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The Effect of Technology and Trade on Wage Differentials Between Nonproduction and Production Workers in Canadian Manufacturing

by John R. Baldwin and Mohammed Rafiquzzaman

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Abstract

The 1980s and 1990s have seen a rising share of skilled labour in total employment in the manufacturing sector of Canada. At the same time, the wage premium for skilled workers has increased, thereby increasing the inequality between skilled and unskilled workers. There is a disagreement about the causes of these changes. Several hypotheses have been offered to explain them—increased international competition, changes in the relative supply of more-skilled versus less-skilled workers, and skilled-augmenting technological change. This paper analyzes the nature, pattern and causes of the shifts in the composition of employment in manufacturing. The paper describes the composition of employment in manufacturing. It focuses on the direction and magnitude of shifts in the proportion of nonproduction workers employed within manufacturing and across sectors within manufacturing. It also investigates the extent to which wage differentials between nonproduction and production workers have widened in the 1980s. In addition, it assesses the extent to which these changes are associated with trade and technology use. The results indicate that the rising wage differentials are associated with both increased trade intensity and the types of technologies that are being used in the plant.

Journal of Economic Literature Classification: F14, J23, J31, O33

Keywords: employment, manufacturing, technology, trade, wage differentials.

1. Introduction

The 1980s and 1990s have seen a rising share of skilled labour in total employment. At the same time, the wage premium for skilled workers has increased, thereby widening the gap between skilled and unskilled workers [(Freeman (1995); Richardson (1995); Katz and Murphy (1992)]. Although the pattern of these changes is well documented, there is disagreement about the causes of these changes. Several hypotheses have been offered to explain them—increased international competition, changes in the relative supply of more-skilled versus less-skilled workers, and skill-augmenting technological change.

Wood (1994, 1995), Batra (1993), and Leamer (1994) have suggested that the expansion of international trade is the main cause of the increased wage differential between skilled and unskilled workers. They argue that rising wage inequality is associated with increased imports of manufacturing goods from less advanced countries.

Central to their argument is the theory of factor price equalization. Developed countries tend to have proportionately more-skilled labour than unskilled labour compared to developing nations. In the absence of trade, factors that are relatively scarce in a country will be relatively expensive, while those that are relatively abundant will be comparatively cheap. Thus, the wages of skilled workers in developed countries will be low relative to those of unskilled workers if the country's supply of skilled labour is abundant relative to other countries and its supply of unskilled labour is relatively scarce.

These conditions give a comparative cost advantage in goods that intensively use skilled labour and a comparative disadvantage in unskilled-intensive goods to developed countries. With trade, they will, on average, export the first type of goods and import the other. Trade will, in turn, tend to bring the structure of relative wages together across countries. In a global economy, the relative wages of skilled workers in advanced countries will move up towards the relative wages of skilled workers in less-advanced countries. Competition from low-wage workers from less advanced countries will drive down relative wages of the unskilled in advanced countries (Freeman, 1995).

An alternate explanation for the recent widening of the premium for skilled workers rests in the type of technological change that the computer based revolution has wrought. Skill-augmenting technical progress also brings about relative shifts in labour demand and, thus, increases the wage differential between the skilled and unskilled, even without international trade pressures. Skill-augmenting technical change increases the marginal product of skilled labour, thereby shifting out its demand curve and increasing the relative wages of this group. Particularly, technological progress which is associated with the computer revolution and the introduction of advanced technologies is likely to raise the relative demand for more-skilled and flexible workers and reduce the demand for less-skilled labour. Since the production process and technical requirements differ across industries, the degree of labour-saving technical progress and the relative demand for skilled workers is also likely to differ across industries.[1]

Several recent studies use factor content calculations to examine the possible effect of trade on the decline of the relative wage of less-skilled workers during the 1980s and 1990s [e.g., Lawrence and Slaughter (1993) and Sachs and Shatz (1994)]. These studies find that changes in actual trade flows have not displaced all that many low skilled workers from manufacturing. Others disagree, arguing that standard factor-content analyses understate the effect of trade on employment [e.g., Wood (1995)].

A number of research studies have concluded that the shift towards more-skilled workers is caused partly or primarily by new technology [e.g., Lawrence and Slaughter (1993); Krueger (1993); Murphy and Welch (1989, 1992); Katz and Murphy (1992); Mincer (1991); Berman, Bound and Griliches (1994); and Dunne and Schmitz (1995)]. Berman, Bound and Griliches (1994), for example, reach this conclusion by relying on evidence that changes in the wage share of nonproduction workers is related to the level of research and development intensity and to computer usage.

In recent years, Canada's manufacturing industries have undergone important structural changes [e.g., Baldwin and Gorecki (1990); and Baldwin and Rafiquzzaman (1994)]. As part of this change, manufacturing employment has shifted from declining sectors to growing sectors. During this process, the composition of the manufacturing labour force has shifted towards more skilled workers. There has been an increase in the share of nonproduction workers in total employment. These are mainly white collar supervisory personnel who are on average more highly paid than production workers who are mainly blue collar. As well, nonproduction workers' share in the total wage bill has increased. At the same time as the utilization of nonproduction workers relative to production workers has gone up, the yearly income of nonproduction relative to production workers has increased.

This paper analyzes the nature, pattern and causes of these shifts. It focuses on the direction and magnitude of these changes within manufacturing and across sectors within manufacturing. It also investigates the extent to which wage differentials between nonproduction and production workers have widened in the 1980s. Finally, it examines the relationship between technology use and wage differentials to examine the extent to which these changes are related both to increased competition from trade and technology use.

The following sections analyze changes in the composition of the manufacturing labour force between nonproduction and production workers. Throughout, changes are examined both for manufacturing as a whole and for each of the five manufacturing sectors—the natural resource-based sector, the labour intensive sector, the scale-based sector, the product-differentiated sector, and the science-based sector. The analysis has five parts.

[1] Richardson (1995) observes that in a world of international trade, labour-enhancing technical progress can only serve to augment the wages of skilled labour if technical progress is felt unequally across industries.

First, data sources and definitions of production workers and nonproduction workers are provided. Second, the extent to which Canada's manufacturing industries have undergone important structural changes is outlined. Third, changes in the composition of manufacturing labour in favour of nonproduction workers are examined. Fourth, the extent to which wage differentials between nonproduction and production workers have widened is investigated. Fifth, multivariate analysis is employed to examine the effect of technology use on wage differentials, first at the plant and then at the industry level. In the first case, micro-economic data at the plant level are used to investigate interplant differences in demand that are related to technology differences. In the second case, trade data at the industry level are used along with plant data that are aggregated to the industry level to examine the extent to which changing trade patterns can be said to also affect the nonproduction worker wage premia.

2. Data Sources and Definitions

The data that are used here come from a longitudinal file constructed from the Canadian Census of Manufactures that tracks plants over the period 1973 to 1992 and links plants to firms. This data source provides information about the use of production and nonproduction workers in four-digit industries. This classification of workers is used to examine trends in the wage differences between blue-collar (less-skilled) and white-collar (more-skilled) workers.

The Census of Manufactures collects statistics on salaries and wages for nonproduction and production workers[2] as well as the number of nonproduction and production workers. Production workers consist of all nonsupervisory workers (including working foremen) engaged in processing, assembling, inspecting, storing, handling, and packing; also workers engaged in maintenance, repair, janitorial and watchman services [e.g., Statistics Canada (1990)]. Nonproduction workers, defined by process of exclusion from the production-worker category, are those engaged in executive, administrative, and sales activities.

Nonproduction workers made up about 27% of total employment in manufacturing in 1980. The annual remuneration of nonproduction workers was about 27% higher than for production workers. Although the broad nonproduction/production worker categories aggregate a number of more detailed occupational groups together, the two categories can be fruitfully used to examine broad changes in relative skills in the workforce. Berman, Bound and Griliches (1994) show that the ratio of nonproduction to production workers taken from the U.S. Survey of Manufactures is much the same as the ratio of white collar to blue collar workers, where the latter are taken from the more detailed occupational data derived from the U.S. Current Population Survey.

[2] Salaries and wages refer to gross earnings of employees before deductions for income tax and employees' contributions to social services such as sickness, accident and unemployment insurance, pensions etc. They include all salaries, wages, bonuses, profits shared with employees as well as any other allowance forming part of the worker's earnings.

Despite this finding, it should be emphasized that neither category is homogeneous across industries. Some industries may require higher skill requirements of their production workers because they make greater use of more advanced technologies. On average, wage differences across industries at least partially reflect these skill differentials. Moreover, skill upgrading can occur over time in both nonproduction and production worker categories and technological change may impact more heavily in the production sector than the non-production sector in some industries. Subsequent sections of the paper examine these issues by asking how the trend in the ratio of nonproduction workers to production workers varies across industries and which technologies widen the wage gap between nonproduction and production workers and which narrow that gap.

In order to examine changes in the proportion of nonproduction to production workers, only a subset of plants from the Canadian Census of Manufactures is used here. This subset consists of those plants that report the actual numbers of production and nonproduction workers. These are plants that receive “long-forms”.[3] Other plants receive “short-forms” and are only asked to list total employees. Since the latter do not divide total workers between nonproduction and production workers and these plants make up an increasing proportion of all plants, the trend in the ratio of nonproduction to production workers derived from the population of both long-form and short-form plants understates changes in the proportion of skilled workers to total employment. By choosing just those plants that are asked to report production and nonproduction workers, this problem is avoided.[4]

3. Structural Change

Much has been made of the fact that the composition of the labour force and wage differentials have been changing in most industries in the United States and, therefore, that trade cannot fully explain these shifts since not all sectors have been equally affected by increases in imports (see Freeman, 1995). Since Canada has a much more open economy and since the five industrial sectors experienced quite different shocks from trade over the period, the Canadian experience is examined in detail at the sector level. This section discusses the changes that were taking place within each sector.

The period of study is divided into three parts—1973-1979, 1979-1989 and 1989-1992—in order to investigate whether the pattern of the changes in the relative demand for labour and wage differentials differs over time. In order to examine the extent to which these changes differ across industries within manufacturing, this paper considers five different industrial sectors—the natural resource based sector, the labour-intensive sector, the scale-based sector, the product differentiated sector, and the science-based sector.[5]

[3] These are the larger plants. However, a sample of smaller plants are also sent long-forms.
[4] Both operating establishments and head offices employ non-production workers. Both groups were used in this analysis.
[5] The classification is taken from a taxonomy developed by the OECD (1987) to investigate structural change in its member states. The OECD classification was verified for its applicability in the Canadian situation using discriminant analysis and modified slightly. For a listing of industries classified to each sector, see Baldwin and Rafiquzzaman (1994).

The five groups are defined on the basis of the primary factors affecting the competitive process in each activity. For the resource-based sector (industries like flour or meat processing), the primary factor affecting competition is access to abundant natural resources. For the labour-intensive sector (industries like clothing and footwear), it is labour costs. For the scale-based sector (industries like motor vehicle manufacturers), it is the length of production runs. For the product differentiated sector (e.g., appliances or sporting goods), it is tailoring production to highly varied demand characteristics. For the science-based sector (e.g. communications equipment, aircraft, instruments), it is the application of advanced scientific knowledge.

Table 1 presents a select set of industry characteristics for the five sectors as of 1979. These include plant size, concentration, foreign ownership, indices of wage rates, and capital-labour ratios, the sales-value added ratio, the number of products produced, the R&D/sales ratio, and the import intensity. The labour-intensive industries have low capital-labour ratios, pay low wages, possess small plants, and were protected by high tariff rates. Scale-based industries are characterized by large plants, high capital/labour ratios and high wages. Product differentiated industries have high advertising-to-sales ratios, produce a large number of products, and spend more on R&D. Science-based industries are the high-tech industries with high R&D ratios and with a large percentage of the workforce in scientific and professional occupations. They also have large plants, high concentration and high foreign ownership.

