raises technical progress by 0.26 percent. FDI accounted for about 30 percent of U.K. manufacturing productivity growth since 1985. By contrast, FDI is not found to contribute significantly to productivity growth in the non-manufacturing sector where some two-thirds of inward FDI has taken place. For the authors, these findings suggest that the benefits of inward FDI seem to lie in sectors (such as manufacturing) where domestic producers are at a comparative disadvantage and relatively less productive.

Objective of Our Study

Following Barrell and Pain (1997), we analyze the impact of technology transfers and spillovers from inward FDI on production costs and the structure of Canadian industries. More specifically: (1) we estimate the effects of inward FDI on the cost of production and total factor productivity; and (2) we examine the impact of FDI on the structure of production, i.e. the effects on demand for factor inputs such as capital, labour, intermediate goods and R&D capital.

Our study makes two empirical contributions to the existing literature. First, in our analysis we apply a cost function approach — a rigorous framework of factor demand analysis. This allows us to trace the response of factor demands to FDI in the production process while investigating its impact on production costs. Second, our analysis controls for domestic and international R&D spillovers. These factors have been found to affect productivity growth in small open economies such as Canada (Coe and Helpman, 1995; Bernstein, 1994; and Gera, Gu and Lee, 1998).

The rest of the paper is organized as follows. In section II, we describe the empirical model used for our estimations. In section III, we present an overview of the data and general trends. Section IV, contains our estimation results. Finally, in section V, we offer some conclusions.

II. EMPIRICAL FRAMEWORK

The duality theory of production has established that there is a unique correspondence between the production function and the cost function. In order to examine the underlying production technology, one can either employ a production function or its associated cost function. In this paper, we use the cost function approach[2]. Our choice of the cost function approach is mainly motivated by our desire to understand the following behavioral response: to what extent inward FDI affects the demand for factors of production among Canadian industries.

We assume that each industry produces one output using four inputs: physical capital, labour, intermediate goods and R&D capital. The cost of production is affected by inward FDI, domestic R&D spillovers and international R&D spillovers. Given that a multinational's decision to invest abroad is influenced by many factors including the economic climate of host and competing countries, we assume that inward FDI, along with domestic and international R&D spillovers are determined exogenously.[3] Assuming also that the industry minimizes its total cost of production, we can write a general form of the industry's cost function as:

(1) $C(w, Y; t, Z)$,

where $w = \{w_i\}$ is a vector of factor prices (the rental price of physical capital, wage of labour input, price of intermediate goods and rental price of R&D capital); $i = K, L, M, R$ indexes physical capital, labour input, intermediate goods and R&D capital; Y is the industry output; t is an index of time representing pure technical change; $Z = \{Z_k\}$ is a vector of exogenous variables (FDI, domestic R&D spillovers, and international R&D spillovers) that affect the cost of production of an industry; and $k = FDI, DRD, FRD$ indexes inward FDI capital stock, domestic R&D spillovers and international R&D spillovers.

$C = \sum_i w_i x_i$ is the total cost of production of the industry, equal to the sum of the rental price of capital stock, the wage bills, the cost of intermediate goods, and the rental price of R&D capital stock; and $x \quad \{x \}$ is a vector of the quantities of factor inputs comprised of physical capital stock, labour input, intermediate goods and R&D capital stock.

According to Shepherd's lemma, the derivative of the cost function with respect to an input price yields the derived demand for the input:

$$\frac{\partial C}{\partial w_i} = x_i(w, Y; t, Z) \; i = K, L, M, R .$$

In our empirical formulation, FDI affects industry production in two ways. FDI shifts the cost of production curve and it affects the structure of production as the industry adjusts its demand for factor inputs such as capital, labour, intermediate goods and R&D capital stock.

For our empirical investigation, we have chosen the transcendental logarithmic (translog) cost function modified to incorporate the effects of exogenous variables Z on the total cost of production. The translog cost function can be viewed as a second order logarithmic approximation to an arbitrary twice continuously differentiable cost function (Diewert and Wales, 1987). Due to possible multicollinearity in our data, we assume constant returns to scale as in Nadiri and Kim (1996).[4] The translog cost function with constant returns to scale technology can be written as:

$$(3)\qquad \begin{aligned} \ln C(w,Y;t,Z) - \ln Y = a_o + \sum_i a_i \ln w_i + a_t t + \sum_k b_k \ln Z_k \\ + \tfrac{1}{2}\sum_i \sum_j g_{ij} \ln w_i \ln w_j + \sum_i g_{it} \ln w_i t + \sum_i \sum_k q_{ik} \ln w_i \ln Z_k \\ + \tfrac{1}{2} a_{tt} t^2 + \tfrac{1}{2}\sum_k \sum_l b_{kl} \ln Z_k \ln Z_l + \sum_k b_{kt} \ln Z_k t\,, \end{aligned}$$

where $i, j = K, L, M, R$ index capital, labour, intermediate goods and R&D capital stock and $k, l = FDI, DRD, FRD$ index inward FDI capital stock, domestic R&D spillovers and international R&D spillovers.

Partially differentiating the translog average cost function (3) with respect to the logarithm of factor prices and using Shepherd's lemma (2), we obtain the following set of cost-share equations:

$$(4)\qquad s_i = \frac{\P \ln C}{\P \ln w_i} = a_i + \sum_j g_{ij} \ln w_j + g_{it} t + \sum_k q_{ik} \ln Z_k\,,\ i = K, L, M, R\,,$$

where $s_i = w_i x_i / C$ is the share of cost accounted for by factor *i*.

There are several parametric restrictions imposed on the cost function. The cost function is linearly homogeneous in factor prices. This implies the following set of restrictions:

$$(5)\qquad \sum_i a_i = 1,\ \sum_j g_{ij} = 0,\ \sum_i g_{it} = 0,\ \sum_i q_{ik} = 0\,.$$

Note that the same set of restrictions are imposed by the constraint that the cost shares of physical capital, labour, intermediate goods and R&D capital add up to one. The set of restrictions (5) imply that only three out of the four share equations are linearly independent. As a result, the share equation for R&D capital stock is dropped from the system of estimation equations.

The cross partial derivatives of the cost function must be equal from Young's theorem in calculus. This implies the following set of symmetry conditions.[5]

$$(6)\qquad g_{ij} = g_{ji}\,,\ b_{kl} = b_{lk}\,.$$

The final system of estimation equations consists of the cost function (3) and three share equations (4) for capital, labour and intermediate goods with parameter restrictions (6). An error term is added to each equation partly to reflect optimization errors. The share equation for R&D capital stock is dropped from the system of estimation equation. To ensure that our parameter estimates are invariant to which share equation is dropped, the iterative seemingly unrelated regression (SUR) method is used.

