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Demand for Skills in Canada: The Role of Foreign Outsourcing and Information-Communication Technology

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Abstract

This study examines the impact of information and communication technologies (ICT) and of foreign outsourcing on the demand for skilled workers. One of the defining features of the Canadian economy in the last two decades has been an increasing wage gap between more- and less-skilled workers. Over the same period, there have been dramatic increases in expenditures on information and communication technologies and in purchases of foreign intermediate inputs. Using data for 84 Canadian manufacturing industries over the 1981-1996 period, we find that both ICT and foreign outsourcing are important contributors to the demand for skills.

Keywords: communication and information technology, foreign outsourcing, skill upgrading

JEL code: F16 O33

Executive summary

One of the defining features of the Canadian economy in the last few decades has been an increasing wage gap between more-skilled and less-skilled workers. Over the same period, there have been dramatic increases in expenditures on information and communication technologies (ICT) and in purchases of foreign intermediate inputs. This raises an obvious and important question: what is the role of ICT and foreign outsourcing in the increased demand for skilled workers?

A number of studies indicate that skill-biased technological change is related to the increased use of skilled workers. As an economy moves towards knowledge-based information-communication technology industries, the role played by ICT on the labour market is worth examining.

Foreign outsourcing might be as important as technology in explaining the shift towards the use of skilled workers. With the reduction of trade barriers and the increasing integration of world markets, firms may switch from domestic low-skill intensive producers to foreign suppliers, or move their low-skill-intensive production process to low-wage countries and import back the processed products. Foreign outsourcing, defined here as the purchase of imported foreign intermediate inputs, may therefore lead to a fall in the demand for unskilled labour at home and increase the relative demand for skilled labour.

Using data of 84 Canadian manufacturing industries over the 1981-1996 period, we examine the impact of ICT and foreign outsourcing on the relative demand for skilled workers. We find that both ICT and foreign outsourcing significantly increase the use of more-skilled non-production workers for the manufacturing sector as a whole.

Their relative importance is, however, sensitive to the exact measure of labour demand. When the demand for skills is measured as the wage bill share of non-production skilled workers, ICT is estimated to have a slightly higher impact on skill demand than foreign outsourcing, with the former increasing the wage bill share by 0.14 to 0.17 percentage points annually while the latter by 0.12 percentage points annually. By way of contrast, using employment share of non-production skilled workers to measure the demand for skills leads to smaller impact of ICT, and a larger role for foreign outsourcing. In this case, ICT leads to a rise in the employment share of non-production workers by 0.05 to 0.08 percentage points annually, compared to the impact of foreign outsourcing at 0.10 percentage points annually.

Despite the sensitivity in comparing the relative contribution, our results indicate that both foreign outsourcing and information-communication technologies played an important role in increasing the demand for skills, whether the demand for skills is measured as wage-bill share or employment share of non-production workers.

1. Introduction

Since the 1980s, there has been an increase in the demand for skilled labour and a rise in the wage gap between skilled and unskilled labour in most industrialized countries.[1] This has generated considerable debate on the causes of this phenomenon, especially on the roles of trade and technology.

Several decomposition analyses (Berman *et al.*, 1994 and Berman *et al.*, 1998) find that the vast majority of the shift towards skilled labour is due to increased use of skilled workers within industries, and that the within-industry skill upgrading is, in turn, highly correlated with investments in research and development (R&D) and in computers. It is therefore argued that skill-biased technological change rather than trade is the major cause of the increased relative demand for skilled labour.

However, trade might be as important as technology in explaining the within-industry skill upgrading. An industry, even at the lowest level of aggregation, is composed of plants engaging in activities with a varying degree of skill-intensity. With the reduction of trade barriers and the increasing integration of world markets, firms may switch from domestic low-skill intensive producers to foreign suppliers, or move their low-skill-intensive production process to low-wage countries and import back the processed products. Foreign outsourcing, defined here as the purchase of imported foreign intermediate inputs, may therefore lead to a fall in the demand for unskilled labour at home and increase the relative demand for skilled labour.[2]

Using data of 84 Canadian manufacturing industries over the 1981-1996 period, we examine the impact of trade (in the form of foreign outsourcing) and high technology (in the form of information and communication technologies) on the relative demand for skilled workers. So far, very little work has been done in Canada on the issue of the impact of trade on skill demand. One study by Baldwin and Rafiquzzaman (1999) has used net export intensity to measure trade's impact on wages. They find that net export intensity contributed to the growing skilled-unskilled wage gap in Canada during the 1980s. This paper will be the first attempt in Canada to examine the impact of trade, in the form of foreign outsourcing, on the relative demand for skilled labour.

As an economy moves towards knowledge-based information-communication technology industries, the role played by ICT has become the subject of recent studies.[3] Baldwin and Rafiquzzaman (1999) use the 1989 Survey of Manufacturing Technology, which contains information on the use by manufacturing establishments of 22 advanced technologies, while Gera *et al.* (2001) use the stock of patents and the age of capital stock as indicators of new technologies in Canadian manufacturing industries. This paper complements these studies by examining the impact of information and communication technologies on the demand for skills.