Share of production employment in each of these sectors is presented in Table 2 for the years 1970, 1980, and 1990. In 1970, scale-based industries are the dominant manufacturing sector in Canada with 31.6% of employment followed by the labour-intensive (25.5%), natural resource based (24.9%), product differentiated (10.0) and science-based (8.1%) sectors. Between 1970 and 1990, the labour-intensive sector declines from 25.5% to 20.9% of total employment; all the other sectors increase their share, with the largest changes occurring in natural resources (from 24.9% to 26.2%), product differentiated (10.0% to 12.0%), and the science-based (from 8.1% to 9.2%) sectors. The scale-based sector experiences only a marginal increase (from 31.6% to 31.7%).

Table 1. *Select Characteristics of Five Sectors*

Characteristics	Natural Resources	Labour Intensive	Scale-Based	Product-Differentiated	Science-Based
Average Plant Size (total employees)	85	78	167	76	242
Market Share (Multi-Establishment Firms)	50	27	50	27	43
Concentration (4-Firm Ratio)	55	43	55	46	62
Foreign Ownership: 1975 (% shipment under foreign control)	40	30	55	52	66
Wages Per Production Worker (Indexed to 100 for labour-intensive sector)	125	100	138	115	116
Relative Capital / Labour Ratio (indexed to 100 for labour-intensive sector)	335	100	338	146	120
Sales / Value-added	3.2	2.2	2.4	2.2	2.5
Advertising / Sales Ratio (1977)	1.3	0.8	0.9	0.8	3.2
Number of ICC Products (5-digit)	32	29	46	63	49
R&D Employment Ratio (1979)	0.6	0.5	1.0	1.4	2.1
R&D / Sales Ratio: 1979 (Current Intramural)	1.2	2.0	3.4	10.4	12.6
Imports / Shipments- 1979	14	30	40	94	70
Nominal Tariff Rate (1975)	9.0	14.5	8.0	9.2	7.6

Note: 1) All data refer to 1979 values unless otherwise specified.
2) Unweighted averages were calculated for each sector.

Structural change during this period occurred as tariff protection for the labour-intensive sector was reduced and the sector diminished in importance. A sector in which Canada had a comparative advantage—the natural resource sector—increased in importance; so too did the science-based and product differentiated sectors.

Table 2. *Employment Shares by Sector (Production Workers)*

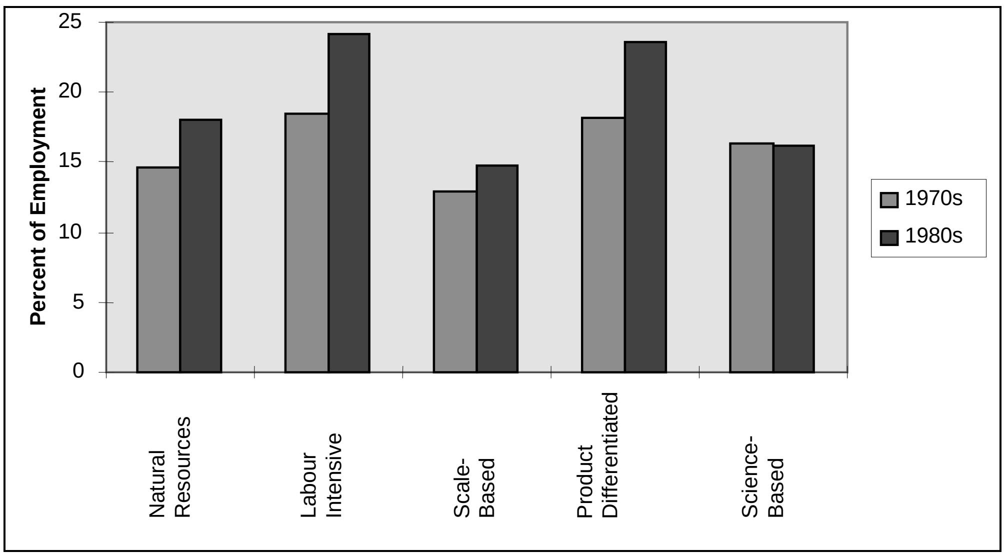
Sector	1970	1980	1990
Natural Resources	24.85	24.65	26.19
Labour Intensive	25.46	22.82	20.94
Scale-Based	31.60	32.74	31.69
Product Differentiated	9.97	11.33	11.99
Science-Based	8.12	8.46	9.19

Source: Baldwin and Rafiquzzaman (1994).

In addition to these intersectoral shifts, restructuring occurred within industries as some firms met the new challenges and expanded, while others failed to adapt and contracted. Restructuring that is internal to an industry can be measured by the amount of job turnover that occurs within an industry as some firms expand while others contract (see Baldwin and Gorecki, 1990). Total job turnover is the number of jobs gained by firms that are expanding employment plus the number of jobs lost by firms that are contracting employment. The rate of job turnover is just the sum of job turnover divided by total employment.

Mean annual job turnover rates for the 1970s and 1980s are presented in Figure 1. The highest rates of job turnover occur in the labour-intensive sector, but the product differentiated sector follows closely behind. More important than the levels of job turnover are the changes that have been occurring in the rates over time. Compared to the 1970s, rates are higher everywhere in the 1980s. The greatest differences occur in the natural-resource based, the labour-intensive, and the product differentiated sectors. There is much less change in the science-based sector. There is virtually no increase in job turnover in the scale-based sector.

Figure 1. A Comparison of Job Turnover Rates in the 1970s and 1980s



Thus, the labour-intensive sector not only underwent the most contraction, it also experienced the greatest increase in internal job restructuring as firms changed relative position during the adaptation period. Industries whose share grew most rapidly—the natural-resource and product differentiated sectors—also experienced an increased amount of internal restructuring.

4. *Changes in Employment of Nonproduction and Production Workers*

4.1 Growth Rates

Changes in the composition of manufacturing employment for selected periods—1973-1992, 1973-1979,1979-1989, and 1989-1992—are presented in Table 3. Overall employment in the sample of plants used here declined by 18.74 percent between 1973 and 1992 (Table 3).[6] While both production and nonproduction workers declined in the same period, the decline was larger for production (21.7%) than for nonproduction workers (11.21%).

The 1970s and the 1980s differed in terms of employment growth in the sample. Although there was a slight growth in total sample employment between 1973 and 1979, sample employment fell between 1979 and 1989, and in the early 1990s. In the first period, nonproduction worker growth is positive, while production workers decline. Thereafter, both groups decline, but production-worker employment always declines by more than nonproduction worker employment.

Table 3. ***Changes in Sample Employment in Manufacturing : 1973-1992***

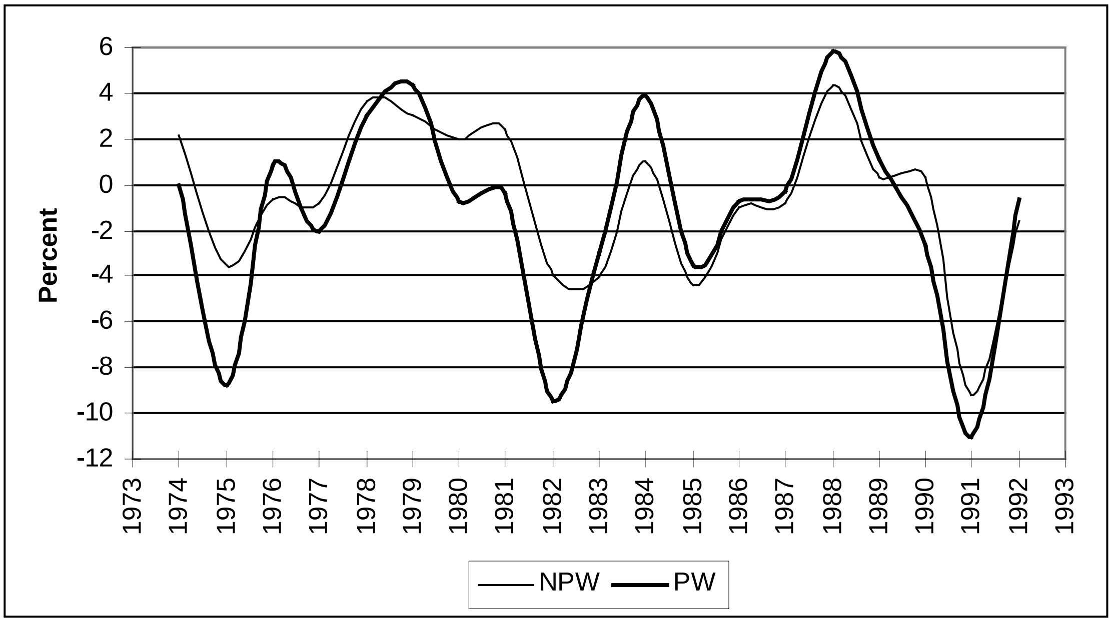
Category	1973-1992	1973-1979	1979-1989	1989-1992
	(Percent)			
Total Employment	- 18.74	+ 0.19	- 6.84	- 12.94
Nonproduction	- 11.21	+ 3.67	- 4.47	- 10.34
Production	- 21.66	- 1.15	- 7.80	- 14.04

Evidence on the relative volatility of the employment of production and nonproduction workers is presented in Figure 2, where the annual percentage changes in production and nonproduction employment are plotted for the period 1973-1992. The peak-to-trough decline in the employment of production workers is generally larger than the peak-to-trough decline in the employment of nonproduction workers. On the other hand, the trough-to-peak increase in the employment of production workers is generally larger than that of nonproduction workers. For example, in the 1975, 1982 and 1991 recessions, the decline for production workers was 8.8%, 9.4%, and 11.1%, respectively; it was 3.6%, 3.9%, and 9.2%, respectively for nonproduction workers.

[6] Total manufacturing employment declined by only one-half of 1 percent over the same period. The difference between the employment change in the sample and the population reflects the fact that the sample of ‘long-form’ plants that are used here includes a disproportionate number of large plants and that the proportion of total employment accounted for by these plants has been declining over the last twenty years (See Baldwin and Picot, 1995).

In the 1979, 1984, and 1988 cyclical peaks, the increase in production workers was 4.3%, 3.9%, and 5.8%, respectively; it was 3.0%, 1.0%, and 4.4%, respectively, for nonproduction workers.

Figure 2. Changes in Nonproduction and Production Workers



Note: NPW = Nonproduction Worker; PW = Production Worker.

4.2 Changes in the Composition of Employment

Differences in growth rates have resulted in a shift in the composition of manufacturing employment in favour of nonproduction workers. The average share of nonproduction workers in total employment for four years—1973, 1979, 1989, and 1992—is presented in Table 4 (first row). During the 1973-1992 period, the share of nonproduction workers in the manufacturing labour force increased from 27.9 percent to 30.5 percent (0.14 percentage points per year).[7] The 1970s experienced a larger increase (0.16 percentage points per year) than the 1980s (0.07 percentage points per year).The increase accelerated in 1990s (0.30 percentage points per year). The Canadian trend is consistent with events in the U.S. manufacturing sector [see Berman, Bound, and Griliches (1994)], though the magnitude of the increase is somewhat less in Canada.[8]

[7] A time trend regression of the form Ln (Share) = a + bT, where T is time, was run for the periods 1973-1992, 1973-1979, and 1979-1989. The results indicated that the share of nonproduction employment was growing at the rate of 0.4 percent per year for the period 1973-1992, 0.7 percent per year for the period 1973-1979, and 0.07 percent per year for the period 1979-1989.

[8] The magnitude of the increase in each period in U.S. manufacturing is larger than Canadian manufacturing. In the U.S., the increase was 0.23 percentage points per year between 1973 and 1979, and 0.38 percentage points per year between 1979 and 1989 [e.g., Berman, Bound and Griliches (1994)]. Thus, the change accelerates in the 1980s in the U.S., but slows in Canada.

