

High technology at work

Fred Wong

During the last decade, most industrialized countries have acknowledged that high-technology industries are important for their social and economic well-being ([OECD](#), 1988). Both the public and the private sectors have commissioned many studies to find ways of developing new high-tech industries and accelerating the growth of existing ones ([Brainard](#), 1988). However, no standard definition of high-tech industries exists: it varies from study to study depending on the objectives ([Markusen et al.](#), 1986). Moreover, little empirical research has been published on defining the Canadian high-tech industry except for the work of the Economic Council of Canada.

It is thus not surprising that there is no consensus on the definition of "high-tech industries". This article reviews some of the current concepts and definitions. It also examines recent employment and earnings trends in Canadian high-tech industries. A modified Economic Council of Canada definition of high-tech industry is used in this study.

Definitions of high-technology industry

The term "high technology" or "high-tech" is commonly used, but what exactly does it mean? What are its unique features and characteristics? To some people, high-tech means industries that devote much of their resources to research and development. To others, it may refer to industries that manufacture innovative and technologically advanced products (for example, new pharmaceutical products, aerospace or electronic equipment). Sometimes high-tech implies state-of-the-art processing techniques using robotic, computer-aided manufacturing or laser technology. Or, it may simply refer to industries that make fashionable consumer goods and services such as "high-tech" tennis racquets and athletic shoes, health care and cosmetic products.

The lack of a standard definition may lie in the very nature of high-tech industries. Many characteristics of high-tech industries are qualitative. It is difficult to devise scales or measurement systems to capture, for example, accelerated obsolescence, high risk or strategic importance to government. High-tech characteristics may also change quickly, influenced by market forces, public policy and technology itself

(for example, a breakthrough in research and development). These changes can alter the technological structure of an industry, and the high-tech industry group as a whole.

Despite the lack of agreement, certain criteria have often been employed to identify high-tech industries ([OECD](#), 1985). These are product sophistication, expenditures on research and development (R & D), and the proportion of scientific and technological workers in the industry.

Product sophistication

Industries are often designated as high-tech if their final product is perceived by the user to be high-tech. The advantage of this approach is simplicity ([Ministry of State for Science and Technology](#), 1987). The disadvantage is that judgements of technological sophistication are based on a range of qualitative and quantitative factors, and invariably lead to subjective and arbitrary classification ([Conklin](#), 1988). Classifying firms or industries that make both high-tech and low-tech goods is also a problem.

Currently, no standard list of high-tech products has been established. Several lists are in use, including three by the Organisation for Economic Co-operation and Development ([OECD](#), 1985), and four developed in the United States ([U.S. Department of Commerce](#), 1985). But none of these lists include high-tech services. Although all the lists are derived from slightly different methodologies, they generally use research and development activity as the most important factor identifying high-tech products. Statistics Canada has published trade statistics for high-tech products based on one of the OECD lists ([Statistics Canada](#), 1987).

R & D expenditures

The research and development activity of an industry is frequently used as an indicator of the level of technology. Industries are ranked according to their ratio of R & D expenditures to net sales of final outputs. The ranking represents the relative effort each industry puts into acquiring new knowledge to introduce or improve products or processing techniques.

But the R & D indicator has limitations. R & D expenditure ratios tend to be higher for firms producing mainly new products or using new processes than for those making well-established products. For example, the ratios are smaller for petroleum and pulp and paper firms than for computer and biotechnology firms. R & D ratios for multinational enterprises can also appear small in one country if much of their R & D activity is carried out in another country. In fact, R & D ratios could misrepresent the actual technological level of industries in a small, open economy where foreign investment and ownership of industries are significant, of which Canada is a good example ([Palda](#), 1986; [ECC](#), 1983; [Caves](#) et al., 1980).

Since the R & D ratio captures only the relative effort of industries in acquiring new technological knowledge, it says nothing about the current technological level of an industry. Moreover, the

commercial application and the exact location of the industry using the new technology are not always certain. They depend ultimately on many factors, such as the size of the potential market, tariff and non-tariff barriers, costs of capital, labour and land, and environmental impacts. In addition, actual commercial application may have a considerable time lag ([ECC](#), 1983). Hence, the R & D ratio is at best an indicator of investment in future high technology, which may or may not yield positive returns in terms of jobs and products.