1. Katz and Murphy (1992), Bound and Johnson (1992), Katz and Autor (1999) for the United States; Berman *et al.* (1998) for other OECD countries.
2. This point has been examined in Feenstra and Hanson (1996, 1999). They find that foreign outsourcing, as well as computer and other high technology, is important in explaining the skill upgrading in the U.S. manufacturing sector in the 1980s.
3. See the Economy in Transition series published by Statistics Canada.

2. Empirical framework

The empirical methodology is based on short-run variable cost function: $C=C(W_s, W_n, Q, K_{ICT}, K_{NICT}, T)$, where W_s and W_n are wages for variable inputs of skilled and non-skilled workers; Q is real value-added output; K_{ICT} and K_{NICT} stand for the quasi-fixed ICT and non-ICT capital stock; and T is a time trend. Value-added output Q is the difference between real gross output Y and intermediate inputs of energy (E), services (S) and material (M). Moreover, total material input (M) is the sum of domestic-produced material (M_d) and foreign-imported material (M_f). The resulting cost function is $C=C(W_s, W_n, Y, E, S, M_d, M_f, K_{ICT}, K_{NICT}, T)$.

The cost function in a translog form (Christensen *et al.*, 1973) can be written as:

$$
\begin{aligned}
lnC &= \alpha_0 + \textstyle\sum_l \alpha_l \, lnW_l + \alpha_y \, lnY + \alpha_e \, lnE + \alpha_s \, lnS + \alpha_d \, lnM_d + \alpha_f \, lnM_f + \sum_m \alpha_m lnK_m + \alpha_t T \\
&+ 0,5[\textstyle\sum_l\sum_j \alpha_{lj} \, lnW_l \, lnW_j + \alpha_{yy} \, lnY \, lnY + \alpha_{ee} \, lnE \, lnE + \alpha_{ss} \, lnS \, lnS + \alpha_{dd} \, ln \, M_d \, lnM_d + \alpha_{ff} \, ln \, M_f \, lnM_f + \\
&\textstyle\sum_m\sum_n \alpha_{mn} \, lnK_m \, lnK_n + \alpha_{tt} \, TT] \\
&+ \textstyle\sum_l \alpha_{ly} \, lnW_l \, lnY + \sum_l \alpha_{le} \, lnW_l \, lnE + \sum_l \alpha_{ls} \, lnW_l \, lnS + \sum_l \alpha_{ld} \, lnW_l \, lnM_d + \sum_l \alpha_{lf} \, lnW_l \, lnM_f + \sum_l\sum_m \\
&\alpha_{lm} \, lnW_l \, lnK_m + \textstyle\sum_l \alpha_{lt} \, lnW_l \, T \\
&+ \alpha_{ye} \, lnY \, lnE + \alpha_{ys} \, lnY \, lnS + \alpha_{yd} \, lnY \, lnM_d + \alpha_{yf} \, lnY \, lnM_f + \textstyle\sum_m \alpha_{ym} lnY \, lnK_m + \alpha_{yt} \, lnY \, T \\
&+ \alpha_{es} \, lnE \, lnS + \alpha_{ed} \, lnE \, lnM_d + \alpha_{ef} \, lnE \, lnM_f + \textstyle\sum_m \alpha_{em} lnE \, lnK_m + \alpha_{et} \, lnE \, T \\
&+ \alpha_{sd} \, lnS \, lnM_d + \alpha_{sf} \, lnS \, lnM_f + \textstyle\sum_m \alpha_{sm} lnS \, lnK_m + \alpha_{st} \, lnS \, T \\
&+ \alpha_{df} \, lnM_d \, lnM_f + \textstyle\sum_m \alpha_{dm} lnM_d \, lnK_m + \alpha_{dt} \, lnM_d \, T \\
&+ \textstyle\sum_m \alpha_{fm} lnM_f \, lnK_m + \alpha_{ft} \, lnM_f \, T + \sum_m \alpha_{mt} lnK_m \, T \qquad (1)
\end{aligned}
$$

where l and j are indices for skilled and non-skilled workers, and m and n are indices for ICT and non-ICT capital stock.

Assume firms choose variable inputs of skilled and non-skilled workers to minimize costs. By Shephard's Lemma, the wage bill share for labour l is,

$$
\begin{aligned}
S_l &= \partial lnC/\partial lnW_l \\
&= \alpha_l + \textstyle\sum_j \alpha_{lj} lnW_j + \alpha_{ly} lnY + \alpha_{le} lnE + \alpha_{ls} lnS + \alpha_{ld} \, lnM_d + \alpha_{lf} \, lnM_f + \sum_m \alpha_{lm} lnK_m + \alpha_{lt} \, T \qquad (2)
\end{aligned}
$$

The parameters in the above equations must satisfy the following restrictions due to the symmetry and homogeneous conditions:

$$
\begin{aligned}
&\alpha_{lj} = \alpha_{jl} \, , \, \alpha_{lm} = \alpha_{ml} \text{ for all } l, j \text{ and } m \\
&\textstyle\sum_l \alpha_l = 1, \ \sum_j \alpha_{lj} = 0, \ \sum_l \alpha_{ly} = 0, \ \sum_l \alpha_{le} = 0, \ \sum_l \alpha_{ls} = 0, \ \sum_l \alpha_{ld} = 0, \ \sum_l \alpha_{lf} = 0, \ \sum_l \alpha_{lm} = 0, \ \sum_l \alpha_{lt} = 0
\end{aligned}
$$