Table 4. ***Nonproduction Workers' Share in Total Employment in Manufacturing by Industry and Size: 1973-1992***

Industry	1973	1979	1989	1992
	(Percent)			
All Manufacturing	27.92	28.89	29.62	30.51
Natural Resources	32.55	30.05	32.95	33.90
Labour-Intensive	18.24	20.73	22.23	23.32
Scale-Based	25.73	25.81	25.72	26.35
Product Differentiated	29.57	32.87	33.64	33.15
Science-Based	43.89	41.25	41.43	42.97

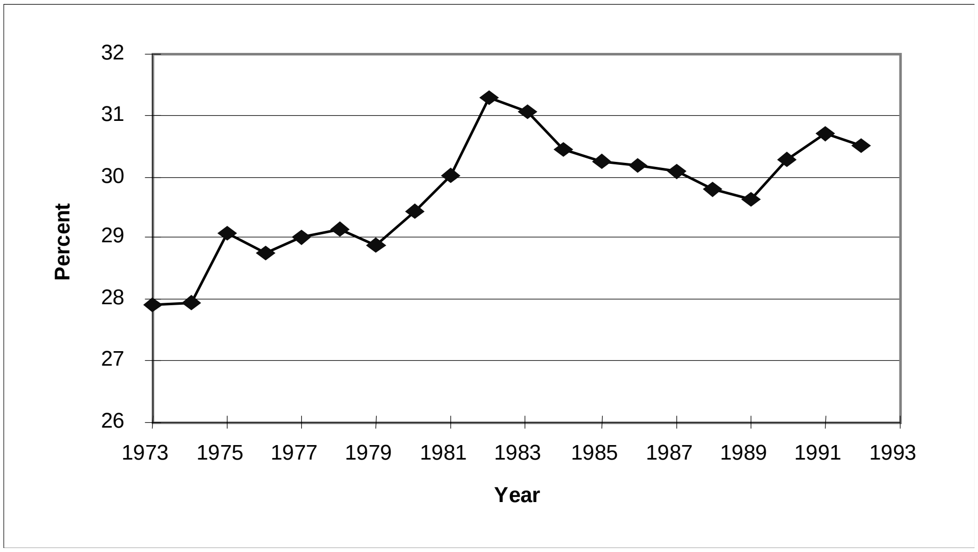
The share of nonproduction workers in total employment from 1973 to 1992 is graphed in Figure 3. Abstracting from cycles, the share of nonproduction workers exhibits an upward trend in the 1970s and peaks in the depth of the 1982 recession. During the 1980s, it remains above the levels of the 1970s but it does not increase further until the recession of the early 1990s.

Table 4 also contains the share of nonproduction workers by industrial sector as a percentage of total manufacturing employment in that sector. Since the production process differs across industries, the share of nonproduction workers in total employment should also differ. In industries where production is more technology-intensive (such as the science-based sector), the share of nonproduction workers should be larger than in industries where production is less technology-intensive (such as labour-intensive industries).

In all periods, the science-based, natural resource based and product differentiated sectors employ the largest proportion of nonproduction to total workers; the labour-intensive sector employs the smallest percentage. In 1973, the nonproduction share of total employment was 43.9% in the science-based sector; 32.6% in the natural resource based sector, 29.6% in the product differentiated sector, 25.7% in the scale-based sector, and 18.2% in the labour-intensive sector. Between 1973 and 1992, the nonproduction share of total employment increased in the natural resource based, labour-intensive, scale-based, and product differentiated sectors. The largest rate of increase occurred in the labour-intensive sector (27.9%), followed by the product differentiated sector (12.1%), the natural resource-based sector (4.1%), and the scale-based sector (2.4%) sector. The science-based sector experienced a decline (0.05 percentage points per year).

There is an inverse relationship between the initial importance of nonproduction workers and changes in their importance. The labour-intensive and the product differentiated sectors had two of the lowest ratios of nonproduction to total workers at the beginning of the period and the strongest growth in this ratio. The science-based sector which had the highest ratio experienced the least growth.

Figure 3. Nonproduction Workers' Share in Total Employment

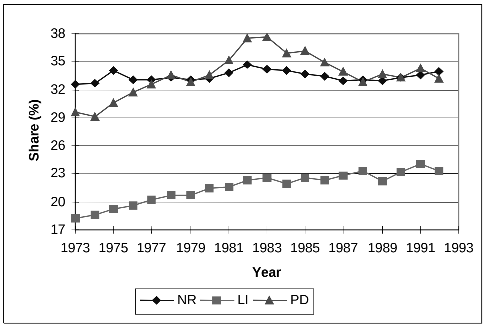


In order to further illustrate the nature of differences across industrial sectors, Figure 4 plots nonproduction employment as a percentage of total employment annually from 1973 to 1992 for each of the five sectors. Panel A of Figure 4 contrasts the time pattern of the share of nonproduction workers in total employment in the natural resource based, labour-intensive, and product differentiated industries. The nonproduction worker share in the natural resource based and product differentiated sectors increases until the 1981-1982 recession , but is no higher at the end of the 1980s than it was at the recessionary peak in 1982. On the other hand, the labour-intensive sector shows a clear upward trend, both in the 1970s and the 1980s.

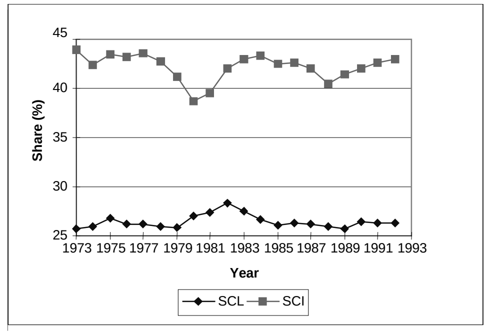
Panel B of Figure 4 plots the time pattern of the ratio of nonproduction workers to total employment in the scale- and science-based sectors. In the science sector, the nonproduction worker ratio declines in the 1970s to a trough in 1982 and then goes through a unique cycle in the mid 1980s. Over the entire period, there is no strong evidence of either growth or decline. The scale-based sector also shows no strong evidence of trend change in share of total employment in nonproduction workers.

Figure 4. Nonproduction Worker Share of Total Employment by Industrial Sector

Panel A



Panel B



Note: NR = Natural Resources; LI = Labour-intensive;
SCL = Scale-Based; PD = Product differentiated; SCI = Science-Based.

4.3 Changes in Nonproduction Workers' Share in the Wage Bill

Changes in the nonproduction worker share of total employment suggests that compositional shifts have been taking place in the manufacturing labour force. An alternate measure of compositional change is provided by the wage share of nonproduction workers. Wage share provides a measure of the importance of the shift in demand for nonproduction labour that is superior, in some instances, to the ratio of quantities demanded since the change in the latter is attenuated to some degree by relative wage changes. As Berman, Bound and Griliches (1994) note, as long as the elasticity of substitution between production and nonproduction labour is greater than one, wage share is a superior measure to quantity share for measuring demand shifts.

Table 5, Figure 5, and Figure 6 contain the nonproduction workers' share in the total wage bill across industries. The nonproduction workers' share in the total wage bill shows virtually no change during the mid 1970s and then an increase to sharply higher levels in the 1980s. The increase in the nonproduction worker share of the wage bill for all sectors is a phenomenon primarily of the 1980s and 1990s, that occurs around the time of the recession in the early 1980s. The dramatic change in nonproduction worker wage share that occurs about the time of the early 1980s' recession along with the increases in the wage share during the 1990s' recession points to the difficulty of abstracting trend from cycle. There is some evidence that long-term changes in the importance of nonproduction workers are occurring as ratchets at or just before recessionary downturns.

The nonproduction share of the total wage bill varies across sectors. The largest share is found in the science-based sector; followed generally by the natural resource based sector and the product differentiated sector; the smallest in the scale-based and the labour-intensive sectors (Table 5). The wage share rises in the labour-intensive, product differentiated and natural resource sectors in the 1970s (Figure 6). In the 1980s, it continues to rise strongly in the labour-intensive sector. The ratio in the natural resource and product differentiated sectors continues at higher rates in the 1980s than the 1970s but does not increase further . The scale-based sector's share remains virtually unchanged through the entire period. The science-based sector shows a decline. These intersectoral differences in wage share broadly reflect the changes that occurred in the nonproduction workers' share in total employment.

Table 5. ***Nonproduction Workers' Share in the Wage Bill by Industry and Size: 1973-1992***

Industry	1973	1979	1989	1992
	(Percent)			
All Manufacturing	34.60	34.16	36.01	37.01
Natural Resources	38.93	38.48	39.94	41.14
Labour-Intensive	27.33	28.59	32.05	33.40
Scale-Based	29.93	29.27	29.60	30.21
Product Differentiated	35.79	37.63	41.60	40.74
Science-Based	52.98	47.65	48.49	49.90

Figure 5. Nonproduction Workers' Share in the Wage Bill

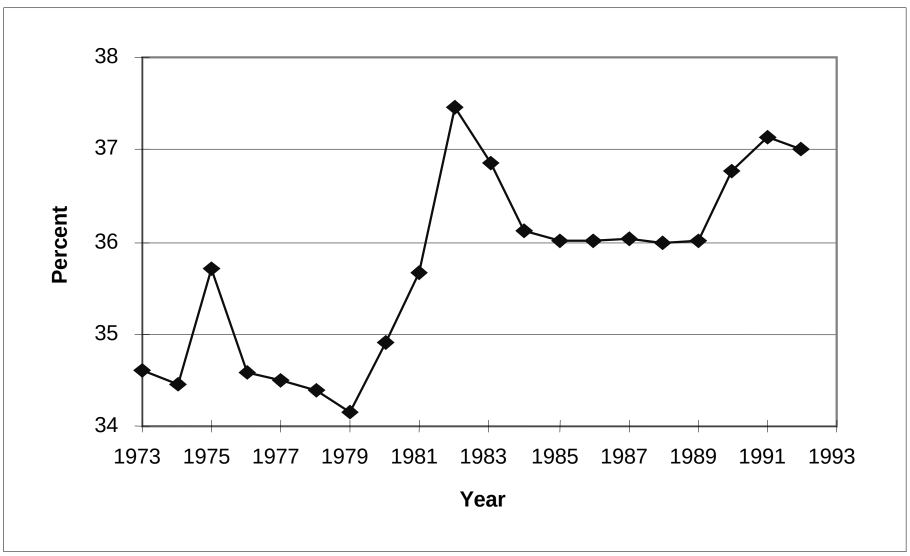
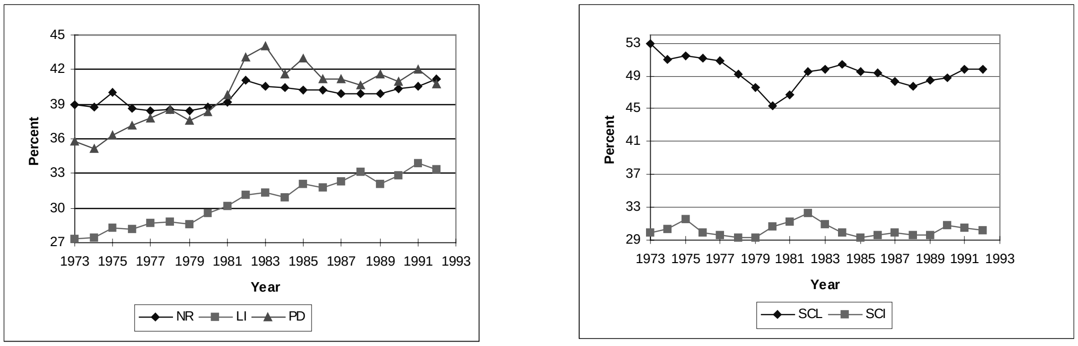


Figure 6. Nonproduction Wage Share by Sector



Note: NR = Natural Resources; LI = Labour-intensive; SCL = Scale-Based; PD = Product-Differentiated; SCI = Science-Based.

4.4 Changes in Wage Differentials Between Production and Nonproduction Workers

The data presented in the preceding sections provide evidence of a shift in the composition of manufacturing employment toward nonproduction workers in Canada. This shift has occurred across several though not all industrial sectors. The rate of increase in the importance of nonproduction workers is higher in the 1970s than the 1980s.

Shifts in the composition of labour can be caused both by shifts in demand or shifts in supply. While a number of researchers have focused on skill-augmenting technical change as the reason that demand for skilled workers may have increased, changes have also occurred in the supply of skilled labour over the last twenty years. This was the period when the proportion of college educated labour increased dramatically. Moreover, this increase was somewhat greater in Canada in the 1970s than the 1980s (Freeman and Needels, 1991).

Examination of the relationship between changes in relative quantities and relative prices helps to discriminate between the relative importance of demand and supply factors.[9] An increase in the supply of nonproduction relative to production workers should be expected to affect the relative wages of the two types of workers in a fashion that is different from a shift in demand. If supply effects are the predominant cause of the changes that were taking place, relative prices and quantities should be inversely related. If demand factors predominate, relative quantities and relative prices should be positively related.