To estimate the cost function and share equations, we pooled together cross-industry time-series data. The pooled cross-sectional time-series data generate more variation, which make it more likely to identify the parameter estimates than if we were using the time series data for a single industry. When using time series data for a single industry, variables often move together generating a serious multicollinearity problem. In order to control for interindustry differences in the production process, we introduce industry fixed effects in the share equations and the cost equation. That is, we allow the parameters a_o and a_i $(i = K, L, M, R)$ to vary across industries.

The own-price and cross-price elasticities of factor demands, e_{ij}, can be computed directly from the translog cost function (3):

(7) $$e_{ii} = g_{ii}/s_i + s_i - 1$$
$$e_{ij} = g_{ij}/s_i + s_j \text{, for } i \neq j,\ i, j = K, L, M, R.$$

The cost function (3) allows us to test additional restrictions regarding the underlying production technology: neutrality of pure technical change and unitary partial elasticities of substitution among all inputs (for a further discussion, see Nadiri and Schankerman, 1981).

Technical change is said to be *i*th-factor neutral (*i*th-factor saving, or *i*th-factor using) if the cost share of the *i*th factor is unchanged (lowered, or raised) in response to technical change and is represented by $g_{it} = 0$ ($g_{it} < 0$ or $g_{it} > 0$). The neutrality of the technical change can be tested by imposing the restrictions:

(8) $$g_{it} = 0,\ i = K, L, M, R.$$

The cost function exhibits unitary partial elasticities of substitution among all inputs if

(9) $$g_{ij} = 0,\ i \neq j \text{ and } i, j = K, L, M, R.$$

Using the cost function (3), we can estimate the effects of FDI, domestic and international R&D spillovers on total cost. They are measured by the cost elasticity computed by taking the first order derivative of the cost function (3):

(10) $$h_{ck} = \frac{\P \ln C}{\P \ln Z_k} = b_k + \sum_i q_{ik} \ln w_i + \sum_l b_{kl} \ln Z_l + b_{kt} t,\ k = FDI, DRD, FRD.$$

The cost elasticity defined in (10) represents the percentage change in total cost resulting from a one percent increase in inward FDI stock, domestic or international R&D spillovers.

The effects of FDI, domestic and international R&D spillovers on the structure of production can be measured by the elasticity of factor demand:

(11) $$h_{ik} = \frac{\P \ln x_i}{\P \ln Z_k} = h_{ck} + \frac{q_{ik}}{s_i}, \quad i = K, L, M, R,\ k = FDI, DRD, FRD.$$

A positive elasticity of input demand *i* with respect to variable *k* indicates that variable *k* is biased toward the use of input *i*. A negative elasticity suggests that variable *k* is biased against the use of input *i*.[6]

III. DATA AND TRENDS

The data required for our empirical analysis include: quantities of output; quantities and prices of capital, labour, intermediate goods and R&D capital; inward FDI capital stock; domestic R&D spillovers; and international R&D spillovers. Data on inward FDI stock are available for 13 SIC-C one-digit industries (Standard Industrial Classification for Companies and Enterprises 1980). All remaining data are aggregated into these 13 SIC-C one-digit industries.[7] The period of analysis is from 1973 to 1992.

The quantity of output is gross output in 1986 constant dollars. The quantity of labour is measured by the total number of hours worked. Intermediate goods consist of energy, materials and services. They are all obtained from Statistics Canada's KLEMS database that provides industry data on total output (Y), physical capital (K), labour (L), energy (E), materials (M) and services (S).

The capital stock is the net physical capital stock based on geometric depreciation, obtained from the Fixed Capital Stock and Flows data from Statistics Canada. We use the beginning-of-year net capital stock since investment is assumed to be productive the following year. The R&D stock is calculated using the perpetual inventory method. Rental prices of physical and R&D capital are calculated using the formula in Appendix A.

Data on the book value of the inward FDI stock are obtained from Statistics Canada. They are available for 13 SIC-C (1980) one-digit industries from 1983 onwards. Before 1983, the data on the book value of inward FDI are based on an earlier SIC (1970) classification. They are converted to the SIC-C (1980) industry classification using the conversion matrix in Statistics Canada Catalogue no. 67-202. The real value of the inward FDI stock for an industry is calculated by dividing the book value of the inward FDI stock by the investment deflator of that industry.

Domestic and international R&D spillovers are calculated as R&D capital stock embodied in goods purchased domestically and internationally. Essentially, we are measuring embodied R&D spillovers as opposed to disembodied R&D spillovers.[8] More specifically, domestic R&D spillovers received by industry i are constructed as:

$$(16) \qquad DRD_i = \sum_{j \neq i} X_{ji} \frac{x_R^j}{v^j},$$

where x_R^j is the R&D capital stock of industry j, v^j is the real value-added of industry j, X_{ji} is the amount of domestic intermediate goods industry i purchased from industry j. Domestic R&D spillovers defined in equation (16) measure R&D embodied in goods purchased by an industry from all other industries. It is commonly referred to as domestic interindustry embodied R&D spillovers.

International R&D spillovers are assumed to be from other G-7 countries. Analogous to domestic R&D spillovers, international R&D spillovers received by Canadian industry i are measured as foreign R&D capital stock embodied in the industry imports and is constructed as:[9]

$$(17) \qquad FRDS_i = \sum_{j \neq i} \sum_{k} M_{ji} a_{jk} \frac{x_R^{jk}}{v^{jk}} .$$

In equation (17), M_{ji} represents total import of good j by industry *i*. a_{jk} is the share of total imports of good *j* accounted for by country *k*. x_R^{jk} is the R&D capital stock of industry *j* in country *k*.[10] v^{jk} is the real value-added of industry *j* in country *k*.[11]

International R&D spillovers, as measured in equation (17), represent international interindustry embodied R&D spillovers. We exclude R&D spillovers embodied in intra-industry trade from our measurement of international R&D spillovers due to two considerations. First, intra-industry trade is mainly comprised of intrafirm trade of the MNEs. Thus, inward FDI should capture international R&D spillovers embodied in intrafirm trade or intra-industry trade. Second, we measure domestic R&D spillovers as R&D embodied in domestic interindustry trade. To be consistent with our measure of domestic R&D spillovers, we have chosen to measure international R&D spillovers as R&D embodied in interindustry imports.