These restrictions mean that we could drop one cost share equation in our estimation. Suppose we drop the cost share for non-skilled workers. Given other parameter restrictions, the wage bill share for skilled workers for industry i in year t could be rewritten as:

$$
\begin{aligned}
S_{it} &= \alpha_i + \gamma T + \beta_1 \, lnY_{it} + \beta_2 \, lnE_{it} + \beta_3 \, lnS_{it} + \beta_4 \, lnM_{d,it} + \beta_5 \, lnM_{f,it} + \beta_6 \, lnK_{ICT,i\,t} + \beta_7 \, lnK_{NICT,it} \\
&+ \beta_8 \, ln(W_{s,it}/W_{n,it}) + \varepsilon_{it} \qquad (3)
\end{aligned}
$$

where ε_{it} is the error term and α_i is industry fixed effect. The time trend T controls for the common shift in skill demand across industries.

The coefficient of $lnK_{ICT,it}$ indicates whether the skilled worker is a complement ($\beta_6 > 0$) or a substitute ($\beta_6 < 0$) to ICT capital stock. A positive coefficient means that ICT capital is relatively skill-using, while a negative coefficient means that ICT capital is relatively skill-saving. An insignificant β_6 implies skill-neutral. Similar interpretation applies to the coefficient on non-ICT capital stock (β_7).

The impact of foreign outsourcing on the demand for skilled labour is captured in the parameter β_5. A positive β_5 indicates that foreign outsourcing increases the use of skilled labour; while a negative β_5 indicates the opposite.

An increase in the wage bill share of skilled workers indicates an increase in the relative demand for such workers. An alternative measure to capture the compositional shift in the labour force is the employment share of skilled workers. The wage bill share is, in some instances, a better measurement than the employment share, since the change in quantities demanded is attenuated to some degree by the relative wage changes.[4] To make sure that the results are not sensitive to measurement, we also report regression results using employment share as the dependent variable.

Berman *et al.* (1994) argue that the relative wages are unlikely to be exogenous, since they may reflect both the mix of different quality of labour and the skill-upgrading effect. The common practice in the literature is therefore to exclude the relative wages of skilled to unskilled workers from equation (3). We adopt this approach as our base case. We also experiment with an alternative specification by using the lagged wages in the regression.

3. Data and summary statistics

The data used in the study are drawn from three sources: the KLEMS (Capital, Labour, Energy, Material and Services) Productivity dataset; the Annual Survey of Manufactures (ASM); and the Input-Output tables from Statistics Canada. The annual data from the three sources are all matched to the 1980 SIC P-level of aggregation, covering 84 manufacturing industries from 1981 to 1996.[5] Data on ($Y, E, S, M_d, M_f, K_{ICT}, K_{NICT}$) are all measured in 1992 constant dollars.

4. As Berman et al. (1994) point out, the wage share measure is a better measure, as long as the elasticity of substitution between production and non-production workers is above one.
5. The KLEMS database contains data from 1981-1996 on SIC-based industry, and data from 1992-2002 on NAICS-based industry. We choose data on 1981-1996, since this is the period when the wage gap between skilled and non-skilled workers increased the most.

3.1 Trends in relative wages and relative cost shares

Information on the prices and quantities of output, capital and labour are obtained from the KLEMS dataset. However, the KLEMS dataset has no detailed information on the labour by skill level. The ASM has such information. It includes the number and compensation for non-production and production workers. From the ASM, we derive the employment and compensation shares for production and non-production workers, and apply them to the total employment and total labour compensation in the KLEMS dataset.

We use non-production and production workers as proxy for more-skilled and less-skilled workers respectively.[6] Dividing total labour compensation by total employment, we get average wages for non-production and production workers. Figure 1 and Table 1 show that the wage ratios of non-production to production workers have been steadily increasing since 1981, at an average of 0.98 percentage points per year. However, the shares of non-production workers in the total wage bill and total employment have seen only a very slight decline over the time period (Figure 2 and Table 1). There is little substitution away from non-production workers despite their increasing relative cost. From the observed trend in the relative quantities and relative prices between non-production and production workers, we infer that for the manufacturing sector as a whole, there is an increase in the demand for skilled workers.

At the aggregate level, the increased demand for skilled workers may be less evident in Canada than in the United States where the employment share of non-production workers increased at an annual average rate of 0.56 percentage points during the 1979-1987 period (Berman et *al.*, 1994). This compares to the relatively stable trend of employment share for non-production workers in the Canadian manufacturing sector.[7] The overall aggregate trend in Canada, however, masks wide variation across industries. Table 1 indicates that the standard deviations on average annual share changes are quite large, at 0.33 and 0.31 for the wage bill share and employment share of non-production workers respectively. Skill intensity has seen the most notable rise in the electrical and electronic products industry and a sharp decline in the chemical products and food industries. This cross-industry variation allows us to pool data across time and sectors to examine whether the differences in the demand for skills across industries are systematically related to the differences in the extent of ICT usage and foreign outsourcing.