[9] It only *helps* to discriminate between these causes because quality may be changing within each category.

Therefore, this section examines the relationship between changes in the share of nonproduction employment and changes in wage differentials—the ratio of wages of nonproduction workers to production workers. In doing so, it must be kept in mind that changes in wage rates can occur not only because of shifts in demand or supply of a particular type of labour but also because the quality of the labour changes. The wage of nonproduction workers may increase relative to production workers if technical progress increases the skill level of non-production workers relative to production workers.

The ratio of the annual income[10] of nonproduction to production workers for selected years is presented in Table 6. The wages of nonproduction workers have been above those of production workers throughout the entire period. However, the differential has moved in quite different directions in the 1970s as opposed to the 1980s. Between 1973 and 1979, the relative wages of nonproduction workers declined by 6.5% (8.9 percentage points); between 1979 and 1989, they increased by 4.7% (5.9 percentage points). The wage differentials between production and nonproduction workers widened in the 1980s. This finding accords with more aggregative studies that find the wage gap between the more and the less educated falling in the late 1970s but rising in the 1980s (Freeman and Needels,1991).

Table 6. ***Wages of Nonproduction Workers Relative to Production Workers: 1973-1992***

Industry	1973	1979	1989	1992
	(Percent)			
All Manufacturing	136.61	127.71	133.65	133.80
Natural Resources	132.07	126.71	135.28	136.26
Labour-Intensive	168.63	153.09	164.96	164.85
Scale-Based	123.32	118.93	121.48	120.99
Product Differentiated	132.75	123.21	140.53	138.65
Science-Based	144.07	129.65	133.08	132.22

The annual pattern of wage differentials—measured by the ratio of the annual income of nonproduction workers to production workers—for all of manufacturing is depicted in Figure 7. It shows a decline until the end of the 1970s, then an increase until the end of the period.

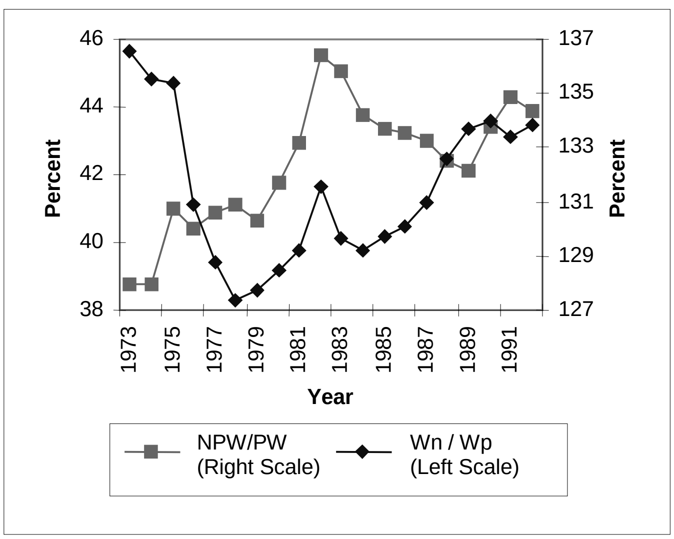
In the 1970s, the relative use of nonproduction workers increases while their relative wage falls. Explanations based on increases in relative supplies of skilled labour or with a substitution away from skilled labour because of its high costs are compatible with the trends observed in the 1970s.

[10] Annual salaries divided by number of nonproduction employees for nonproduction workers and annual wages divided by number of production employees for production workers.

The 1980s are characterized by a reversal in the relative quantity decline of the 1970s and a steady increase in relative prices. This may partially be the result of a decline in the rate of increase in the supply of skilled labour in the latter period (Freeman and Needels, 1991). However, based on the 1970s experience, the increasing nonproduction worker wage premium should have been accompanied by a decline in the ratio of nonproduction to production workers. This did not occur. Abstracting from the cyclical peak in the 1982 recession, there is little decline in the relative importance of nonproduction workers from 1979 to 1989. Indeed, the share of nonproduction workers in the wage bill moves to a higher level in the early 1980s and then remains relatively constant for the rest of the decade (Figure 5). Increasingly higher relative wages in the 1980s did not lead to a substitution of production workers for nonproduction workers, though it did lead to a slowing down in the rate of increase of the quantity of nonproduction labour being used.[11]

The asymmetry between the experience of the 1980s and the 1970s suggests that the demand for nonproduction workers increased in the second period relative to the first and accords with the argument that skill-augmenting technical change became more important in the 1980s. It also might be the result of changing trade patterns which increased the demand for nonproduction workers relative to production workers. The extent to which both factors are at play is discussed in succeeding sections.

Figure 7. Ratio of Nonproduction Workers to Production Workers, and Wages of Nonproduction Workers Relative to Production Workers



Note: NPW/PW = Ratio of nonproduction workers to production workers;
Wn/Wp = Ratio of wages of nonproduction workers to production workers.

[11] In order to investigate this further, time series correlations between the ratio of nonproduction workers to production workers and the ratio of wages of production to nonproduction workers were calculated. Correlation values were -.71 for the period 1973-1979, +.20 for the period 1979-1989, and +.31 for the period 1989-1992.

Wage differentials for each sector are also presented in Table 6 and in Figure 8. In 1973, the wage differentials were highest in the labour-intensive sector (168.6%), followed by the science-based sector (144.1%), the product differentiated sector (132.8%), the natural resource based sector (132.1%), and the scale-based sector(123.3%). The decline in the wage differentials in the entire manufacturing sector in the 1970s is mirrored by a decline in wage differentials across all sectors within manufacturing during this period. The largest relative decline occurred in the science-based sector (10.1%), followed by the labour-intensive sector (9.2%), the product differentiated sector (7.2%), the natural resource based sector (4.1%) and the scale-based sector (3.6%).

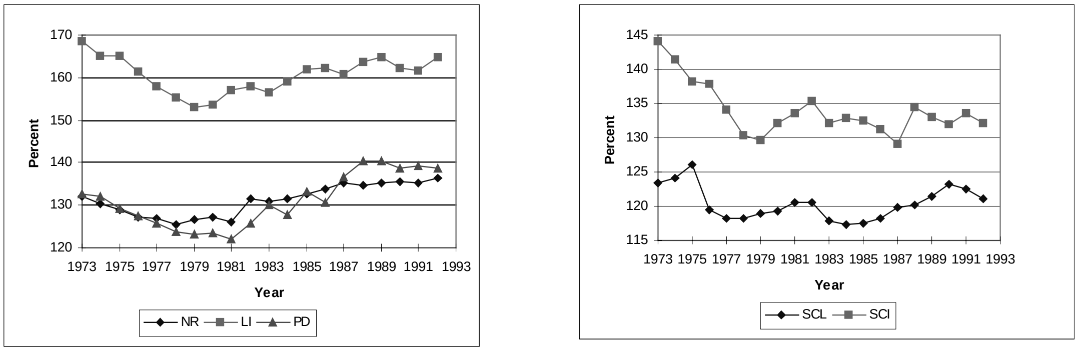
In the 1970s, the sectors with the highest wage differentials experienced the largest declines in these differentials; the sectors with relatively smaller wage differentials at the beginning of the period experienced the least change. This pattern is consistent with a substitution effect, for the greatest incentive to substitute unskilled for skilled labour occurs where the wage differential is highest.[12] This pattern is also compatible with a supply explanation if the sectors with the highest wage differentials were most affected by the increases in the supplies of skilled workers.

Wage differentials between nonproduction and production workers increased in all sectors in the 1980s. Between 1979 and 1989, the inequality widened dramatically in product differentiated (14.1%), labour-intensive (7.8%) and natural resource based (6.8%) industries—the sectors where the greatest internal restructuring was occurring. The smallest increases occurred in science-based and scale-based sectors, 2.6% and 2.1%, respectively. The largest increases in wage differentials occurred in those sectors (product differentiated, labour intensive, and natural resources) where the ratio of nonproduction workers to total employment also increased the most. The smallest increases in relative wages occurred where the nonproduction worker share of employment changed the least (in scale-based and science-based industries). The cross-sectoral pattern experienced in the 1980s is strongly suggestive of a shift in demand for nonproduction workers relative to production workers that is of a different intensity across sectors.

The pattern of intersectoral change in the relative quantities of nonproduction workers and the nonproduction worker wage premia are compatible with the following explanation: In those areas where high wage differentials indicate that the skill gap between nonproduction and production workers was large (such as the labour-intensive sector), skill-augmenting technical progress impacted more on nonproduction workers since they most embodied the types of skills that technical progress was making more valuable. Other sectors where wage differentials were lower (like science-based industries) were those where existing skill differentials were smaller. In these sectors, where production workers were already relatively highly skilled relative to nonproduction workers, technical progress increased the demand for both nonproduction and production workers, leaving their relative wage differentials virtually unchanged.

[12] This could occur if cross-sectoral differences in wage differentials are directly related to greater substitution possibilities along the production frontier.

Figure 8. Relative Wages by Industrial Sector



Note: NR = Natural Resources; LI = Labour-intensive; SCL = Scale-Based;
PD = Product-Differentiated; SCI = Science-Based.

The next two sections provide evidence to support this interpretation. The first examines how technology affects the wage structure. The second examines the intersectoral differences in technology usage.

5. Wage Rates and Technology Usage

Changes in the composition of the manufacturing labour force and the skill premium for nonproduction workers suggest that technological change has increased the demand for skilled workers. However, the effect has varied across industries, partially because the new technologies have not penetrated each sector equally. Moreover, even within industries, there are substantial differences in technology use across firms. It is, therefore, best to examine the connection between technology use and the wage structure at the plant level.

Other studies have emphasized the need for a micro-economic examination of wage differentials by arguing that most of the changes that are occurring in the ratio of nonproduction to production workers take place at the level of the plant. Berman, Bound and Griliches (1994) decompose the nonproduction worker share change that occurred in the United States into two components—that due to a shift in the importance of different industries and that due to change occurring within industries. Between 1973 and 1979, within-industry change accounted for some 63% of total change; between 1979 and 1987, the within-industry share is 70%. In Canada, the within-industry share accounted for 71% of total change over the period 1973-90.[13]

While the debate over the causes of the growing skilled/unskilled wage differential attributes at least some of this to technological changes, technology itself is generally treated as a black box. Sometimes this technological change is attributed to computer use, but measures of advanced technology use are rarely employed to test this proposition.

[13] The US estimates use a four-digit industry breakdown; the Canadian estimate uses the five-sector taxonomy.

One exception is Krueger (1993), who uses a cross-section of workers and finds that after accounting for easily measurable worker characteristics, a substantial wage premium of 10 to 15 percent exists for those workers having computer skills. However, simple measures of computer use do not capture in much detail the complicated way in which computers have affected the production process. Computers are imbedded in machines used in different phases of the production process—design and engineering, fabrication and assembly, and inspection and communications. A measure of the importance of computer-driven technologies requires a more comprehensive measure. Dunne and Schmitz (1995) do so by examining wages in a cross-section of manufacturing establishments that use different computer-based advanced technologies and find that production workers using these advanced technologies receive higher wages.

This section uses a similar, direct measure of technology use—the number of technologies in use in different parts of the production process. It investigates the relationship between technology use and the nonproduction worker wage premium for Canada. It recognizes that technology use may impact differentially on nonproduction and production workers and estimates wage rate equations for both production workers and for nonproduction workers at the plant level for the manufacturing sector using matched data from a Survey of Manufacturing Technology and the Census of Manufactures.

5.1. Advanced Technology Use in Canadian Manufacturing

The data used to investigate the relationship between technology and the wage structure are drawn from two sources—the 1989 Survey of Manufacturing Technology (SMT) which contains data on technology usage at the plant level and the Census of Manufactures.

The responses to the SMT are linked to longitudinal panel data going back to 1980, taken from the Census of Manufactures.[14] This source yields information on a plant's employment, shipments, wages, and value added in manufacturing. In addition, data on the plant's owning enterprise—nationality, employment and age—are generated from special files maintained by the Micro-Economic Analysis Division. For this analysis, the wage rate of production workers is calculated as wages paid to production workers divided by the number of production workers employed; for salaried (nonproduction) workers, the wage rate is calculated as the salaries paid divided by the number of salaried workers.