We now turn to the basic data for our regression analysis (Tables 1 to 5). Tables 1 and 2 present the mean values and annual growth rates of some key variables for the regression analysis including: total cost, gross output, physical capital stock, labour input, intermediate goods, R&D capital stock, inward FDI stock, and domestic and international R&D spillovers. These variables show considerable variation across industries. Compared with the non-service industries, the service industries in general had larger annual growth rates in gross output, physical capital stock, employment, intermediate goods and R&D capital stock over the 1973-92 period. The stock of inward FDI increased in all industries except energy with annualized growth rates ranging from a low of -0.26 percent in the energy industry to a high of 6.44 percent in the finance and insurance industry.

The mean values of cost shares accounted for by capital, labour, intermediate goods, and R&D capital are shown in Table 3. Intermediate goods account for the largest share of total cost in almost all industries, ranging from 31.8 percent in other service industries to 73.5 percent in the transportation equipment industry. Not surprisingly, the service industries show a very different pattern of cost structure than the non-service industries. Compared with the non-service industries, the service industries have relatively large cost shares of labour and relatively small shares of intermediate goods. In all industries, the cost share of R&D capital is rather small; the electrical and electronic products manufacturing industry has the highest cost share of R&D capital (6.6 percent).

Given our focus on inward FDI, the following two tables (Tables 4 and 5) examine closely the distribution and relative importance of inward FDI among Canadian industries. Inward FDI is found to be concentrated in the energy industry and in the finance and insurance industry. However, the ratio of FDI to gross output is the highest in machinery and equipment (64 percent), followed by chemicals and chemical products (38 percent).

Table 1
Mean values of main variables by industry, 1973–92
(millions of 1986 dollars)

Industry (SIC-C)	Total cost	Gross Output	Physical capital stock	Labour (millions of hours)	Intermediate goods	R&D capital stock	Inward FDI stock	Foreign R&D spillovers	Domestic R&D spillovers
1. Food, beverage & tobacco	53,720.18	63,785.13	22,287.21	1,580.82	4,1573.13	613.23	5,464.88	2,268.27	1,037.13
2. Wood & paper	31,889.61	35,412.40	12,190.12	544.97	2,1420.81	839.95	5,001.23	1,179.45	951.33
3. Energy	60,948.36	57,392.76	93,941.39	357.38	2,6447.14	2,548.81	19,437.93	1,756.73	1,642.13
4. Chemicals & chemical products	26,119.47	29,034.30	9,063.02	410.63	1,8372.73	1,984.13	8,661.58	704.35	491.20
5. Metallic minerals & metal products	37,048.73	41,312.91	15,716.94	592.16	25,150.15	1,534.49	6,303.79	2,024.77	1,015.04
6. Machinery & equipment	6,420.91	8,376.00	653.66	152.22	4,862.67	612.58	3,165.71	1,052.56	418.18
7. Transportation equipment	32,285.45	40,006.29	4,094.95	382.97	29,811.97	2,610.26	8,442.66	1,844.92	1,169.17
8. Electrical & electronic products	12,382.30	13,606.57	1,419.91	252.63	8,066.65	5,163.37	4,196.13	342.47	194.62
9. Construction	64,656.71	77,239.98	6,072.58	1,425.14	46,139.44	126.97	4,718.93	2,588.23	3,368.07
10. Transportation & communication	51,825.89	56,023.50	41,156.74	1,311.77	24,045.94	600.03	1,737.30	3,416.64	2,198.30
11. Finance & insurance	47,522.10	57,178.25	31,729.35	974.81	20,622.58	327.92	11,918.29	201.73	370.27
12. Other industries[1]	51,916.39	57,369.73	29,614.83	2,259.60	18,591.88	1,311.69	2,740.29	5,143.60	812.80
13. Consumer goods & services	73,109.86	87,780.37	12,781.29	3,894.68	30,727.19	289.34	4,447.53	845.43	660.88

1. Other industries include services to business; education, health & social services; accommodation, restaurants & recreation; and food retailing.

Table 2
Annual growth rates of main variables by industry, 1973–92
(percentage)

Industry (SIC-C)	Total cost	Gross Output	Physical capital stock	Labour (millions of hours)	Intermediate goods	R&D capital stock	Inward FDI stock	Foreign R&D spillovers	Domestic R&D spillovers
1. Food, beverage & tobacco	6.85	1.57	-0.52	-0.45	1.74	3.30	4.73	2.95	4.45
2. Wood & paper	7.77	1.53	3.44	-0.94	1.90	1.15	1.27	2.72	4.57
3. Energy	9.47	1.60	3.67	2.22	1.41	6.73	-0.26	1.10	3.59
4. Chemicals & chemical products	8.23	2.63	3.40	0.09	2.33	3.75	3.31	3.84	6.74
5. Metallic minerals & metal products	6.54	0.37	1.58	-1.47	0.73	2.45	1.05	1.22	3.69
6. Machinery & equipment	7.02	0.25	3.70	0.05	0.70	3.87	4.40	-0.45	2.32
7. Transportation equipment	9.23	2.46	6.11	0.48	2.63	5.14	3.29	2.09	4.68
8. Electrical & electronic products	8.78	5.07	5.45	-0.48	5.27	6.41	5.92	6.53	8.00
9. Construction	7.46	1.57	3.60	0.44	1.39	3.86	3.42	1.49	3.68
10. Transportation & communication	8.70	3.33	3.09	0.67	3.11	9.95	2.81	3.87	5.43
11. Finance & insurance	11.81	4.22	9.97	3.01	5.78	16.93	6.44	5.68	11.39
12. Other industries[1]	10.99	4.27	3.62	4.31	4.95	16.93	1.87	5.36	7.44
13. Consumer goods & services	8.83	2.72	6.49	1.73	2.60	16.93	2.37	3.71	7.15

1. Other industries include services to business; education, health & social services; accommodation, restaurants & recreation; and food retailing.

Table 3
Average cost shares of inputs by industry, 1973–92
(percentage)

Industry (SIC-C)	Physical capital	Labour	Intermediate goods	R&D capital
1. Food, beverage & tobacco	15.52	18.95	65.35	0.18
2. Wood & paper	14.03	26.55	59.00	0.42
3. Energy	47.94	10.84	40.58	0.64
4. Chemicals & chemical products	15.34	21.40	62.05	1.21
5. Metallic minerals & metal products	15.78	24.38	59.17	0.68
6. Machinery & equipment	5.06	32.31	61.20	1.43
7. Transportation equipment	5.81	19.39	73.48	1.32
8. Electrical & electronic products	6.16	29.42	57.80	6.62
9. Construction	4.20	35.89	59.88	0.03
10. Transportation & communication	24.62	36.06	39.16	0.16
11. Finance & insurance	23.41	37.33	39.17	0.09
12. Other industries[1]	19.51	48.39	31.77	0.33
13. Consumer goods & services	8.80	54.84	36.30	0.05

1. Other industries include services to business; education, health & social services; accommodation, restaurants & recreation; and food retailing.