---

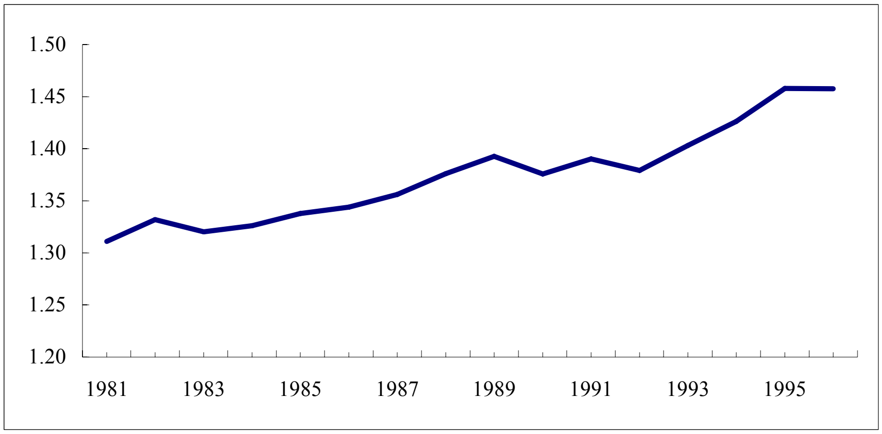
6. Production workers include all non-supervisory workers engaged in processing, assembling, inspecting, storing, handling and packing, and workers engaged in maintenance, repair, janitorial and watchman services. All others are non-production workers that are engaged in executive, administrative, and sales activities (Statistics Canada 1990). This broad classification of production and non-production workers has its limitations due to the heterogeneous nature of workers skills within each category (Leamer, 1994). However, Berman *et al.* (1994) show that the production/non-production workers distinction closely mirrors the distinction between the blue and white collar occupational categories**,** and the blue-collar/white-collar classification, in turn, closely reflects an educational classification of high school/college.
7. Evidence from several other micro-level special surveys also shows little increase in the employment share of skilled workers (Gera *et al.*, 2001) at the aggregate level, where skill classification is based on the National Occupational Classification.

Table 1. Manufacturing-wide averages, 1981-1996

Year	Wage ratio of non-production to production workers	Wage bill share of non-production workers	Employment share of non-production workers	Log of implicit ICT price index	Log of implicit non-ICT price index	Share of ICT investment in total investment	Share of ICT capital stock in total capital stock	Share of imported intermediate inputs	Log of real gross output	Log of energy	Log of services	Log of imported material	Log of domestic material	Log of ICT capital stock	Log of non-ICT capital stock
1981	1.31	0.32	0.27	1.03	-0.31	0.015	0.008	0.304	14.45	10.50	12.06	12.38	13.27	7.39	12.67
1982	1.33	0.33	0.28	1.05	-0.23	0.022	0.009	0.296	14.32	10.43	11.98	12.19	13.14	7.53	12.65
1983	1.32	0.32	0.27	0.83	-0.20	0.034	0.012	0.297	14.35	10.42	12.00	12.23	13.16	7.71	12.59
1984	1.33	0.32	0.26	0.75	-0.16	0.034	0.014	0.316	14.45	10.46	12.07	12.40	13.24	7.92	12.57
1985	1.34	0.32	0.27	0.67	-0.11	0.034	0.016	0.319	14.50	10.46	12.13	12.47	13.29	8.07	12.58
1986	1.34	0.32	0.27	0.55	-0.09	0.039	0.018	0.342	14.53	10.49	12.19	12.60	13.31	8.27	12.61
1987	1.36	0.32	0.26	0.43	-0.07	0.045	0.022	0.329	14.58	10.49	12.21	12.62	13.39	8.54	12.64
1988	1.38	0.32	0.26	0.36	-0.07	0.048	0.024	0.337	14.62	10.57	12.21	12.70	13.43	8.69	12.68
1989	1.39	0.32	0.26	0.27	-0.04	0.048	0.026	0.342	14.64	10.60	12.19	12.75	13.46	8.82	12.71
1990	1.38	0.33	0.26	0.18	-0.02	0.059	0.028	0.366	14.57	10.54	12.11	12.76	13.35	8.93	12.72
1991	1.39	0.33	0.27	0.08	-0.03	0.069	0.032	0.390	14.49	10.53	12.02	12.74	13.22	9.01	12.70
1992	1.38	0.32	0.26	0.00	0.00	0.090	0.036	0.417	14.49	10.53	12.02	12.80	13.16	9.10	12.65
1993	1.40	0.32	0.26	-0.06	0.04	0.101	0.042	0.447	14.52	10.53	12.03	12.90	13.10	9.23	12.62
1994	1.43	0.32	0.25	-0.11	0.10	0.102	0.046	0.462	14.60	10.54	12.14	12.99	13.14	9.36	12.66
1995	1.46	0.31	0.25	-0.18	0.14	0.121	0.052	0.467	14.64	10.55	12.19	13.04	13.17	9.51	12.69
1996	1.46	0.31	0.24	-0.29	0.14	0.127	0.058	0.469	14.68	10.56	12.32	13.08	13.22	9.66	12.72
Annualized changes in percent (1981-1996)															
Mean	0.98	-0.04	-0.16	-8.84	2.99	0.75	0.34	1.10	1.47	0.39	1.73	4.65	-0.38	15.11	0.32
	(1.14)	(0.33)	(0.31)	(3.56)	(0.37)	(0.59)	(0.26)	(0.48)	(3.44)	(3.03)	(2.59)	(3.74)	(3.19)	(6.09)	(3.37)