Proportion of technology workers

This indicator is based on the proportion of an industry's work force employed in technology occupations. Technological workers include engineers, scientists, mathematical specialists, engineering and science technicians, and computer specialists. Conceptually, this indicator reflects the characteristics of the human resource inputs in an industry. It shows the extent of the technical skill of the labour required to make the final product. This indicator's major drawback is that it excludes manufacturing sectors that produce high-tech goods using a relatively low-skilled labour force (for example, electronic assembly plants). It also excludes industries whose state-of-the-art processing techniques require relatively few skilled workers, such as automated bottling plants and data-entry services.

U.S. Bureau of Labor Statistics definitions

The U.S. Bureau of Labor Statistics (BLS) offers three definitions of high-tech industry for labour market analysis ([Riche et al.](#), 1983). The first is based on the proportion of technological workers in the industry. An industry is high-tech if this proportion is at least 50% above the average for all industries. Under this definition, 48 out of 278 industries are included. [\(1\)](#) The second definition uses the ratio of R & D expenditures to net sales, and includes industries with at least twice the average ratio for all industries. Only six U.S. industries meet this definition.

The third definition is based on a combination of the first two. It includes industries with (1) a proportion of technology workers to total employment equal to or greater than the average for all manufacturing industries, and (2) a ratio of R & D expenditures to net sales equal to or above the average for all industries. A group of 28 industries falls under this definition.

In 1983, the first group of industries accounted for about 13% of total paid workers in the U.S., the second group for almost 3%, and the third group for slightly over 6% ([Burgan](#), 1985).

Economic Council of Canada definition

The objective of the Economic Council of Canada's (ECC) high-tech industry definition is to ascertain the extent or the intensity to which Canadian industries employ advanced technology to produce their current goods and services, not the ability of the industries to create future technology or new products. To identify the intensive high-tech users among industries, high-tech input ratios were devised (see [box](#)

[below](#)). This indicator is based on the proportion of high-technology embodied in final goods and services ([ECC](#), 1987).

To produce goods and services, industries require many inputs. A portion of these inputs often consists of high-tech goods, such as computer chips, plastic resins, graphite materials, robots, computer numerical control tools, and precision instruments. A remaining portion consists of less sophisticated inputs, such as logs and bricks. Industries are ranked in descending order of the ratio of the high-tech inputs to total inputs. The industries are then divided into three equal industry groups. The first group is classified as high-technology, the second as mid-technology, and the third as low-technology.

Conceptually, the high-tech input ratio embodies several criteria simultaneously. It accounts for the proportion of high-tech inputs that are *imbedded* in the final goods and services as well as *used* in the production processes. [\(3\)](#) Thus, the effects of the users of high-tech, rather than just the producers of high-tech goods and services, are captured. Furthermore, this approach enables service industries to be considered as an integral part of the high-tech industry analysis. The ratio shows, in relative terms, each industry's use of current high technology available from domestic and foreign sources. Ratio values indicate the intensity of usage. In other words, they capture the relative impact of current high technology on various industries.

Modification of the ECC "high-tech" definition

This study has adopted the ECC method of evaluating the technological level of industries. It ranks the industries in descending order, using the same high-tech input ratios used by the ECC.

Under the ECC technological classification, the first third of the ranking is designated as high-technology, the second third as mid-technology, and the last third as low-technology. Each technology group is extensive, covering a large segment of the economy. The high-technology group, for example, produces nearly fifty percent of the goods and services in Canada and employs about the same proportion of the work force.

To examine employment and earnings trends, a narrower high-tech industry group is defined by slightly modifying the ECC classification. In this study, industries (at the two-digit SIC level) are divided into four equal industry groups instead of three. Those in the top quartile of the ranking are designated high-technology, second-quartile industries are medium-high technology, third-quartile industries are medium-low technology, and fourth-quartile industries are low-technology. With this modified classification, each group has fewer industries and the ratio values in each group are more homogeneous ([Table 1](#)).



Table 1 The business sector by technology group

Sources: Technology Ranking of Industries, Economic Council of Canada; Employment by Industry, Input-Output Division, CANSIM. (Note that the high-tech ratio is based on 1980 data.)