Table 4
Distribution of inward FDI by industry, 1973 and 1992
(percentage)

Industry (SIC-C)	1973	1992	Change
1. Food, beverage & tobacco	5.21	7.54	2.33
2. Wood & paper	7.98	5.98	-2.00
3. Energy	27.99	15.69	-12.30
4. Chemicals & chemical products	9.52	10.51	0.99
5. Metallic minerals & metal products	9.87	7.10	-2.77
6. Machinery & equipment	2.81	3.82	1.01
7. Transportation equipment	8.53	9.39	0.86
8. Electrical & electronic products	3.33	6.04	2.71
9. Construction	4.91	5.54	0.63
10. Transportation & communication	2.52	2.53	0.01
11. Finance & insurance	9.40	18.82	9.42
12. Other industries[1]	3.28	2.75	-0.53
13. Consumer goods & services	4.63	4.28	-0.35

1. Other industries include services to business; education, health & social services; accommodation, restaurants & recreation; and food retailing.

Table 5
Significance of FDI by industry, 1973 and 1992
(percentage of gross output)

Industry (SIC-C)	1973	1992	Change
1. Food, beverage & tobacco	7.31	13.34	6.03
2. Wood & paper	19.50	18.56	-0.94
3. Energy	41.91	29.43	-12.48
4. Chemicals & chemical products	33.46	38.12	4.66
5. Metallic minerals & metal products	18.18	20.68	2.50
6. Machinery & equipment	29.04	63.90	34.86
7. Transportation equipment	20.35	23.83	3.48
8. Electrical & electronic products	28.45	33.42	4.96
9. Construction	5.89	8.36	2.48
10. Transportation & communication	4.95	4.48	-0.47
11. Finance & insurance	19.66	30.02	10.35
12. Other industries[1]	6.90	4.37	-2.53
13. Consumer goods & services	5.25	4.92	-0.33

1. Other industries include services to business; education, health & social services; accommodation, restaurants & recreation; and food retailing.

IV. EMPIRICAL RESULTS

As discussed earlier, the estimation model consists of the cost equation (3) and three share equations (4) for capital, labour and intermediate goods. In the estimation process, we also impose parameter restrictions (5).[12] Regressions are performed on pooled cross-section time series data for 13 industries over the period 1973-92.

Parameter Estimates

Table 6 presents the parameter estimates of the model and their asymptotic *t*-statistics. The high R-square value suggests that the model fits the data quite well. The industry dummy variables are generally found to be statistically significant.

In our empirical formulation, the factor demands and the cost of production are affected by pure technical change. Our estimates show that the biased technical change coefficients on capital, labour and intermediate goods (g_{Kt}, g_{Lt}, g_{Mt}) are not statistically different from zero. However, the coefficient on R&D capital ($g_{Rt} = -(g_{Kt} + g_{Lt} + g_{Mt})$) is positive and statistically significant at the 5 percent level. These results imply that pure technical change is essentially Hicks-neutral with respect to physical capital, labour and intermediate goods, and is R&D capital-using across Canadian industries. Furthermore, the estimated rate of pure technical change ($-(a_t + a_{tt}t)$) is found to be negative.[13] The joint hypothesis of unitary partial elasticities of substitution among all inputs is strongly rejected. Thus, the Cobb-Douglas functional form does not adequately represent the production technology of Canadian industries — a common finding in the literature.

Estimates of Factor-Price Elasticities

To give a concise description of the production structure, we calculated the own- and cross-price elasticities of factor demand using equation (7). As an illustration, we present the mean values of the price elasticities over the period 1973-92 for the electrical and electronic products industry (Table 7). The estimated own-price elasticities of demand (along the main diagonal) have the expected negative sign and are statistically significant at the 5 percent level, with the exception of the own-price elasticity of capital. The cross-price elasticity estimates indicate that (i) both capital and labour are substitutes for intermediate goods; (ii) capital and labour are weak substitutes; and (iii) R&D capital is a complement of physical capital but a substitute for labour and intermediate goods.

The estimates of own- and cross-price elasticities of factor demands for all other industries are similar to those for the electrical and electronic products industry.[14] An exception is the sign of own-price elasticity of demand for R&D capital. The own-price elasticity of demand for R&D capital for the remaining 12 industries is found to be positive. This surprising result may be due to the fact that R&D capital only accounts for less than 2 percent of total cost in these industries. It can be argued that the rental price of R&D capital is unlikely to be a major factor in determining the firm's choice of R&D expenditures when R&D accounts for such a small share of total cost.[15]

Table 6
Parameter estimates (13 industries over the 1973–92 period)

Parameters	Estimates	*t*-statistics	Parameters	Estimates	*t*-statistics
a_o	10.6417	323.89	a_{K8}	-0.4380	-1.98
a_K	0.1464	19.44	a_{K9}	0.4703	1.41
a_L	0.2585	28.17	a_{K10}	-0.1208	-0.71
a_M	0.5991	66.87	a_{K11}	-0.1595	-0.94
a_t	0.0709	18.44	a_{K12}	0.3878	1.67
g_{KK}	0.0575	6.16	a_{K13}	0.5553	3.58
g_{LL}	0.0791	7.44	a_{L2}	-1.0990	-8.06
g_{MM}	0.0753	6.53	a_{L3}	-1.4533	-18.50
g_{KL}	-0.0281	-4.02	a_{L4}	-0.9490	-6.79
g_{KM}	-0.0212	-2.70	a_{L5}	-1.1024	-11.48
g_{LM}	-0.0474	-5.06	a_{L6}	-1.3407	-5.53
q_{KFDI}	0.0062	1.01	a_{L7}	-0.8108	-4.31
q_{KDRD}	0.0252	2.35	a_{L8}	-1.0035	-6.29
q_{KFRD}	-0.0231	-2.37	a_{L9}	-0.3908	-1.80
q_{LFDI}	-0.0116	-2.26	a_{L10}	-0.6170	-2.38
q_{LDRD}	-0.0373	-4.23	a_{L11}	-0.1894	-0.65
q_{LFRD}	-0.0111	-1.37	a_{L12}	0.8696	2.86
q_{XFDI}	0.0032	0.56	a_{L13}	-0.4484	-1.61
q_{XDRD}	0.0154	1.54	a_{M2}	0.2610	1.36
q_{XFRD}	0.0274	2.99	a_{M3}	0.6337	7.48
g_{Kt}	-0.0004	-0.72	a_{M4}	-0.0194	-0.09
g_{Lt}	0.0006	1.33	a_{M5}	0.1779	1.09
g_{Mt}	-0.0005	-1.13	a_{M6}	0.4055	1.58
b_{DRD}	0.1178	1.67	a_{M7}	-0.1216	-0.47
b_{FRD}	-0.1693	-3.16	a_{M8}	-0.2484	-0.98
b_{FDI}	-0.2068	-4.98	a_{M9}	-0.7406	-1.99
b_{FDIFDI}	-0.2082	-5.11	a_{M10}	-0.0018	-0.01
b_{DRDDRD}	0.1354	1.66	a_{M11}	-0.2134	-0.74
b_{FRDFRD}	-0.1123	-2.21	a_{M12}	-1.5732	-4.77
b_{FDIDRD}	0.0239	0.52	a_{M13}	-0.7551	-2.40
b_{FDIFRD}	-0.1159	-2.75	a_{o2}	-0.1119	-2.36
b_{DRDFRD}	0.0463	0.87	a_{o3}	0.5752	4.55
a_{tt}	-0.0037	-8.17	a_{o4}	-0.1686	-2.56
b_{FDIt}	0.0091	3.91	a_{o5}	0.0479	1.30
b_{DRDt}	-0.0084	-2.26	a_{o6}	-0.2372	-2.88
b_{FRDt}	0.0002	0.06	a_{o7}	-0.1101	-1.52
a_{K2}	-0.0640	-0.41	a_{o8}	-0.2693	-2.27