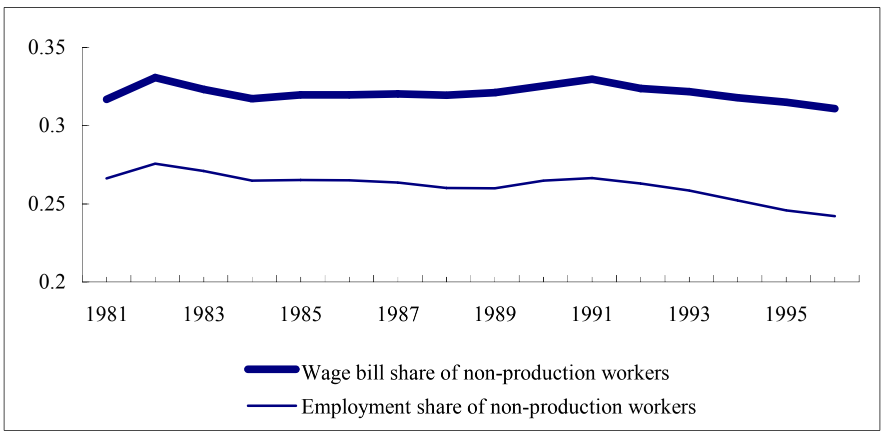
Note: Annualized change is calculated as the difference between the first and the last year divided by the number of years. Standard deviation in parentheses.
Source: KLEMS, ASM and Input-Output tables, Statistics Canada.

Figure 1. Ratio of non-production workers wage to production workers wage—Canadian manufacturing average



Source: KLEMS and ASM, Statistics Canada.

Figure 2. Wage and employment shares of non-production workers—Canadian manufacturing average

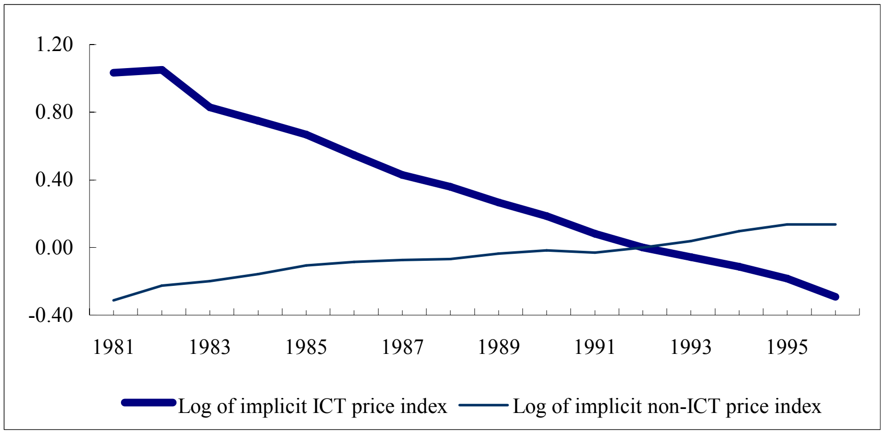


Source: KLEMS and ASM, Statistics Canada.

3.2 Measure of ICT capital

The productivity program at Statistics Canada estimates 22 non-residential asset capital stocks, using the real investment data and the perpetual inventory method. To deal with the problems of quality improvements of successive generations of ICT assets, the real investment for these assets is obtained by deflating the nominal value with the "constant-quality price indices". The "constant-quality price indices" are estimated using hedonic techniques to correct for quality changes. They measure the price of a common set of characteristics over time, and treat the quality gains as a reduction in the price of ICT assets.

Figure 3. Prices of ICT and non-ECT investment—Canadian manufacturing average (in log, 1992=1)



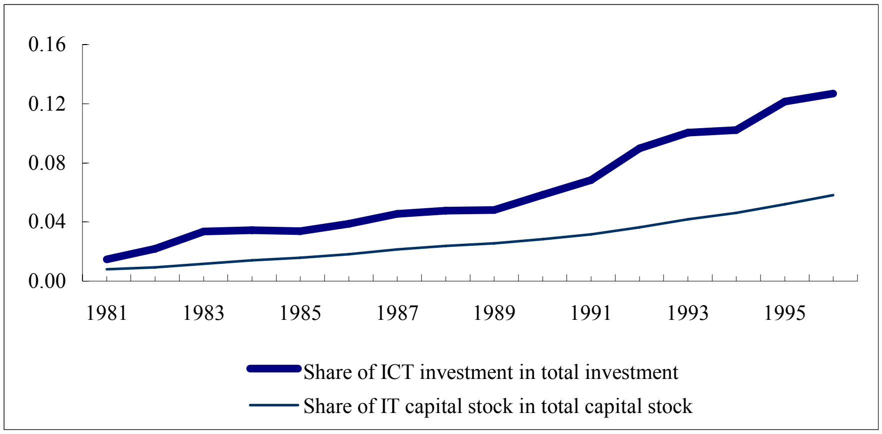
Source: KLEMS and ASM, Statistics Canada.

Among the 22 non-residential assets, we define 5 assets as ICT investment goods: computers and office equipment, communication equipment, software-own account, software-pre-packaged, and software-custom design. The remaining 18 assets are classified as non-ICT assets. The different types of assets are aggregated by a chain-weighted Fisher index.