Since this paper compares the wage structure of plants in 1989 and 1980, only those firms that continue throughout the decade are used in the analysis. The sample includes neither the deaths nor the births that occurred between 1980 and 1989. When births and deaths

[14] Of the 3,952 respondents, some 96% are linked into the panel from the Survey of Manufactures.

are excluded from the linked file, the total number of observations used in the calculations is 3,642.

The 1989 Canadian SMT contains information on the use by establishments in the manufacturing sector of 22 separate advanced technologies. These technologies are used in design and engineering, fabrication and assembly, inspection and communications, automated materials handling, manufacturing information systems, and integration and control. The survey, conducted by mail, was based on a sample of all establishments in the Canadian manufacturing sector. The sample is stratified by size class, with a greater proportion of the larger plants being sampled than of smaller plants. Of the 4,200 establishments in the sample, 3,952, or 94 percent, responded to the survey.

The individual technologies included in the survey are listed in Table 7 by functional group. The functional groups differ in terms of the degree to which they are directly involved in the production and assembly process or whether they serve to monitor it via diagnostics and quality control.

The technologies emanate from the current technological revolution that is related to the computer, or more correctly to micro-chip use. On the one hand, the relatively cheap processing power of micro chips has spawned the development of a host of labour-saving technologies. These technologies have permitted the replacement of costly labour with efficient, reliable, computer-controlled machinery. For example, robots provide an efficient and safe alternative to humans for repetitive jobs like spot welding or painting on the automobile assembly line. Automated guided vehicle systems replace delivery personnel.

As important as these labour-saving technologies might be, the new technological revolution has also involved new labour-enhancing technologies. These have important effects on enhancing labour, often but not exclusively managers, in the tasks that they perform. The dramatic impact of information technologies involved in inspection and communications has been felt in many different parts of the production process. They have allowed management to receive, digest, and analyze unprecedented amounts of information. They have permitted designers to ponder problems that they did not have time to consider previously, and to shorten the design phase of projects.

The integration of labour-saving and labour-enhancing technologies has created new manufacturing processes that are at the heart of what has been called “soft manufacturing”. Bylinsky (1994) notes that “soft manufacturing” differs from traditional manufacturing in that software and computer networks are as important as production machines. These new technologies complement problem-solving skills in the workforce. The introduction of labour-enhancing technologies has been stimulated by the recognition that humans possess the invaluable kind of dexterity and judgment that has yet to be programmed into a robot. On the one hand, inspection and communications technologies permit skilled engineers to control a vast array of processes. On the other hand, they allow real time ordering and the production of products on demand, tailored to specific needs.

Inspection and communications as well as integration and control technologies facilitate the rapid transmission of orders to the assembly process, the delivery of parts to the assembler, and the assembly of specialized products by a worker who is instructed by a computer as to what parts are needed for the particular product ordered and the nature of the assembly required. Instead of replacing workers with robots, these soft technologies have enhanced human skills. In this environment, robots are relegated to repetitive tasks, while computer technologies aid workers to assemble custom-designed products with the aid of computer-transmitted requests.

The effect of the technological revolution has not been felt equally in all areas of production. The labour-enhancing inspection and communications functional group has the highest adoption rate (Table 7). Some 79% of shipments in 1989 come from establishments using labour-enhancing technologies from this group. The high adoption rate here is due mainly to the use of automatic control devices—programmable controllers and stand-alone computers used for control on the factory floor. The inspection and communications group is followed by design and engineering (52.1%), and manufacturing information systems (51.2%). Labour-saving technologies in fabrication, the traditional heart of the production process, are only fourth with 46.7%. While the computer-based revolution is often described in terms of its effects on fabrication and assembly, its usage so far has been greatest in the area of the labour-enhancing technologies in inspection and communications as well as in design and engineering.

The introduction of new advanced technologies is associated with skill upgrading. Baldwin, Gray, and Johnson (1995) find that plants that have introduced these technologies have increased their skill requirements, and have responded by implementing internal training programs at a substantial increase in training costs.

Labour-saving technologies do not impact just on production workers; similarly labour-enhancing technologies do not impact just on nonproduction workers. While advanced fabrication and technologies directly affect the skills required of production workers, they may also affect the skills required of nonproduction workers. For example, the introduction of many of these technologies has led to a greater requirement for skilled supervisory personnel. Therefore, the use of labour-saving technologies may be associated with either an increase or decrease in the relative skills of nonproduction relative to production workers.

Similarly, the use of advanced communications labour-enhancing technologies affects both the skills required of production and nonproduction workers. They directly involve supervisory personnel but they may also increase the skill levels of production workers who may require greater cognitive skills as a result of the new technologies. The direction of the impact of both types of technologies on the relative skills and wage rates of each group is indeterminate, *a priori*.

Table 7. *Advanced Manufacturing Technologies by Functional Group*

Functional Group	Technology	Adoption Rate (Percent of Shipments)
Design and Engineering		52.1
	Computer-aided design and engineering (CAD/CAE)	49.0
	CAD output to control manufacturing machines (CAD/CAM)	20.1
	Digital representation of CAD output	12.7
Fabrication and Assembly		46.7
	Flexible manufacturing cells/systems (FMC/FMS)	20.6
	Numerically Controlled (NC) and Computer Numerically Controlled (CNC) Machines	29.6
	Materials Working Lasers	9.3
	Pick & Place Robots	14.9
	Other Robots	15.6
Automated Materials Handling Systems		18.4
	Automated Storage/Retrieval Systems (AS/RS)	14.7
	Automated Guided Vehicle Systems (AGVS)	9.2
Inspection and Communications		79.0
	Automatic Inspection Equipment - Inputs	30.7
	Automatic Inspection Equipment - Final Products	34.9
	Local Area Network for Technical Data	40.8
	Local Area Network for Factory Use	36.7
	Inter-Company Computer Network (ICCN)	35.4
	Programmable Controllers	63.6
	Computers used for control in factories	49.9
Manufacturing Information Systems		51.2
	Materials Requirement Planning (MRP)	48.6
	Manufacturing Resource Planning (MRP II)	33.0
Integration and Control		39.8
	Computer Integrated Manufacturing (CIM)	21.1
	Supervisory Control & Data Acquisition (SCADA)	33.9
	Artificial Intelligence/Expert Systems (AI)	6.5

5.2. The Effects of Technology on Wage Rates and Wage Rate Differentials at the Plant Level: 1989

Wage differentials are the result of both demand and supply effects. Disentangling the relative importance of each is difficult. This section focuses on the demand side by primarily using data at the plant level. This permits the results of interplant differences in technology to be set against changes that are occurring in wage differentials and thus inferences to be made about the changing nature of demand.[15] The results do not imply that supply shocks are unimportant. But these supply shocks are presumed in this paper to be more equally felt across the plant universe than the demand shocks arising from differences in changing trade patterns and differences in technology usage. Thus, the analysis here is used to try and isolate the nature of the changes that more aggregate analyses have had to infer from residual unexplained effects in their models.[16]

[15] On this see Hamermesh (1993, p. 352).
[16] For a discussion of this literature, see Levy and Murnane (1992).

In order to examine the effects of technology use on plant wages and plant wage differentials between nonproduction and production workers, wage and salary equations are estimated at the plant level. Plant wages are hypothesized to be a function of plant size, the relative size of other factors (capital and other types of labour) and a number of plant characteristics related to a plant's technological capabilities. There are a number of reasons that plant size is included. Larger plants have been observed to use higher skilled workers. They also tend to be more profitable, and more unionized, which is likely to give rise to higher wages as a result of the bargaining process. Relative quantities of other factors (capital/production workers, or nonproduction/production workers in the case of the wage equation for production workers) are included because larger quantities of each may increase the marginal product of labour and thus increase the wage rate. A number of other plant characteristics that are posited to be related to the demand for skilled labour are also included. The most important are the variables that directly capture a plant's use of advanced technologies. But a number of other variables like age, diversification, innovativeness and nationality are also included to capture aspects of sophistication that even the technology variables cannot be expected to capture on their own.

Two different sets of specifications are used. First, the plant level wages of production and nonproduction workers are examined by estimating separately the following two log-wage equations:[17]

$$\ln (W_P)_j = \alpha_0 + \alpha_1 \ln (K/L_P)_j + \alpha_2 \ln (NPR)_j + \alpha_3 \ln (PLANT\text{-}SIZE)_j + \alpha_4 X_j + \alpha_5 (TECH_{kj}) + \varepsilon_j, \quad (5.1)$$

$$\ln (W_N)_j = \lambda_0 + \lambda_1 \ln (K/L_N)_j + \lambda_2 \ln (NPR)_j + \lambda_3 \ln (PLANT\text{-}SIZE)_j + \lambda_4 X_j + \lambda_5 (TECH_{kj}) + \omega_j, \quad (5.2)$$

where P and N indicate production and nonproduction labour, respectively; j indexes plant; W_P and W_N represent the wages of production and nonproduction workers, respectively; NPR represents the use of nonproduction workers relative to production workers; K/L_P and K/L_N are capital intensities of production and nonproduction workers, respectively; PLANT-SIZE is the plant size; X is a vector of other plant-specific characteristics; $TECH_k$ represents a vector of the type of technology use (k = 1,2,...,6); and ε and ω are error terms.

Second, the effects of technology use, plant characteristics, and other relevant production related variables on plant level wage differentials are investigated by estimating the following wage inequality equation:[18]

$$(W_N/W_P)_j = \beta_0 + \beta_1 (K/L)_j + \beta_2 (NPR_j) + \beta_3 (PLANT\text{-}SIZE)_j + \beta_4 X_j + \beta_5 (TECH_{kj}) + \upsilon_j, \quad (5.3)$$

where (W_N/W_P) is the ratio of wages of nonproduction workers to those of production workers and υ is an error term. Other variables represent the same characteristics as in equations (5.1) and (5.2).

[17] In a three-factor world--physical capital, production workers, and nonproduction workers, these wage equations may be derived by assuming that the production technology is Cobb-Douglas and the firm maximizes profits by selling in a perfectly competitive product market.

[18] See footnote 17. This wage inequality equation may also be derived by considering the simplest CES technology with three factors--physical capital, production workers, and nonproduction workers.

5.2.1. The Variables of the Models

In this section, description and the measures of both dependent and explanatory variables of the econometric models are outlined.

Production Worker Wage Rates (W_P)

The average annual wage is calculated as the total wage bill for production workers divided by the total number of production workers. A two-year average (over 1988-89 for 1989) is used in order to smooth out random movements that reflect regression-to-the-mean effects.

Nonproduction Worker Salary Rates (W_N)

The average annual salary is calculated as the total salary bill for nonproduction workers divided by the total number of nonproduction workers. A two-year average (over 1988-89 for 1989) is used in order to smooth out random movements that reflect regression-to-the-mean effects.

Plant Size (PLANT-SIZE)

Plant size in the relative wage equation (5.3) is represented by plant employment which includes both production and nonproduction workers. Plant employment for 1989 is calculated as the average plant employment of 1988 and 1989. PLANT-SIZE in the wage equations of production workers (5.1) and nonproduction workers (5.2) is measured by the log of the average plant employment of production workers in 1988 and 1989, and the log of the average employment of nonproduction workers in 1988 and 1989, respectively.

Capital-Labour Ratio (CLR)

The capital-labour ratio is proxied by profits in manufacturing divided by total employment of workers, again calculated as the average over 1988-1989—the relevant two-year period. The ratio is calculated as total activity value-added minus the sum of the wage bills of production and nonproduction workers divided by the total number of workers in the wage inequality equation (5.3). It is calculated as total activity value-added minus the wage bill of production and nonproduction workers divided by the total number of production workers in the wage equation of production workers. In the wage equation of nonproduction workers, it is calculated as total activity value-added minus the wage bill of production and nonproduction workers divided by the total number of nonproduction workers.