Table 6 (cont'd)

Parameters	**Estimates**	***t*-statistics**	**Parameters**	**Estimates**	***t*-statistics**
a_{K3}	-0.4022	-1.38	a_{o9}	-0.5067	-3.74
a_{K4}	0.0336	0.13	a_{o10}	-0.3370	-3.91
a_{K5}	-0.1229	-0.70	a_{o11}	-0.4546	-3.43
a_{K6}	-0.4323	-2.76	a_{o12}	0.3065	2.23
a_{K7}	0.2934	2.05	a_{o13}	-0.5695	-7.01

Equation	**R^2**	**Std. error**
Total cost	0.946	0.088
Capital share	0.975	0.018
Labour share	0.984	0.015
Intermediate goods share	0.983	0.017
Log likelihood	3011	

Table 7
Own- and cross-price elasticities of factor demand in the electrical and electronic products industry (mean values for the 1973–92 period)[1]

	Capital	**Labour**	**Intermediate goods**	**R&D capital**
Capital	-0.0052 (-0.03)	-0.1616 (-1.42)	0.2339 (1.83)	-0.0671 (-1.69)
Labour	-0.0338 (-1.42)	-0.4369 (-12.09)	0.4170 (13.10)	0.0537 (7.03)
Intermediate goods	0.0249 (1.83)	0.2122 (13.10)	-0.2918 (-14.62)	0.0546 (13.90)
R&D capital	-0.0624 (-1.69)	0.2384 (7.03)	0.4764 (13.90)	-0.6524 (-20.04)

1. Numbers in parentheses are *t*-statistics.

The Effects of Inward FDI

Table 8 presents the mean values of estimated cost and factor demand elasticities of FDI for the period 1973-92. These elasticities measure the impact of FDI on the cost and structure of production across Canadian industries.

The estimated elasticities of capital, labour and intermediate goods are generally negative and statistically significant. It shows that inward FDI is biased against the use of capital, labour and intermediate inputs in almost all Canadian industries. In other words, inward FDI lowers the industry's demand for capital, labour and intermediate goods for a given level of output. However, if we take into account the output expansion (scale) effects of FDI, the overall employment of capital, labour and intermediate inputs may well increase.

The relationship between FDI and R&D capital is not found to be significant for most manufacturing industries. However, FDI appears to be biased toward the use of R&D in most services industries.

For all industries, we find that inward FDI has a negative and statistically significant influence on the cost of production. As one would expect, there is considerable variation in the estimated cost elasticities across industries. The maximum gains from inward FDI arise in the energy industry — each 1 percent increase in the FDI stock reduces the total cost of production by 0.5 percent in the long-run. By contrast, there does not appear to be any perceptible significant effect from inward FDI in industries such as machinery and equipment, electrical and electronic products, and transportation and communication. Finally, in finance and insurance, which has attracted most recent inward FDI flows, a 1 percent rise in the FDI stock is estimated to reduce the total cost of production by 0.16 percent.

Table 8
Elasticities of foreign direct investment[1]
(mean values for the 1973–92 period)

Industry (SIC-C)	Total cost	Capital	Labour	Intermediate goods	R&D
1. Food, beverage & tobacco	-0.2553 (-5.59)	-0.2154 (-2.88)	-0.3165 (-6.46)	-0.2504 (-5.80)	0.9635 (1.55)
2. Wood & paper	-0.1780 (-4.42)	-0.1338 (-1.80)	-0.2216 (-5.15)	-0.1725 (-4.68)	0.3370 (1.31)
3. Energy	-0.5019 (-6.67)	-0.4889 (-6.14)	-0.6087 (-6.93)	-0.4939 (-6.75)	-0.1661 (-0.93)
4. Chemicals & chemical products	-0.2463 (-4.86)	-0.2059 (-2.65)	-0.3004 (-5.55)	-0.2411 (-5.01)	-0.0688 (-0.74)
5. Metallic minerals & metal products	-0.2891 (-6.32)	-0.2498 (-3.42)	-0.3366 (-6.87)	-0.2836 (-6.63)	0.0268 (0.17)
6. Machinery & equipment	-0.0821 (-1.53)	0.0403 (0.26)	-0.1180 (-2.16)	-0.0768 (-1.51)	0.0684 (0.82)
7. Transportation equipment	-0.3312 (-6.64)	-0.2245 (-1.64)	-0.3910 (-7.14)	-0.3268 (-6.91)	-0.1683 (-1.95)
8. Electrical & electronic products	-0.0115 (-0.18)	0.0892 (0.65)	-0.0509 (-0.78)	-0.0059 (-0.09)	0.0209 (0.33)
9. Construction	-0.2261 (-4.10)	-0.0785 (-0.44)	-0.2584 (-4.63)	-0.2207 (-4.21)	6.5739 (1.87)
10. Transportation & communication	-0.0578 (-1.08)	-0.0326 (-0.48)	-0.0900 (-1.65)	-0.0496 (-0.98)	1.2569 (1.87)
11. Finance & insurance	-0.1616 (-2.44)	-0.1352 (-1.71)	-0.1927 (-2.87)	-0.1534 (-2.40)	2.1968 (1.81)
12. Other industries[2]	-0.2262 (-3.07)	-0.1944 (-2.20)	-0.2501 (-3.38)	-0.2160 (-3.01)	0.4176 (1.27)
13. Consumer goods & services	-0.1208 (-2.76)	-0.0503 (-0.49)	-0.1419 (-3.28)	-0.1118 (-2.82)	3.8953 (1.88)

1. Numbers in parentheses are *t*-statistics.
2. Other industries include services to business; education, health & social services; accommodation, restaurants & recreation; and food retailing.