Figure 3 and Table 1 highlight the considerable decline in the quality-adjusted price of ICT assets. From 1981 to 1996, the price of ICT assets fell at an average of 8.84 percent per year. This compares to the implicit price index of non-ICT assets, which rose at an average of 2.99 percent per year. The decline in the relative price of ICT assets reflects the higher technological progress in the production of ICT assets than in the production of non-ICT assets.

Figure 4 and Table 1 show that the contribution of ICT investment in total investment has been rising fairly steadily over time, from an average share of 1.5 percent in 1981 to 12.7 percent in 1996. The relatively faster ICT investment directly determines the growth of the capital stock and leads to an increase in the share of ICT assets in total capital stock. The share of ICT capital stock increased at an average of 0.34 percentage points per year.

Figure 4. Share of ICT investment and capital stock—Canadian manufacturing average (valued at constant price, 1992=1)



Source: KLEMS and ASM, Statistics Canada.

3.3 Measures of foreign outsourcing

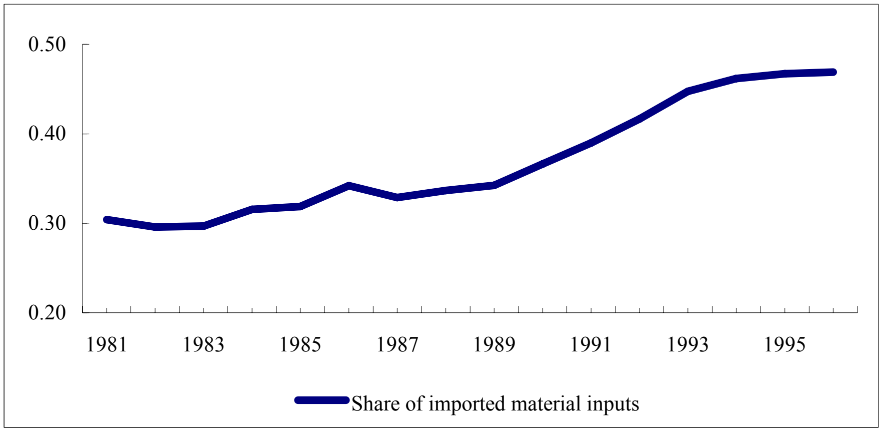
The measurement of foreign outsourcing follows Feenstra and Hanson (1996). Foreign outsourcing is defined as imported intermediate material. It is constructed using Canadian input-output tables. These tables show the intermediate goods purchased by each three- or four-digit manufacturing industry from every other manufacturing industry. Multiplying the value of input purchases from each supplier industry by the import propensity of each supplier industry, and summing overall supplier industries, we derive the total imported intermediate material $M_{f,it}$ for each purchase industry i at time t. That is

$$M_{f,\, it} = (\sum_k V_{k,it} R_{k,\, t})$$

where V_{kit} is the value of the intermediate material purchased by industry i from supplier industry k, and $R_{k,t}$ is the import propensity for supplier industry k at time t. The import propensity for each supplier industry is calculated as the ratio of imports to total consumption (total output + imports – exports). Domestic material ($M_{d,it}$) is then simply the difference between total material used and imported material ($M_{f,it}$).

Figure 5 and Table 1 depict the dramatic expansion of foreign outsourcing for Canadian manufacturing industries over 1981-1996. The imported intermediate inputs increased from an average of 30.4 percent of total material purchases in 1981 to 46.9 percent in 1996. It was especially prominent during the 1990s, expanding by 1.8 percentage points per year as compared to 0.5 percentage points per year in the 1980s.

Figure 5. Share of imported intermediate material—Canadian manufacturing average



Source: Input-Output tables, Statistics Canada.

4. *Empirical results*

4.1 Panel unit root tests

Equation (3) is estimated using pooled time-series data consisting for 84 manufacturing industries over the 1981-1996 period. Pooling cross-sectional data over time, however, may introduce non-constant variance to the error terms due to non-stationarity of the data.

Prior to estimation, we therefore check for stationarity of individual variables and, if needed, the regression residuals, using the panel unit root test method proposed by Im, Pesaran and Shin (2003). The method begins with estimating a Dickey-Fuller regression for each industry. For example, for variable *X*, the Dickey-Fuller regression involves the following equation:

$$dX_t = c + \rho\, X_{t-1} \qquad (4)$$

where $dX_t = X_t - X_{t-1}$ and c is a constant. Equation (4) is run both with and without trend. The panel unit root test is then conducted by obtaining an average *t*-statistics for coefficient ρ across industries and by testing for a system-wide unit root by comparing the average *t*-statistics with the critical values that are tabulated in Im, Pesaran and Shin (2003).

Following this method, we calculate in Table 2 the average *t*-statistics for each independent variable and the residuals from equation (3). The null of a unit root cannot be rejected for some variables, but is rejected for the residuals from equation (3). The rejection of the unit root null for the residuals implies that the regression is co-integrated and the standard statistical inference applies.