Technology Use (TECH)

Technology in use within the plant captures aspects of capital intensity that the dollar measure of capital does not. While the normal practice is to encapsulate all information on capital into one aggregate measure using dollars as the common numeraire, these measures cannot capture differences in the efficiency of machines. Some plants may have more of the latest equipment than others, even though investment levels are about the same. Specification of the capital stock in more detail, using information on the types of machines in use, potentially corrects for the shortcomings of dollar measures of capital.

Technology use is measured for each of six functional categories. The 22 separate advanced technologies for which the SMT collected data are grouped into 6 *functional groups*, according to their place of application in the production process. These functional groups are: design and engineering (DESIGN); fabrication and assembly (FAB); automated materials handling systems (MATHAN); inspection and communications technologies (INSCOM); manufacturing information systems (MANIF); and integration and control technologies (INTCON). A binary variable that captures the use of *any* technology within each group is used in the regression.

Other Plant Characteristics (X)

A number of additional characteristics are included to capture other factors that have been found to be related to wage rates—age of plant, ownership by a firm with multi-plant ownership (Davis and Haltiwanger, 1991). Each of these characteristics is hypothesized to capture some aspect of differences in technologies not captured by the other variables and, therefore, to affect the dependent variables of the models. The characteristics are:

Age (AGE)

Older plants are those that have managed to survive and will have built up accumulated knowledge that allow them to apply the same machines in a more sophisticated manner. Therefore, it is hypothesized that age is related to higher skill levels. A binary variable is used that takes on a value of 0 for those plants that existed in 1970 and 1 for those born since that date.

Diversification

Making advanced technologies work requires a set of sophisticated organizational skills. These are more likely to be present in a multi-establishment enterprise where a wider range of experiences is mastered by the firm's production engineering team. Therefore, firms are hypothesized to have higher skill levels when they are diversified. Diversification is captured here as a multi-plant binary variable (MULTI-PLANT), which equals one if the firm operates more than one plant in the same 4-digit SIC industry where the plant is located, and zero otherwise.

Innovation

Plants in some industries are likely to be receive greater benefits from the use of advanced technologies and to require higher skills because these industries engage in more complex technological and innovative activities. In order to capture this effect, a binary variable classifying industries as either more- or less-innovative (INNOV-INDS) is included in the regression. The classification is derived from Robson et al. (1988). Their study of the differences in the innovative tendencies of 2-digit industries classifies industries into three basic groups. The first two groups, defined here as the innovative industries, produce the majority of innovations. The more innovative industries consist of electrical and electronic products, chemicals and chemical products, machinery, refined petroleum and coal, transportation equipment, rubber products, non-metallic mineral products, plastics, fabricated metals, and primary metals. The less innovative group are made up of the textiles, paper, wood, clothing, leather, beverages, food, furniture and fixtures, and printing and publishing industries.

Foreign Control

The nationality of a plant is used to capture other competencies that are hypothesized to require higher skill levels. Multinationals are the vehicle through which hard-to-transfer scientific knowledge is moved from one country to another (Caves, 1982). This may be either because of scale economies associated with their larger size or because of an inherent advantage associated with information that is uniquely held by these types of firms. To capture the effect of foreign-owned plants, a binary variable (FOREIGN-OWNER) is included that equals one if a manufacturing plant is foreign-controlled, and zero otherwise.

In what follows, regressions for the production-worker wage, the salary of nonproduction workers and the ratio of the annual remuneration of nonproduction to production workers are reported.[19] The first and the second allow us to investigate how technology use affects wages of production and nonproduction workers. The third allows us to examine whether technology use affects the relative wages of nonproduction and production workers.

5.2.2. The Empirical Evidence

There is strong evidence that advanced technologies are closely associated with the use of more highly skilled workers. For the manufacturing sector as a whole, advanced technologies are associated with higher production worker wage rates.

[19] These regressions are all OLS. Various alternatives that used corrections for simultaniety found no significant effect on the coefficients attached to technology use. For some of these results, see Baldwin, Gray and Johnson (1996).

The production worker wage rate (Table 8, column 1) depends both on the size of plant—PLANT-SIZE—(Mellow, 1982, Brown and Medoff, 1989)—and the ratio of capital to labour—CLR—(Davis and Haltiwanger, 1991). After both plant size and the capital-labour ratio are taken into account, the use of advanced technologies is positively related to the wage rate. The use of technologies from four functional groups—inspection and communications (INSCOM), integration and control (INTCON), design and engineering (DESIGN), and automated material handling systems (MATHAN)—have a positive and significant effect on the wage rate paid to production workers. The largest positive effects are associated with the two labour-enhancing categories—inspection and communications, and integration and control. The smallest positive effect occurs for design and engineering technologies. Wages are no higher in plants using fabrication and assembly (FAB) technologies than in those not using these technologies.

Thus, the presence of labour-enhancing advanced technology is associated with a positive wage premium for production workers. The advanced technologies used in fabrication and assembly that most directly affect the plant floor have the least affect of all on wage rates. It is the communications and control technologies that are at the heart of the soft manufacturing revolution that have the greatest affect on production worker wage rates. While these technologies have often been thought of as enhancing the abilities of management, their incidence of use is directly related to higher wage levels for production workers.

Most of the hypotheses about the effect of other plant characteristics are confirmed. Plants that are older, more diversified, foreign-controlled, and are located in more-innovative industries also pay higher production worker wage rates. The coefficient on age of plant (AGE), however, is statistically insignificant.

The salary of nonproduction workers is also related to size, to capital intensity of the plant, to the innovative environment, and to the technologies being employed. A regression of the 1989 salary rates similar to the production worker wage rates (Table 8, column 2) finds significant coefficients on most of the variables that affected the wage rate of production workers. In particular, the coefficients attached to PLANT-SIZE, CLR, AGE, and INNOV-INDS are significant. However, the coefficients attached to the technology variables are generally not significant, though they mainly have the same sign as in the production worker equation. The one exception is the fabrication and assembly (FAB) variable. Plants that use fabrication and assembly technologies pay lower nonproduction worker salaries. However, even when the coefficients have the same signs in both the production worker and nonproduction worker equations, the coefficients are smaller for the nonproduction worker equation.

Table 8. ***Multivariate Analysis of Wages of Nonproduction Workers (W_N), Production Workers (W_P), and Wages of the Former Relative to the Latter (W_N/W_P): 1989***

Variable	Production Worker Wage ln (W_P): Column 1			Nonproduction Worker Wage ln (W_N): Column 2			Relative Wage (W_N/W_P): Column 3		
	Parameter Estimate		S.E.[a]	Parameter Estimate		S.E.[a]	Parameter Estimate		S.E.[a]
Intercept	9.7367	***	0.0317	10.2112	***	0.0369	1.8306	***	0.0287
AGE	-0.0234	*	0.0136	-0.0376	**	0.0158	-0.0223		0.0359
FOREIGN-OWNER	0.0439	***	0.0120	0.0307	**	0.0139	-0.0924	***	0.0319
INNOV-INDS	0.0992	***	0.0112	0.0528	***	0.0130	-0.0768	***	0.0296
MULTI-PLANT	0.1173	***	0.0109	-0.0195		0.0127	-0.2577	***	0.0291
Technology Use									
DESIGN	0.0223	*	0.0125	0.0211		0.0146	-0.0195		0.0330
FAB	-0.0188		0.0126	0.0070		0.0147	0.0755	**	0.0335
MATHAN	0.0624	***	0.0134	0.0342	**	0.0157	0.0036		0.0357
INSCOM	0.0621	***	0.0130	0.0112		0.0151	-0.1476	***	0.0339
MANINF	-0.0744	***	0.0122	-0.0237	*	0.0142	0.0674	**	0.0323
INTCON	0.0460	***	0.0156	0.0227		0.0182	-0.0590		0.0417
CLR[b]	0.0168	***	0.0021	0.0059	**	0.0024	-4.17E-07	***	1.6E-07
PLANT-SIZE[b]	0.0429	***	0.0055	0.0327	***	0.0064	-3.83E-05		2.5E-05
NPR[b]	0.0522	***	0.0063	-0.0411	***	0.0073	-0.1529	***	0.0258
N[c]	2847			2847			2847		
Adj R^2	0.234			0.051			0.078		
F	67.81			12.83			19.50		

[a] Standard error. [b] They are in logarithmic form in the production and nonproduction worker wage equations. [c] Number of observations.
*** Significant at the 1% level. ** Significant at the 5% level. * Significant at the 10% level.

As a result of these differences, the premium paid to nonproduction workers depends on the technologies that are being used in the plant (Table 8, column 3). Nonproduction worker relative wages are significantly lower in plants that are using inspection and communications (INSCOM) as well as integration and control (INTCON) technologies. These are the technologies at the heart of the soft manufacturing revolution. In contrast, the premium paid to nonproduction workers is higher for plants using advanced fabrication and assembly (FAB) technologies. Thus, labour-enhancing technologies affect the skills required of production workers more than they do of non-production workers, while the reverse occurs for labour-saving technologies.

Other plant characteristics that positively affect the production worker wage rate tend to negatively affect the premium paid to nonproduction workers. Being older, larger, owned by a foreign controlled firm, belonging to a more diversified parent, or being located in an innovative industry leads to a lower nonproduction worker premium.[20] These then are characteristics that lead to higher skill levels on the part of production workers but not *relatively* higher skill levels for nonproduction workers. Whether it be plant characteristics that are strongly associated with technological innovativeness in general or the specific technological variables, all suggest that technological change is being felt more in the blue collar than the white collar segment of the manufacturing workforce.

5.2.3. Discussion of the Results

These plant level wage equations are estimated for the manufacturing sector as a whole. Yet, the sectors have a different adoption rate for technologies in each of the functional groups (Table 9). Moreover, wages of production workers differ across sectors. For example, the scale-based sector has consistently paid the highest wage in the 1970s and the 1980s; the labour-intensive sector has paid the lowest.[21] Figure 9 plots the relative production and nonproduction worker wages for the five sectors (indexed to the scale-based sector) and the usage rates (shipment weighted) of fabrication as well as inspection and communications technologies for the period 1989. The three sectors with the highest production worker wages (the scale, science-based and product differentiated sectors) are the most frequent users of advanced fabrication technologies. Some 51% of shipments in scale-based industries and 64% of shipments in science-based industries originate in plants that use these technologies. The sector with the lowest production-worker wage rate (labour intensive industries) has less than 40% of shipments in plants that use these technologies.

[20] The coefficients of almost all of these variables are highly significant. The exception is plant size which becomes very significant if foreign control or innovation are removed.

[21] See Baldwin and Rafiquzzaman (1994). They find that both in the 1970s and 1980s, the scale-based sector pays the highest wage, followed by the science-based, product-differentiated, natural-resource based and labour intensive sectors. The lowest wage sector—the labour intensive sector pays 67% and 62% of the highest wage paying sector in 1970 and 1980, respectively.

The scale and science-based sectors also pay the highest nonproduction worker salaries and use more of both labour-enhancing and labour-saving technologies than the three other sectors. Intersectoral wage differentials for nonproduction workers in both periods are not as large as for production workers although they exhibit the same cross-sectoral pattern. The lowest nonproduction worker wage sector—the labour-intensive sector—pays 91% and 85% of the highest nonproduction worker wage paying sector—the scale-based sector—in 1970 and 1990, respectively. The sectors paying the lowest nonproduction worker salaries employ fewer labour-saving and labour-enhancing technologies but relatively less of the latter (Table 9).

The coefficients presented in Table 8 indicate that the use of inspection and communications as well as integration and control technologies reduces the wage gap between nonproduction workers and production workers while the use of fabrication and assembly technologies increases it. Labour-intensive industries fall 12 percentage points behind the scale-based sector in fabrication and assembly but 35 percentage points behind in inspection and communications (Table 9). Product differentiated industries do relatively poorly as well in inspection and communications. In addition, these two sectors do relatively poorly in integration and control. Compared to the scale-based sector, the labour intensive and product differentiated sectors had relatively less of the labour-enhancing technologies (Figure 9), thereby helping to explain why their wage premia for nonproduction workers is higher than for the scale-based sector.[22] Figure 10 plots the nonproduction/production worker wage premium across sectors along with the ratio of the usage of inspection and communications/fabrication technologies (FAB/INSCOM). Lower technology use within both labour-saving and labour-enhancing categories in these sectors (labour intensive, product-differentiated) means that fewer skilled workers in both the nonproduction and production groups were required; but the relatively smaller use of labour-enhancing technologies reduced the need for skilled production workers further than for non-production workers.