Table 9
Contribution of FDI to TFP growth, 1973–92[1]
(annualized growth rates)

Industry (SIC-C)	TFP growth	FDI contribution	Cost elasticity of FDI	Growth of FDI
1. Food, beverage & tobacco	0.59	1.21	-0.2553	4.73
2. Wood & paper	0.17	0.23	-0.1780	1.27
3. Energy	-1.01	-0.13	-0.5019	-0.26
4. Chemicals & chemical products	0.59	0.82	-0.2463	3.31
5. Metallic minerals & metal products	0.03	0.30	-0.2891	1.05
6. Machinery & equipment	-0.43	0.36	-0.0821	4.40
7. Transportation equipment	0.01	1.09	-0.3312	3.29
8. Electrical & electronic products	1.41	0.07	-0.0115	5.92
9. Construction	0.42	0.77	-0.2261	3.42
10. Transportation & communication	1.09	0.16	-0.0578	2.81
11. Finance & insurance	-1.52	1.04	-0.1616	6.44
12. Other industries[2]	-0.15	0.42	-0.2262	1.87
13. Consumer goods & services	0.24	0.29	-0.1208	2.37
Average	0.11	0.51	---	---

1. The contribution of FDI to TFP growth equals minus the cost elasticity of FDI multiplied by the growth of FDI.
2. Other industries include services to business; education, health & social services; accommodation, restaurants & recreation; and food retailing.

Next, we identify the contribution of inward FDI to TFP growth across Canadian industries. The contribution is calculated by multiplying the cost elasticity estimates by the change in FDI stock. The results are presented in Table 9.

The results show that inward FDI contributed to TFP growth across Canadian industries by an average of 0.5 percent per year over the 1973-92 period. In the manufacturing sector, the effect of FDI on TFP growth was found to be the strongest in food, beverage and tobacco (1.2 percent per year), chemicals and chemical products (0.8 percent), and transportation equipment (1.1 percent). FDI also contributed significantly to TFP growth in finance and insurance (1 percent per year). Despite the significant contribution of inward FDI to TFP growth, TFP grew, on average, by a meagre 0.11 percent per year in Canadian industries over the 1973-92 period. The factors behind the slow productivity growth still remain an enigma .[16]

Effects of Domestic R&D Spillovers

In our empirical model, we also take into account R&D spillovers (domestic and international) across Canadian industries. This section discusses the effects of domestic R&D spillovers on the total cost of production and the demand for factor inputs. The results are presented in Table 10.

Table 10 shows that the estimated elasticities of domestic R&D spillovers are positive but not statistically significant at the 5 percent level in 7 out of 13 industries. While these results appear to be counter-intuitive, other researchers have found similar results for Canadian industries. For example, Bernstein (1994) found that domestic R&D spillovers increased production cost in a number of industries such as chemical products, fabricated metals, non-electrical machinery, and non-metallic mineral products.[17]

Table 10
Elasticities of domestic R&D spillovers[1]
(mean values for the 1973–92 period)

Industry (SIC-C)	Total cost	Capital	Labour	Intermediate goods	R&D
1. Food, beverage & tobacco	0.2007 (2.58)	0.3628 (2.81)	0.0038 (0.05)	0.2243 (3.05)	-1.6218 (-1.47)
2. Wood & paper	0.1230 (1.71)	0.3023 (2.32)	-0.0176 (-0.23)	0.1491 (2.25)	-0.6471 (-1.42)
3. Energy	0.2430 (2.30)	0.2955 (2.56)	-0.1013 (-0.78)	0.2808 (2.78)	-0.2591 (-0.85)
4. Chemicals & chemical products	0.0264 (0.36)	0.1904 (1.51)	-0.1479 (-1.83)	0.0512 (0.75)	-0.2390 (-1.52)
5. Metallic minerals & metal products	0.1652 (2.16)	0.3247 (2.59)	0.0121 (0.15)	0.1912 (2.69)	-0.3071 (-1.11)
6. Machinery & equipment	0.0107 (0.13)	0.5076 (1.94)	-0.1048 (-1.25)	0.0358 (0.47)	-0.2144 (-1.54)
7. Transportation equipment	0.1870 (2.30)	0.6201 (2.61)	-0.0054 (-0.06)	0.2079 (2.71)	-0.0566 (-0.38)
8. Electrical & electronic products	-0.1542 (-1.58)	0.2542 (1.10)	-0.2810 (-2.81)	-0.1276 (-1.37)	-0.2026 (-2.13)
9. Construction	0.3346 (2.72)	0.9337 (2.91)	0.2306 (1.86)	0.3602 (3.02)	-9.8339 (-1.58)
10. Transportation & communication	0.2573 (2.43)	0.3595 (2.80)	0.1538 (1.44)	0.2966 (2.93)	-1.7086 (-1.44)
11. Finance & insurance	-0.0946 (-1.14)	0.0128 (0.12)	-0.1946 (-2.30)	-0.0554 (-0.72)	-3.6213 (-1.69)
12. Other industries[2]	0.1584 (1.51)	0.2874 (2.14)	0.0813 (0.77)	0.2068 (2.06)	-0.8042 (-1.39)
13. Consumer goods & services	0.0734 (1.04)	0.3592 (2.06)	0.0054 (0.08)	0.1158 (1.85)	-5.9321 (-1.62)

1. Numbers in parentheses are *t*-statistics.
2. Other industries include services to business; education, health & social services; accommodation, restaurants & recreation; and food retailing.