Alternative methods for re-grouping the industries are also possible. For example, industries could be grouped relative to the average ratio value, which would also involve arbitrary threshold values for each group. Another method would be to group industries according to distinct breaks in the distribution of ratio values. However, no discernible breaks are evident.

Profile of Canadian industries

This study focuses on the business sector of the economy from 1977 to 1986, based on the 1980 industry ranking. [\(4\)](#) All public goods and services and the activities of religious and other non-profit organizations were excluded, as were agriculture, fishing, hunting and trapping industries. [\(5\)](#)

In total, 40 industries are examined, 10 industries in each technology group. According to the high-tech input ratio, the transportation equipment manufacturing industry ranks first overall, followed by communications, the rubber and plastics industries, and the electrical and electronic products industries. In the high-technology group, four of the ten industries are in the service producing sector; the remaining six are in the goods producing sector one in mining, and five in manufacturing. [\(6\)](#) Also, data from the Survey of Manufacturing Technologies ([Statistics Canada](#), 1989) showed that the five manufacturing industries in the high-technology group were leaders in intensive use of advanced technology and in the speed with which they embraced technologies.

The high proportion of service industries in the high-technology group reflects the technological revolution of the service industries in recent decades ([Barras](#), 1986). For example, electronic data processing, computer-aided design, medical diagnostic equipment, and advanced computer software are now standard in the related professional offices. Electronic banking and accounting systems have transformed the method of delivering financial services. Results of a recent survey have confirmed the widespread use of these technologies among Canada's service industries ([Communications Canada](#), 1989).

High-technology is popularly associated with manufacturing industries, yet most of the 19 manufacturing industries in this analysis rank low on the input ratio scale. Five manufacturing industries are found in the high-technology group, one is in the medium-high technology group, five more are designated as medium-low technology, while the remaining eight are ranked as low-technology. This ranking of manufacturing industries may be partly attributed to the high-tech input ratio being a relative, not an absolute, measure of high-tech inputs. Because substantial portions of the inputs are raw materials in many manufacturing industries, the ratios tend to be low.

Output

Measured in terms of gross domestic product (GDP) - that is, the value of all goods and services - industries in the high-technology group have less economic impact than medium-high technology industries. Between 1977 and 1986, high-technology industries produced almost a quarter of the GDP, whereas medium-high technology industries contributed nearly 50% of the GDP during this period ([Table 2](#)). Medium-low technology industries accounted for about 10% of the GDP from 1977 to 1986, while low-technology industries contributed about 16%.



Table 2 **Gross domestic product: system of national accounts in 1981 constant dollars (millions)**

Source: Input-Output Division, CANSIM



Chart A **Gross domestic product and employment: distribution by technology group, 1986**

Source: Input-Output Division, CANSIM

Over the ten-year period, the high-technology group's share of GDP gradually increased from 21% in 1977 to 25% in 1986. In contrast, the shares of the other three technology groups decreased slightly.

Employment

Each technology group's share of employment is roughly comparable to its share of GDP. Between 1977 and 1986, high-technology industries employed almost a quarter of the total paid workers in the business sector, while medium-high technology industries employed nearly half. For medium-low technology industries, the paid-worker share ranged from 15% to 16%, and for low-technology industries from 13% to 15%.

Earnings

Earnings data for the 1983-1986 period ([7](#)) show that low-technology industries had the highest annual average earnings, followed by high-technology, medium-low and medium-high technology industries ([Table 3](#)). Paid workers in the high-tech group earned, on average, 8% less than those in the low-tech

group. This is because jobs in the low-technology group were mainly in manufacturing industries, whereas many of the paid workers in the high-technology group had jobs in the service industries. The annual average wages and salaries of service jobs were generally lower than those of manufacturing jobs. Annual average earnings in medium-high and medium-low technology industries were 16% and 12%, respectively, below those of high-technology industries.



Table 3 Annual average earnings in current dollars, 1983-1986

Source: Data are derived from the Survey of Employment, Payrolls and Hours.

Employment growth

Over the 1977-1986 period, the high-tech group ranked second in both net employment growth (323,000) and rate of growth (25%). The medium-high technology group had the largest increase in the number of jobs (626,000), while the medium-low technology group had the highest growth rate (30%). In contrast, the low-technology group lost about 13,000 jobs.