Table 9. *Technology Use by Sector (Shipment Weighted)*

Technology	Industrial Sector				
	Labour Intensive	Natural Resource	Product Differentiated	Scale-Based	Science-Based
Design and Engineering	40.7	40.7	63.6	58.9	74.4
Fabrication and Assembly	39.0	37.4	60.6	50.9	63.9
Inspection and Communications	55.0	74.7	73.9	89.6	87.2
Manufacturing Information Systems	46.3	42.5	54.0	57.4	70.6
Integration and Control	16.8	39.4	21.6	49.3	48.7

[22] See the relative wages of nonproduction workers in 1989 (Table 6).

Figure 9. The Relative Production and Nonproduction Worker Wages and the Rate of Technology Use: 1989

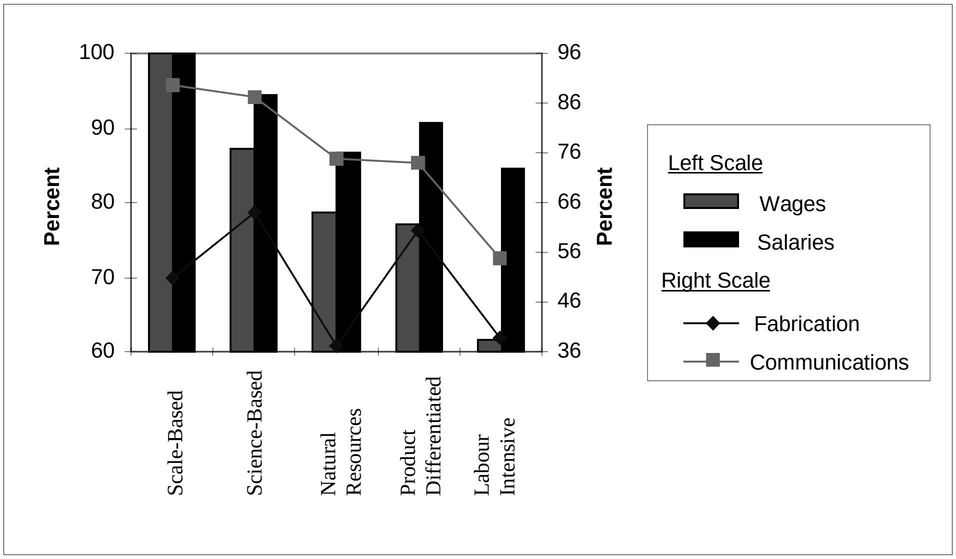
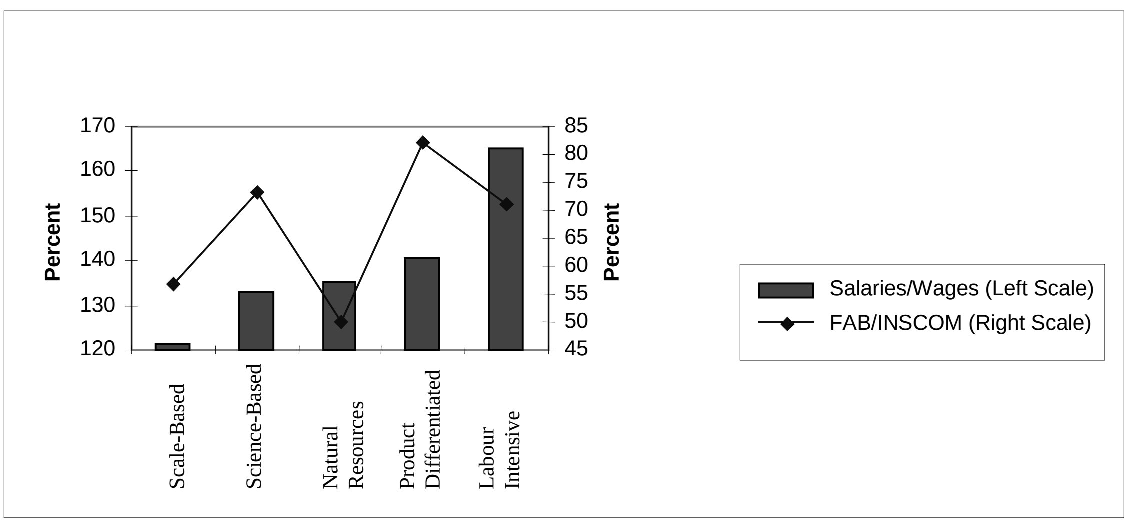


Figure 10. Nonproduction Worker Wage Premia and the Relative Use of Fabrication and Inspection and Communications Technologies



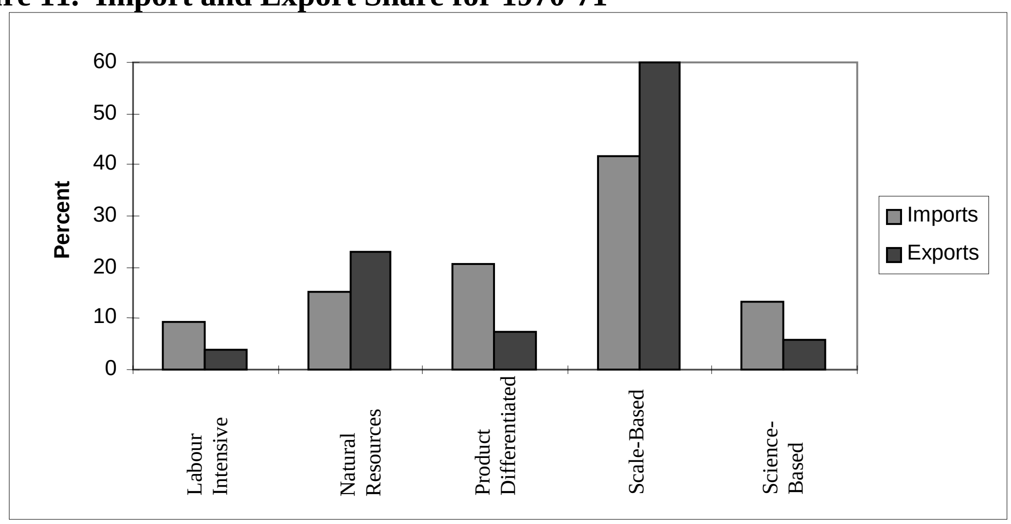
6. The Effects of Trade and Technology on Relative Wages at the Industry Level

The previous section finds that the wage premium paid to nonproduction workers is related to the type of technologies that are being used in the plant (Table 8). Changing technology use then would affect the nonproduction worker wage premium.

This should not be interpreted to mean that technological change is the only factor at work. It is possible that increased import competition has played an important role in shifting relative demand in favour of more-skilled workers and as a consequence wage inequality has increased.

Since changes in the nonproduction worker wage premia differ across the five sectors, it is at this level that the effect of changes in trade intensity will be first investigated. There are considerable differences in each sector's exposure to international trade. Of the five sectors, scale-based industries in the early 1970s accounted for some 60% of exports (Figure 11). The natural-resource based sector is second. Both of these sectors have a greater share of exports than they do of imports. In contrast, the labour-intensive, product differentiated and science-based sectors all accounted for a greater share of imports than they did of exports.

Figure 11. Import and Export Share for 1970-71



Part of the reason for the dominance of the scale-based sector is the large quantity of two-way trade in the automobile industry. However, even when the importance of trade is measured with intensity measures—exports as a percentage of domestic shipments, the scale-based sector also dominates all others with regards to exports (Table 10). The export intensity of the scale-based sector is 34 percent, while it is 18 percent and 16 percent for the product differentiated and science-based sectors, respectively.

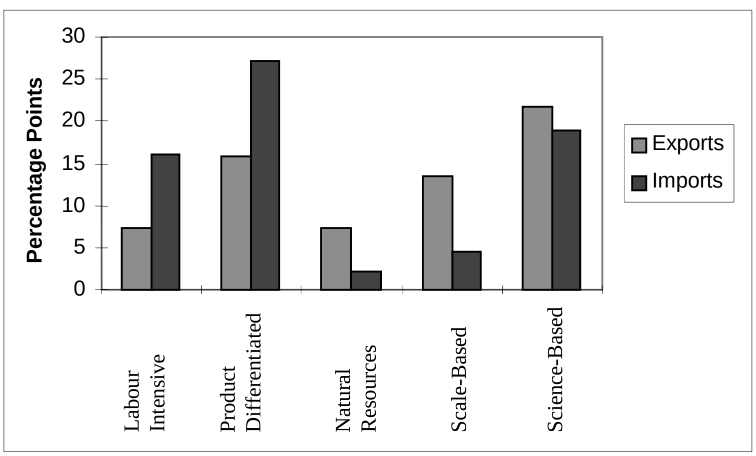
On the import side, the product differentiated sector has the highest import intensity (64%) in the early 1970s followed by the science-based sector (48%). The high tariff labour-intensive sector has only a 20 percent import intensity and the natural resource sector has the lowest import intensity at 12 percent.

All sectors experience a substantial change in trade intensity between the early 1970s and the late 1980s. However, increases are not equal for both exports and imports in each sector; patterns of specialization emerged. Import intensity increases more than the export intensity in the labour intensive sector, leaving this sector with a large negative trade balance at the end of the period. Export and import intensities increase most in product differentiated industries (15.9 and 27.2 percentage points) and in science-based industries (21.7 and 18.8 percentage points). Since science-based industries experience a lower rate of increase in import than export intensity, this sector moves towards an export orientation—even though it still retains a trade deficit by the end of the period. On the other hand, the product differentiated sector experiences a higher rate of growth in its import than its export intensity. Export intensity increases more than the import intensity in natural resource-based and scale-based industries.

Table 10. ***Export and Import Intensities by Industry: 1973-1974 and 1990-1991***

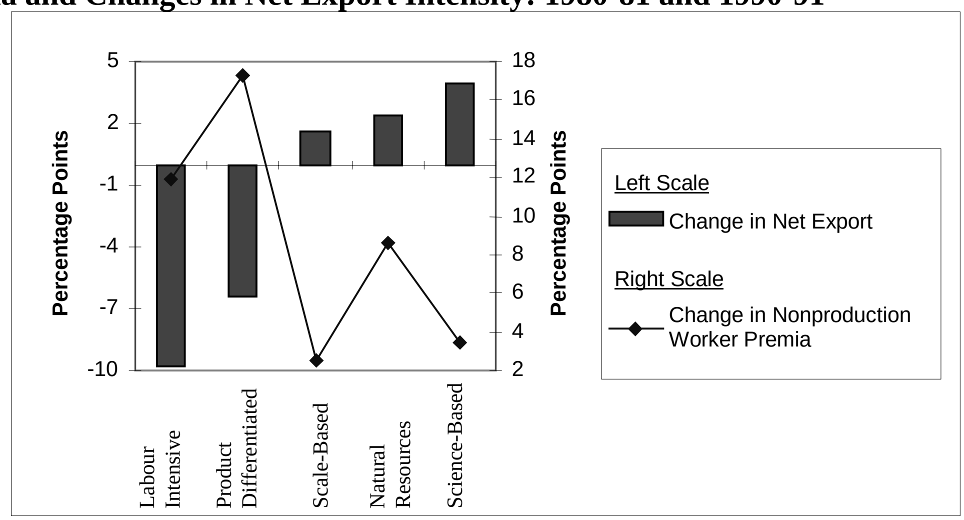
Industry	Import Intensity 1973-1974	Export Intensity 1973-1974	Import Intensity 1990-1991	Export Intensity 1990-1991
	(Percent)			
Natural Resources	12.10	14.30	14.29	21.68
Labour Intensive	20.11	6.17	36.15	13.58
Scale-Based	30.54	34.07	34.93	47.59
Product-Differentiated	64.33	18.19	91.50	34.06
Science-Based	48.07	16.22	66.91	37.87

Figure 12. Increase of Import and Export Intensity from 1970-1990



Changes in the nonproduction worker wage premia are directly related to changes in trade intensity. The sectors where import competition increased the most are those where the production worker wage fell furthest behind the highest paying scale-based industries, thereby increasing the nonproduction/production wage ratio. The wages of both production and nonproduction workers in sectors like the labour-intensive, product-differentiated, and natural resource sectors fell compared to those in the scale-based sector, but those of production workers fell more. Figure 13 plots the percentage point increase in net export intensity (export intensity - import intensity) by sector against the percentage difference in the nonproduction worker wage premia over the 1980s. The sectors are ranked from left to right by the change that occurred in net export intensity. The sectors with the greatest decrease in net export intensity (greatest increase in import intensity) generally have the largest increase in the nonproduction wage premia. The sectors with increases in net export intensity have much less of an increase in the premia. This is what would be expected if production worker wages were decreased in proportion to the size of the increase in import intensity while the demand for nonproduction workers is generally maintained by export increases.