Table 11
Elasticities of international R&D spillovers[1]
(mean values for the 1973–92 period)

Industry (SIC-C)	Total cost	Capital	Labour	Intermediate goods	R&D
1. Food, beverage & tobacco	-0.2102 (-3.50)	-0.3588 (-3.21)	-0.2686 (-4.05)	-0.1682 (-3.06)	3.6016 (3.64)
2. Wood & paper	-0.1416 (-2.70)	-0.3060 (-2.73)	-0.1833 (-3.17)	-0.0951 (-2.09)	1.4690 (3.61)
3. Energy	-0.3180 (-3.99)	-0.3662 (-4.05)	-0.4202 (-3.99)	-0.2505 (-3.36)	0.7320 (2.73)
4. Chemicals & chemical products	-0.1813 (-3.05)	-0.3317 (-2.99)	-0.2330 (-3.52)	-0.1371 (-2.56)	0.3739 (2.71)
5. Metallic minerals & metal products	-0.2273 (-3.86)	-0.3735 (-3.45)	-0.2727 (-4.20)	-0.1809 (-3.43)	0.7606 (3.09)
6. Machinery & equipment	-0.1188 (-1.84)	-0.5744 (-2.43)	-0.1530 (-2.28)	-0.0739 (-1.26)	0.3520 (2.94)
7. Transportation equipment	-0.2513 (-4.04)	-0.6484 (-3.05)	-0.3084 (-4.33)	-0.2140 (-3.77)	0.2582 (2.02)
8. Electrical & electronic products	-0.0507 (-0.65)	-0.4252 (-2.05)	-0.0883 (-1.10)	-0.0033 (-0.04)	0.0506 (0.67)
9. Construction	-0.1706 (-2.33)	-0.7200 (-2.59)	-0.2014 (-2.70)	-0.1248 (-1.83)	21.0966 (3.77)
10. Transportation & communication	-0.0938 (-1.35)	-0.1875 (-1.95)	-0.1245 (-1.73)	-0.0237 (-0.37)	4.0179 (3.77)
11. Finance & insurance	-0.0832 (-1.14)	-0.1818 (-1.82)	-0.1129 (-1.52)	-0.0132 (-0.20)	7.2927 (3.78)
12. Other industries[2]	-0.2394 (-2.78)	-0.3577 (-3.09)	-0.2623 (-3.02)	-0.1531 (-1.88)	1.7740 (3.42)
13. Consumer goods & services	-0.1153 (-2.02)	-0.3773 (-2.41)	-0.1354 (-2.41)	-0.0397 (-0.82)	12.4452 (3.77)

1. Numbers in parentheses are *t*-statistics.
2. Other industries include services to business; education, health & social services; accommodation, restaurants & recreation; and food retailing.

Effects of International R&D Spillovers

The spillover effects of international R&D on the production cost and input demand across Canadian industries are presented in Table 11. International R&D spillovers lower production costs and hence increase TFP in all Canadian industries. These results confirm the previous finding that international R&D spillovers have a positive and significant effect on productivity growth in small open economies like Canada (Bernstein, 1994; Coe and Helpman, 1995; Gera, Gu and Lee, 1998). The maximum gains from international R&D spillovers arise in energy — each 1 percent increase in international R&D spillovers reduces the total cost of production by 0.3 percent.

The elasticity estimates indicate that international R&D spillovers are biased against the use of physical capital, labour, and intermediate inputs across Canadian industries. However, it is interesting to note that international R&D spillovers are biased toward the use of domestic R&D capital in Canadian industries.[18] This result suggests that international technology transfers lead to higher domestic R&D in Canadian industries. We interpret this result to imply that domestic industries must invest in R&D to benefit from R&D originating from foreign sources.

V. SUMMARY AND CONCLUSIONS

This paper investigates the effects of FDI on the cost of production and total factor productivity of Canadian industries. In addition, the paper examines the impact of FDI on the structure of production, i.e., the effects on demand for factor inputs such as capital, labour, intermediate goods and R&D capital.

Our major findings are as follows: First, inward FDI lowers production cost and hence increases productivity in most Canadian industries. Second, inward FDI alters the structure of production as industries adjust their demand for factor inputs. Our results show that inward FDI is biased against the use of capital, labour and intermediate goods. In contrast, inward FDI is somewhat biased toward the use of domestic R&D. Third, international R&D spillovers have a significant negative impact on production costs across Canadian industries. Our results indicate that international R&D spillovers through trade are biased against the use of physical capital, labour and intermediate goods, and biased toward the use of domestic R&D capital across Canadian industries. The relationship between domestic R&D and international R&D spillovers suggests that domestic firms must invest in R&D to capture the benefits of R&D spillovers from abroad.

In view of our findings, inward FDI appears to act as an important channel for the diffusion of ideas and innovations. While Canada's inward FDI stock has been increasing over the past decade, its share of FDI in North America and worldwide has been declining since the Free Trade Agreement (FTA). A key challenge for policymakers is how to attract more FDI into Canada.

APPENDIX A
DATA CONSTRUCTION

Rental Price of Capital Stock

As in Mohnen and Dagenais (1997), the rental price of capital stock is measured as:

$$\text{(A.1)} \quad w_k = \frac{p_I(g + d_I)(1 - itc_I)(1 - u_c z)}{(1 - u_c)},$$

where p_I is the investment deflator. g is the annual interest rate on prime business loans from the Bank of Canada (CANSIM 2560, B14020). The capital depreciation rate d_I is computed as a residual from the data on gross fixed capital formation and geometric net capital stock: $d_I(t) = 1 - (K(t) - I(t))/K(t-1)$ where $K(t)$ and $K(t-1)$ are the end-of-year net capital stock in years *t* and $t-1$ and $I(t)$ is the gross fixed capital formation in year *t*. The investment tax credit itc_I and the corporate income tax rate u_c are taken from the various issues of Statistics Canada Catalogue no. 61-208 (*Corporation Taxation Statistics*) and the *Canadian Master Tax Guide*. The present value of capital cost allowance is computed as $z = a/(a + g)$, where the geometric depreciation rate a is assumed to be 5 percent for non-residential structures and 20 percent for machinery and equipment.

R&D Capital Stock

R&D capital stock is defined as the beginning-of-year R&D stock and is calculated from real R&D expenditures using the perpetual inventory formula:

$$\text{(A.2)} \quad x_R(t) = (1 - d_R)x_R(t-1) + RD(t-1),$$

where the R&D capital depreciation rate d_R is assumed to be 10 percent, a rate commonly used in the literature (Mohnen and Dagenais, 1997); x_R is the beginning-of-year R&D capital stock; and RD is real R&D expenditures.

The R&D capital stock in the base year is equal to:

$$\text{(A.3)} \quad x_R(0) = \frac{RD(0)}{g + d_R}$$

where g is the average growth rate of real R&D expenditures over the entire period.