As with all industry groups, most employment growth in the high-tech group occurred from 1977 to 1981, when 212,000 jobs were added, an increase of 16%. The 1981-1982 recession had a major impact on the low-technology industries, which lost 81,000 workers, a decrease of 8%. On the other hand, the high and the medium-high technology groups weathered the recession with virtually no change in employment level. In the medium-low technology group, employment growth continued, although at a much slower pace - about 2%.

In the post-recession period (1982-1986), all groups recorded employment growth. In absolute terms, the high-tech group had the second largest increase, with 146,000 additional workers. The employment growth rate was highest in the medium-low technology group (13%). In the low-technology group, employment growth was comparatively weak, increasing by only 29,000 jobs (3.3%) between 1982 and 1986.

Dynamics of the high-technology group

As a group, high-tech industries employed 1.6 million workers in 1986, up from 1.3 million in 1977. The service industries provided more than half of these jobs during this ten-year period. Moreover, the service industries' share of jobs grew from 55% in 1977 to 61% in 1986. Substantial employment increases occurred in most high-tech service industries: 80% in health services, 55% in services to business management, (8) and 45% in the finance industries. In communications, however, employment showed little change (-1%).



Chart B **Employment growth rate by technology group, 1977-1986**

Source: Input-Output Division, CANSIM

Manufacturing industries, on the other hand, employed slightly more than one-third of paid workers in the high-technology group. But manufacturing's share of all jobs in this group declined from 40% in 1977 to 36% in 1986. Compared with the service industries, the growth of high-tech manufacturing industries was moderate: 22% in rubber and plastics, 21% in transportation equipment, 6% in chemicals and chemical products and in machinery, and 3% in electrical and electronic products.

How did high-tech industries fare during the 1981-1982 recession? All high-technology manufacturing industries registered an employment decline, except for a 2% increase in the chemical products industry. The most severe decline occurred in the machinery industry, where employment dropped by 13%. The recession had less impact on the high-technology service industries - in fact, here employment continued to grow, although at a reduced rate.



Chart C **Employment distribution in high-technology industries, 1986**

Source: Input-Output Division, CANSIM



Chart D **Employment growth rate of high-technology industries, 1977-1986**

Source: Input-Output Division, CANSIM

Jobs in metal mining - the only mining industry in the high-technology group - declined by 5% during the 1981-82 recession. But this seems to be part of a longer-term decline: employment in metal mining dropped from 60,000 in 1977 to 41,000 in 1986, a decline of 32%.

Despite its employment decline, the metal mining industry had the highest post-recession average annual wages and salaries of the high-technology group. Next were transportation equipment manufacturing and the chemical product industries. The lowest average wages and salaries were paid to workers in the health services industry. Service industry workers earned less, on average, than workers in high-technology manufacturing industries.

Summary

High-technology industries can be identified by several qualitative and quantitative characteristics, yet most classification systems are based on a single characteristic. For some applications, this may be misleading. The high-technology input ratio adopted for this study accounts for several characteristics simultaneously, reflecting the relative impact of domestic and foreign high technology currently available to industry. In addition, this ratio considers service industries in the analysis of high-technology.

From 1977 to 1986, the high-technology group produced approximately one-quarter of all goods and services in the business sector of the economy. It employed a similar proportion of total paid workers, and registered the second-highest employment growth rate over this ten-year period. From 1983 to 1986, paid workers in the high-technology group had the second highest average annual earnings.

The high-technology group was not hit as hard by the 1981-1982 recession as other groups. In 1986, about half of all paid workers in the high-tech group were employed in service industries, which weathered the recession better than manufacturing industries. Overall, during the 1977-1986 period, employment growth was much higher in high-technology service industries than in high-technology manufacturing industries. However, average annual earnings in service industries were generally lower than in manufacturing industries.

Deriving the high-tech input ratio

The high-tech input ratio of an industry is derived by dividing the high-tech inputs by the total inputs. Statistics Canada's input-output tables provide estimates of non-labour inputs (made up of 600 commodities) and paid labour used by industries to produce the final goods and services of the economy. The list of commodities designated as high-tech by the Economic Council of Canada is almost identical to the commodity lists used by the U.S. and the Organisation for Economic Co-operation and Development. Ideally labour skills should also be included as a factor in deriving the ratio. Unfortunately, occupational data are not available in the input-output tables.