Table 2. Panel unit root test

Variable	Average t-statistics	
	With trend	Without trend
Wage bill share of non-production workers (S_{it})	-2.38 *	-1.97 *
Log of real gross output (lnY_{it})	-2.26	-1.64
Log of energy input (lnE_{it})	-2.38 *	-1.71 *
Log of services input (lnS_{it})	-1.77	-1.38
Log of imported material input ($lnM_{f,\ it}$)	-2.46 *	-1.21
Log of domestic material input ($lnM_{d,\ it}$)	-2.26	-1.66
Log of ICT capital stock ($lnK_{ICT,\ it}$)	-1.98	-1.14
Log of non-ICT capital stock ($lnK_{ICT,\ it}$)	-1.46	-1.06
Residuals from cointegrating regression equation (3)	-2.55 *	-2.03 *

Note: Test-statistics are calculated as the average *t*-statistics of Dickey-Fuller regressions with and without time trend. * indicates that the statistic is significant at 5% level. The *t*-critical values for 5% significance level are -2.31 and -1.67 for with and without trend respectively, as tabulated in Im, Pesaran and Shin (2003).

Source: KLEMS, ASM and Input-Output tables, Statistics Canada.

4.2 Regression results

The estimation results for the industry fixed effects model of equation (3) are presented in Table 3. All regressions are weighted OLS, where the weight is the industry share of manufacturing employment. We report results both with time trend and with year dummies.

Specification (1), based on equation (3), is our base case. The coefficient on imported material inputs is positive and significant. It shows that a 1 percent increase in the use of imported foreign material leads to an average of 0.026 percentage points increase in the wage share of non-production workers. This lends support to our hypothesis that firms switching from domestic low-skill intensive producers to foreign suppliers reduces the demand for unskilled labour at home and increases the relative demand for skilled workers. The coefficient on the domestic intermediate material is statistically insignificant.

The estimated coefficient of the ICT capital stock also has a significant and positive sign. A one percent increase in ICT capital stock, on average, increases the wage share of non-production workers by about 0.011 percentage points. This suggests that skilled workers are complementary to ICT capital: the adoption of ICT increases the demand and use of more skilled workers relative to less skilled workers. The coefficient on the non-ICT capital stock is not statistically significant.

The next three columns (*Columns (2)* to *(4)*) report results using alternative specifications. *Column (2)* includes the lagged relative wages of non-production to production workers as an additional independent variable; *Columns (3)* and *(4)* use the employment share of non-production workers, instead of wage bill share, as the dependent variable. The results are qualitatively similar to the base case: the coefficients on the ICT capital stock and foreign outsourcing remain significant and positive.[8]

8. To examine if our results are sensitive to the possible endogeneity problem of the independent variables, we run equation (3), using lagged values of all independent variables as regressors. The results are qualitatively similar to those reported in Table 3.

To evaluate the relative importance of ICT and foreign outsourcing, we report in Table 4 the average annual contribution of each covariate. The contribution is calculated as the product of the estimated coefficients in Table 3 and the average annual percentage changes reported in Table 1. For example, when the coefficients are estimated under specification (1) with time trend, the contributions from foreign outsourcing is calculated to be 0.121 (Table 4), the product of the estimated coefficient of 0.026 (Table 3) and the average annual percentage increase of 4.65 (Table 1).

Table 4 shows that foreign outsourcing increases the demand for skilled workers by 0.12 percentage points annually when the wage-bill share of non-production workers is used as a measure of skill demand, and by 0.10 percentage points annually when employment share is used. The contribution from ICT is sensitive to the empirical specification used: when wage-bill share is used to measure skill demand, the average annual contribution from ICT is estimated to be between 0.14 and 0.17 percentage points, but dropped to between 0.05 and 0.08 percentage points when employment share is used. As a result, the relative importance of foreign outsourcing and ICT to the demand for skills depends on how we measure skill demand. Using wage bill share as a measure for the demand for skills leads to a slightly higher impact of ICT than foreign outsourcing, while using employment share leads to smaller impact of ICT.

Table 3. Regression results based on 84 Canadian manufacturing industries 1981-1996: industry fixed effect model