Figure 13. The Relationship Between Changes in the Nonproduction Worker Wage Premia and Changes in Net Export Intensity: 1980-81 and 1990-91



6.1 Multivariate Analysis

While the increasing openness of the Canadian economy affected the nonproduction worker wage premia, it does not serve to explain why those sectors where the nonproduction worker premia increased most were also the sectors where the quantity of nonproduction to production workers increased rather than decreased.

Both changes in technology and changes in trade intensity would appear to be related to the observed increases in the wage differentials between nonproduction and production workers in the 1980s. Therefore, multivariate analysis is used to further explore the relationship between both trade intensity and technology and the rising wage inequality between nonproduction and production workers.

Data is brought together at the industry level[23] on trade, wages and technology use. Essentially the formulation reported at the plant level is estimated at the industry level with the addition of measures of trade intensity. Two questions are posed. The first is whether the effect of technology found at the plant level also exists at the industry level.[24] The second is whether both trade intensity and technology are found to be related to the nonproduction/production worker ratio when trade intensity is added to the effect of technology.

To determine the relative contributions of trade and technology to changes in the wage premia in the 1980s, the relative wage regression was estimated by pooling together the samples from 1981 and 1989. The basic relationship is given in equation (6.1).

$$(W_N/W_P)_j = \xi_0 + \xi_1(NETEXP_j) + \xi_2(NPR_j) + \xi_3(CLR_j) + \xi_4(TECH_{ij}) + \xi_5 D_j + \xi_6(NETEXP_j)*D_j + \xi_7(NPR_j)*D_j + \xi_8(CLR_j)*D_j + \xi_9(TECH_{ij})*D_j \quad (6.1)$$

where N and P indicate nonproduction and production labour, respectively; j indexes industry; W_N and W_P represent the wages of nonproduction and production workers, respectively; NETEXP is the net export intensity[25] which is defined as the value of net exports divided by the total value of shipments; NPR represents the use of nonproduction workers relative to production workers, CLR indicates the capital-labour ratio; D is a dummy variable = 1 for observations in 1989 and zero for observations in 1981; and $TECH_i$ represents a vector of the type of technology use (i = 1, 2,..., 6). The TECH vector includes the use of six different technologies—design and engineering (DESIGN), fabrication and assembly (FAB), automated materials handling (MATHAN), inspection and communications (INSCOM), manufacturing information systems (MANINF), and integration and control (INTCON). Technology use is measured as the proportion of industry shipments in plants using the technologies.

[23] The technology data is available at the 3-digit level.
[24] If the effect of technology is felt differently across industries and the number of plants varies by industry, aggregation from the plant to the industry level changes the weights used to estimate average technology effects.
[25] Exports and imports were used separately and were found to have coefficients whose absolute values were not significantly different from one another.

Table 11. *Trade and Technology Effects on Wage Differentials: Pooled Data*

Variable	Industry Level (1)			Plant Level (2)			Industry Level (3)			Plant Level (4)		
	Parameter Estimate		S.E.[a]	Parameter Estimate		S.E.[a]	Parameter Estimate		S.E.[a]	Parameter Estimate		S.E.[a]
Intercept	1.5979	***	0.0460	2.2279	***	0.0230	1.6290	***	0.0479	2.2395	***	0.0230
NETEXP	-0.0009	***	0.0003				-0.0010	***	0.0027			
DESIGN	-0.0035		0.0832	-0.0464	*	0.0251	-0.0173		0.0826	-0.0482	*	0.0252
FAB	-0.2060	**	0.0833	0.0235		0.0255	-0.1926	**	0.0827	0.0239		0.0254
MATHAN	0.2646	**	0.1347	-0.0285		0.0273	0.2747	**	0.1335	-0.0281		0.0273
INSCOM	-0.2661	**	0.0809	-0.1960	***	0.0258	-0.3257	***	0.0849	-0.2203	***	0.0272
MANINF	0.2588	**	0.0875	0.0473	*	0.0246	0.2429	***	0.0870	0.0487	**	0.0246
INTCON	-0.1143		0.1011	-0.0271		0.0316	-0.1172		0.1001	-0.0293		0.0316
CLR	-0.0021		0.0015	-0.0017	***	0.00003	-0.0017		0.0015	-0.0017	***	0.0003
NPR	-0.1732	***	0.0539	-0.3492	***	0.0167	-0.1707	***	0.0533	-0.3472	***	0.0167
D-CLR	0.0001		0.0015	0.0011	***	0.00037	-0.0043	*	0.0533	-0.0030		0.0016
D	0.1146	**	0.0572	-0.4328	***	0.0243	0.1575	**	0.0572	-0.4173	***	0.0253
D-CLRTECH							0.0044	**	0.0021	0.0013	***	0.0005
N[b]	190			5257			190			5257		
Adj R^2	0.394			0.156			0.406			0.157		
F	12.25			98.00			11.81			89.91		

[a] Standard error. [b] Number of observations. *** Significant at the 1% level. ** Significant at the 5% level. * Significant at the 10% level.

This equation is run with interaction binary terms (D_j) both separately for the intercept and in conjunction with each of the exogenous variables. The interactive terms reveal the extent to which there is a different impact of a particular variable in 1989 as opposed to 1981.

All variables except for technology are measured in both 1989 and 1981. Data are available from two sources. The data on technology variables come from the 1989 SMT survey. The data on all other variables that are used in this section come from a longitudinal file constructed from the Canadian Census of Manufactures that tracks plants over the period 1980 to 1993 and links plants. For the purpose of this inquiry, industry observations were taken at the 3-digit industry level since this is the lowest level at which technology characteristics of the industry can be calculated.

Table 11 reports the results for the relative wage equation derived from industry data (column 1). For comparison, the same equation is estimated at the plant level (without the trade variable). The capital-labour ratio (CLR), the relative use of nonproduction and production workers (NPR), and net export intensity (NETEXP) are, as expected, all significantly negatively related to relative wages. Thus the results above suggest that changes in net exports have affected the skilled-unskilled wage gap in the Canadian manufacturing sector during the 1980s.

The coefficients of FAB and INSCOM are significantly negative, while the coefficients of MATHAN, and MANINF are positive and significant. The use of fabrication and assembly, and inspection and communication technologies decreases the wage differentials in the 1980s. On the other hand, the use of automated material handling and manufacturing information systems technologies contributes significantly to the wage differentials. In addition, the use of both design and engineering (DESIGN) and integration and control (INTCON) technologies decreases the wage differentials. However, these coefficients are not statistically significant.

The pooled data at the plant level (column 2), which exclude the trade variable, produce very similar results to the industry-level data. Both the capital-labour ratio, its interaction term, and the ratio of nonproduction to production workers have the same signs as are reported in the industry equation and are highly significant. The use of inspection and communications (INSCOM) technologies has a negative and significant effect on the nonproduction worker wage premium, as it does at the industry level. The same is true of design and engineering (DESIGN) and integration and control (INTCON), though in this case, only the first is weakly significant. The main difference is the positive sign on fabrication and assembly (FAB) technologies in the plant equation and a significantly negative sign on the same technologies in the industry equation. The difference between the two suggests that the negative effect of this variable is larger in those industries where there are fewer plants.

The interaction term—D-CLR—is included to examine whether the contribution of the capital-labour ratio differs between 1989 and 1981.[26] The negative coefficient of D-CLR indicates that the effect of the capital-labour ratio has changed between 1981 and 1989. However, the coefficient is not statistically significant. To further investigate this change, a variable was included to test whether this differential effect of capital was related to advanced technology use. Column 3 contains the same version as column 1 with the exception of an interaction term

[26] Exclusion of other interaction terms does not change the other coefficients in any significant fashion.

between the capital-labour ratio and the use of 3 groups of technologies (fabrication, inspection and communications, and design and engineering)—D-CLRTECH—that have a similar effect on the nonproduction worker premia. This coefficient is positive and significant. Changes have occurred that have increased the nonproduction worker wage premium where the capital/labour ratio is high and these technologies are being used.

The pooled plant data that include an interaction term between capital and technology use in the second period (D-CLRTECH) produces very similar shifts to the industry equation (column 4). The nonproduction worker premia increases in 1989 relative to 1981 for those plants that are more capital intensive and that use inspection and communications technologies, design and engineering, and fabrication and assembly technologies.

It is useful to compare the effects of the trade and technology variables by contrasting their elasticities. The elasticity of the net export intensity variable is 0.013.[27] The increase in the net balance of trade between 1980-1981 and 1990-1991 for the natural resources, labour intensive, scale-based, product-differentiated, and science-based sectors is 39.45%, 55.29%, 13.62%, 11.90% and -12.60%, respectively (Table 12, column 3). If it is assumed that the net export elasticity is 0.013 across sectors, the changes in the wage premia in the 1980s attributable to the changes in net export intensity are given in Table 12 (column 4). Some 17% of the change in the wage premium in the labour intensive sector is attributable to the changes in net export intensity.[28] Changes in net trade balance contribute 7.8%, 7.2%, and 1.2% of the changes in the wage premia in the natural resources, scale-based, and product-differentiated sectors, respectively.

Table 12. ***Changes in Wage Differentials Due to Changes in Net Balance of Trade***

Industry	Percentage Change in Wage Premia (2)	Percentage Change in Net Export Intensity (3)	Change Due to Change in Net Export Intensity (4)[a]
Natural Resources	6.62	39.45	0.51
Labour Intensive	4.25	55.29	0.72
Scale-Based	2.46	13.62	0.18
Product-Differentiated	12.37	11.90	0.15
Science-Based	-0.06	-12.60	-0.16

[a] Column 3 x Elasticity (= 0.013)

[27] The net export intensity elasticity (0.013) was estimated at the mean by using the coefficient of NETEXP from Table 11. The mean ratio of wages of production and nonproduction workers and the mean net export intensity across three digit industries were 1.374 and -19.809, respectively. The value of the elasticity is positive because both the value of NETEXP and the coefficient of NETEXP are negative.
[28] The contribution of the changes in net export intensity is calculated as: (column 4 - column 2) x 100.

7. Conclusion

The past twenty years have seen a change in earnings inequality, both in the United States and Canada. The debate over the causes of increasing inequality has focused on whether it is changes in trade patterns or whether it is technological change that is at fault. This paper has demonstrated that both are at work. As other authors (Wood, 1995) have indicated, there is good theoretical reason to believe that both trade and technology go hand in hand. This is indeed the finding of this paper. Industries that have experienced the greatest increase in exports are also those where advanced manufacturing technologies are used most intensively. These are also the industries where the wages of production workers and the salaries of nonproduction workers are highest. Physical capital in the form of advanced technologies and human capital as evidenced by higher wage rates are complementary. Moreover, it is in these industries where wages and by inference human capital have been increasing the most. Industries that have experienced the greatest increase in imports are less likely to use advanced manufacturing technologies. They pay the lowest wage rates. Moreover, over the nineteen eighties, they have fallen increasingly behind the other sectors in terms of their wages paid.

This paper also shows that the effects of technology have not been felt equally in all segments of the labour market. In particular, the wages of nonproduction workers have gone up relative to production workers. Some of this is related to changing trade patterns. The differential between nonproduction and production workers is related to import intensity. Increases in import intensity over the period would have contributed to the growing wage premia. But technology use is also related to the wage premium. The premium is directly related to the intensity of use of labour-saving technologies and inversely related to the intensity of use of labour-enhancing technologies. The premia has increased over the 1980s where capital intensity and labour enhancing technology use is highest.

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