The rental price of the R&D capital stock is constructed as follows:

$$\text{(A.4)} \quad w_R = \frac{p_R(g + d_R)\left[(1 - u_c)(1 - itc_R) - u_c d\right]}{1 - u_c},$$

where p_R is the R&D investment deflator. g and u_c are interest rates and corporate income tax rates. The R&D investment tax credit itc_R was first introduced in 1977 and is taken from the various issues of Statistics Canada Catalogue no. 61-208 (*Corporation Taxation Statistics*) and the *Canadian Master Tax Guide*. An incremental R&D investment tax credit was introduced in the early 1980s (1983, 1984, and 1985). The incremental R&D credit allowed corporations to transfer to their investors a tax credit equal to 50 percent of designated R&D expenditures. For those years, the present value of incremental R&D investment allowances is calculated as:

$$d = iia_R\left[1 - \sum_{i=1}^{3}\frac{1}{3(1+r)^t}\right], \tag{A.5}$$

where iia_R is the incremental investment allowance rate and is equal to 50 percent (Bernstein, 1996). For all other years, $d = 0$.

APPENDIX B
TOTAL FACTOR PRODUCTIVITY DECOMPOSITION

The effects of FDI, domestic and international R&D spillovers on productivity growth can be analyzed using the estimated cost function. The Divisia index of total factor productivity (TFP) growth is defined as:

$$\text{(B.1)} \qquad T\dot{F}P = \dot{Y} - \sum_i s_i \dot{x}_i \ ,$$

where the dot ($\cdot$) indicates the rate of change and $s_i = w_i x_i / C$ is the cost share of *i*th factor input.

The cost function is defined as:

$$\text{(B.2)} \qquad C(w, Y; t, Z) = \sum_i w_i x_i \ .$$

Taking the logarithm of Equation (B.2) and then differentiating with respect to time *t* yields:

$$\text{(B.3)} \qquad \sum_i \frac{\partial \ln C}{\partial \ln w_i} \dot{w}_i + \frac{\partial \ln C}{\partial \ln Y} \dot{Y} + \frac{\partial \ln C}{\partial t} + \sum_k \frac{\partial \ln C}{\partial \ln Z_k} \dot{Z}_k = \sum_i s_i \dot{x}_i + \sum_i s_i \dot{w}_i \ .$$

Combining (B.1) and (B.3) to substitute out $\sum_i s_i \dot{x}_i$, we obtain the following decomposition equation:

$$\text{(B.4)} \qquad T\dot{F}P = (1 - \eta_{cy}) \dot{Y} - \sum_k \eta_{ck} \dot{Z}_k - \frac{\partial \ln C}{\partial t} \ ,$$

where $\eta_{cy} = (\partial \ln C / \partial \ln Y)$ is the cost elasticity of output, and $\eta_{ik} = (\partial \ln C / \partial \ln Z_k)$ is the cost elasticity of FDI, domestic or international R&D spillovers. According to equation (B.4), TFP growth can be decomposed into three components: (i) a scale effect given by the first term; (ii) contributions of FDI, domestic and international R&D spillovers given by the second term; and (iii) contribution of pure technological change. With constant returns to scale production as assumed in this paper, the cost elasticity of output η_{cy} equals 1 and the scale effect equals zero.

NOTES

1 See, for example, Blomström and Kokko, 1994; Barrell and Pain, 1997; Blomström and Lipsey, 1989; Blomström, Fors and Lipsey, 1997.

2 Until recently, most empirical studies on the effect of inward FDI on productivity performance were based on the production function approach employing a Cobb-Douglas functional form (see, for example, Borensztein et al., 1994). While yielding an important insight into the technological relationship between inward FDI and productivity growth, this production function approach does not address the question of the behavioural response of factors of production to FDI.

3 Most existing empirical studies use foreign control (measured by the share of employment, assets, or output accounted for by MNEs) to examine the effect of inward FDI on productivity (Globerman, 1979; and Caves, 1996). One exception is the contribution by Lucas (1993). He modeled MNEs' capital as an input into host countries' production along with local labour and capital. The treatment of inward FDI in this paper is very similar to that of Lucas.

4 Jorgenson et al. (1987) found no evidence of pervasive economies of scale at the broad industry level in the United States.

5 We do not impose the restriction that the cost function be concave in factor prices in our estimation because of well-known difficulty in imposing such restriction for a translog cost function (Diewert and Wales, 1987).

6 The former concept is commonly referred to as a complementary relationship and the latter is refereed to as a substitution relationship.

7 All aggregations are based on a Tornqvist formula, which corresponds exactly to a translog production function.

8 For details on data sources and a discussion of embodied and disembodied R&D spillovers, see Gera, Gu and Lee (1998).

9 Of course the international R&D spillovers variable could be serving as a proxy for "openness to trade" and, therefore, indirectly serving as a proxy for foreign competition.

10 The R&D capital stock is calculated from real R&D expenditures based on the perpetual inventory model with a depreciation rate of 10 percent. Real R&D expenditures are computed by dividing nominal R&D expenditures by national GDP deflators.

11 Canadian I-O tables from the OECD are used to calculate domestic and international R&D spillovers. The tables are only available for the following years: 1971, 1976, 1981, 1986 and 1990. We found an implausibly large change between I-O tables for 71 and 76 and I-O tables for 81, 86 and 90. As a result, we take the average I-O structures over the years 81, 86 and 90 to measure international and domestic R&D spillovers.

12 The share equation for R&D capital can be obtained as a residual using restrictions (5) that the cost shares of all inputs must sum up to one.

13 This is consistent with the previous findings for Canadian industries. See, for example, Gera, Gu and Lee (1998).

14 The estimates are available from the authors upon request.

15 Other studies have found similar results. For example, Mohnen and Dagenais (1997) find a low response of industry's R&D expenditures to R&D tax incentives for Canadian industries.

16 A major explanation for the post-1973 slow productivity growth focuses on issues related to the mismeasurement of output, particularly in the services sector.

17 It may well be that international R&D spillovers are capturing the effects of domestic R&D spillovers given the high degree of foreign ownership in many Canadian industries. In contrast to our findings, the results for the United States show that domestic R&D spillovers contribute positively to TFP growth (see, for example, Bernstein, 1994; Lichtenberg et al., 1996).

18 Bernstein (1994) and Mohnen (1992) found that international R&D spillovers are biased toward physical capital, while Nadiri and Kim (1996) found that international R&D spillovers are biased against physical capital. Our results are consistent with Nadiri and Kim (1996). Mohnen (1992) and Nadiri and Kim (1996) also found that international R&D spillovers are biased against labour and biased toward domestic R&D capital — a finding similar to ours.

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