	Regression: dependent variable							
	Column (1) Wage bill share of non-production workers		*Column (2)* Wage bill share of non-production workers		*Column (3)* Employment share of non-production workers		*Column (4)* Employment share of non-production workers	
	with time trend	with year dummies	with time trend	with year dummies	with time trend	with year dummies	with time trend	with year dummies
Log of imported material input (lnM_f)	0.026	0.025	0.027	0.026	0.022	0.022	0.021	0.021
	(4.16) *	(3.82) *	(4.35) *	(4.00) *	(4.03) *	(3.86) *	(3.93) *	(3.77) *
Log of ICT capital stock (lnK_{ICT})	0.011	0.011	0.009	0.009	0.004	0.003	0.005	0.004
	(5.04) *	(5.05) *	(4.07) *	(3.88) *	(1.99) *	(1.35)	(2.70) *	(2.19) *
Log of real gross output (lnY)	-0.027	-0.023	-0.029	-0.025	-0.03	-0.026	-0.028	-0.025
	(-3.41) *	(-2.88) *	(-3.66) *	(-3.15) *	(-4.16) *	(-3.70) *	(-4.00) *	(-3.52) *
Log of intermediate energy input (lnE)	0.006	0.004	0.006	0.005	0.007	0.005	0.006	0.005
	(1.19)	(0.9)	(1.33)	(1.02)	(1.57)	(1.27)	(1.48)	(1.19)
Log of services input (lnS)	-0.026	-0.012	-0.028	-0.013	-0.026	-0.012	-0.024	-0.011
	(-4.74) *	(-1.86)	(-5.13) *	(-2.13) *	(-5.22) *	(-2.22) *	(-4.96) *	(-2.02) *
Log of domestic material input (lnM_d)	0.003	-0.007	0.004	-0.006	0.006	-0.005	0.005	-0.005
	(0.58)	(-1.21)	(0.79)	(-1.16)	(1.38)	(-0.98)	(1.22)	(-1.04)
Log of non-ICT capital stock (lnK_{NICT})	-0.002	-0.007	0.001	-0.003	0.008	0.007	0.006	0.004
	(-0.55)	(-1.65)	(0.27)	(-0.64)	(2.27) *	(1.82)	(1.61)	(1.01)
Year	-0.002		-0.003		-0.003		-0.002	
	(-5.99) *		(-6.36) *		(-7.05) *		(-6.83) *	
Lag (log of relative wages) $ln(W_s/W_n)$			0.06	0.059			-0.042	-0.042
			(4.91) *	(4.79) *			(-3.89) *	(-3.82) *
Constant	5.356	0.482	5.587	0.46	5.436	0.374	5.274	0.39
	(6.65) *	(7.00) *	(6.99) *	(6.73) *	(7.64) *	(6.18) *	(7.44) *	(6.46) *
Observations	1259	1259	1259	1259	1259	1259	1259	1259
R-squared	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Within R-squared	0.03	0.06	0.08	0.1	0.14	0.16	0.14	0.16

Note: t-statistics in parentheses; * significant at 5% level or better. All regressions are weighted OLS, where the weight is the industry share of manu-facturing employment. All specifications include industry dummies. Observations for year 1981 are deleted due to the lagged variables on relative wages.

Source: KLEMS, ASM and Input-Output tables, Statistics Canada.

Table 4. Average annual contribution to the demand of non-production workers relative to production workers

In percentage points	Regression: dependent variable							
	Column (1) Wage bill share of non-production workers		*Column (2)* Wage bill share of non-production workers		*Column (3)* Employment share of non-production workers		*Column (4)* Employment share of non-production workers	
	with time trend	with year dummies	with time trend	with year dummies	with time trend	with year dummies	with time trend	with year dummies
Log of imported material input (lnM_f)	0.121	0.116	0.126	0.121	0.102	0.102	0.098	0.098
Log of ICT capital stock (lnK_{ICT})	0.166	0.166	0.136	0.136	0.060	0.045	0.076	0.060
Log of real gross output (lnY)	-0.040	-0.034	-0.043	-0.037	-0.044	-0.038	-0.041	-0.037
Log of intermediate energy input (lnE)	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002
Log of services input (lnS)	-0.045	-0.021	-0.049	-0.023	-0.045	-0.021	-0.042	-0.019
Log of domestic material input (lnM_d)	-0.001	0.003	-0.002	0.002	-0.002	0.002	-0.002	0.002
Log of non-ICT capital stock (lnK_{NICT})	-0.001	-0.002	0.000	-0.001	0.003	0.002	0.002	0.001

Note: The contribution is calculated as the product of the estimated coefficients in Table 3 and the average annual percentage changes reported in Table 1.

Source: KLEMS, ASM and Input-Output tables, Statistics Canada.

This corroborates the findings for the United States. Feenstra and Hanson (1999) find that both foreign outsourcing and computer technology are important in explaining the shift towards more skilled non-production workers in the U.S. manufacturing sector. They also find that the relative contributions between outsourcing and high technology are very sensitive to the exact measure of technology: total foreign outsourcing leads to an annual average of 0.05-0.09 percentage point increase of non-production workers wage share, while computer and other high technology leads to 0.03-0.15 percentage point increase, depending on the measure of technology. Our results suggest that the relative contribution not only depends on the exact measure of technology, as in the U.S. case, but also on how we measure skill demand.

Despite the sensitivity in comparing the relative contribution, we conclude that both foreign outsourcing and ICT are important contributors to the relative demand for skilled workers, whether the demand for skills is measured as wage bill share or employment share of non-production workers.

5. Conclusion

There have been very few studies in Canada that examine the impact of information and communication technologies (ICT) and of foreign outsourcing on the demand for skills. Using 84 Canadian manufacturing industries over the 1981-1996 period, we find that both ICT and foreign outsourcing have significant impact on the use of more-skilled workers for the manufacturing sector as a whole.

Their relative importance is, however, sensitive to the exact measure of labour demand. When the demand for skills is measured as the wage bill share of non-production workers, ICT is estimated to have a slightly higher impact on skill demand than foreign outsourcing, with the former increasing the wage bill share by 0.14 to 0.17 percentage points annually while the latter by 0.12 percentage points annually. By way of contrast, using the employment share of non-production workers to measure the demand for skills leads to a smaller impact of ICT, and a larger role for foreign outsourcing. In this case, ICT leads to a rise in the employment share of non-production workers by 0.05 to 0.08 percentage points annually, compared to the impact of foreign outsourcing by 0.10 percentage points annually.

Despite the sensitivity in comparing the relative contribution, our results indicate that both foreign outsourcing and information-communication technologies played an important role in increasing the demand for skills, whether the demand for skills is measured as wage-bill share or employment share of non-production workers.

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