The ratio of high-tech inputs to total inputs was derived for the business sector [\(2\)](#) of the economy at the

two-digit level of the *1970 Standard Industrial Classification* (SIC) for 1971-1980. The industries were then ranked in decreasing order of the high-tech input ratio value. Although the ratio values fluctuated over the years, the ranking showed little change.

Notes

Note 1

The U.S. *Standard Industrial Classification Manual* (1977) groups industries into 278 categories at the 3-digit level.

Note 2

The business sector includes all transactors who operate for gain, including corporations, unincorporated business enterprises, independent professional practitioners and government business enterprises (Statistics Canada, [*National Income and Expenditure Accounts*](#), p. 102). For more details, see Statistics Canada, [*The Input-Output Structure of the Canadian Economy*](#).

Note 3

A weak argument can also be made that the high-tech input ratio implicitly takes into account R & D because some of the high-tech inputs will be used for R & D activities.

Note 4

Employment data from the input-output tables are currently available up to 1986.

Note 5

The Survey of Employment, Payrolls and Hours, the data source used to analyze earnings, does not provide earnings data for agricultural, fishing, hunting and trapping industries.

Note 6

In the high-technology group, the service-producing sector consists of communications; health services; finance industries; and services to business management. The goods-producing sector consists of transportation equipment manufacturers; rubber and plastics makers; electrical and electronic products; metal mines; machinery industries; chemicals and chemical products. Manufacturing industries comprise all the goods-producing industries except metal mines.

Note 7

Because the Survey of Employment, Payrolls and Hours dates from 1983 (when it replaced an earlier survey), earnings data are available only for the 1983-1986 period.

Note 8

Services to business management consist of the following: employment agencies and personnel suppliers; computer services; security and investigation services; advertising services; offices of architects; engineering and scientific services; offices of lawyers and notaries; offices of management and business consultants; and miscellaneous services to business management.

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This is the second of seven articles in the issue.

 HIGHLIGHTS

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Table 1

The business sector by technology group

Rank	High-tech ratio		Paid workers		Rank	High-tech ratio		Paid workers	
			1977	1986				1977	1986
			'000					'000	
High-technology			1,285	1,608				904	1,175
<i>% of total</i>			<i>21</i>	<i>22</i>				<i>15</i>	<i>16</i>
1	56	Transport equipment manufacturing	178	214	21	13	Education and related services	18	24
2	38	Communications	192	191	22	13	Textile industries	58	56
3	37	Rubber and plastics manufacturing	55	67	23	11	Insurance carriers	73	82
4	36	Electrical and electronic products	114	118	24	11	Non-metal mines	15	12
5	32	Health services	63	113	25	10	Paper and allied industries	121	116
6	30	Finance industries	173	251	26	9	Accommodation and food services	425	667
7	27	Metal mines	60	41	27	9	Storage	17	18
8	25	Services to business management	279	433	28	8	Non-metallic mineral products	54	53
9	23	Machinery industries	89	95	29	8	Printing, publishing and allied industries	96	122
10	23	Chemicals and chemical products	82	87	30	7	Leather industries	25	23
Medium-high technology			2,954	3,580				935	922
<i>% of total</i>			<i>49</i>	<i>49</i>				<i>15</i>	<i>13</i>
11	22	Amusement and recreation services	47	90	31	6	Electric power, gas and water utilities	90	92
12	20	Trade	1,416	1,773	32	4	Furniture and fixture industries	42	55
Low-technology									

13	19	Quarries and sand pits	7	8	33	4	Wood industries	110	114
14	19	Construction	575	561	34	4	Metal fabricating	152	148
15	18	Insurance and real estate	206	240	35	4	Primary metal industries	118	102
16	17	Miscellaneous manufacturing industries	62	69	36	3	Knitting mills and clothing industries	120	118
17	15	Personal and miscellaneous services	217	359	37	3	Tobacco products	9	7
18	15	Mineral fuel mines/wells	28	47	38	2	Food and beverage industries	222	228
19	14	Transportation	372	396	39	1	Logging and forestry services	54	44
20	14	Services incidental to mining	23	36	40	1	Petroleum and coal products	17	14

Sources: Technology Ranking of Industries, Economic Council of Canada; Employment by Industry, Input-Output Division, CANSIM. (Note that the high-tech ratio is based on 1980 data.)

Table 2

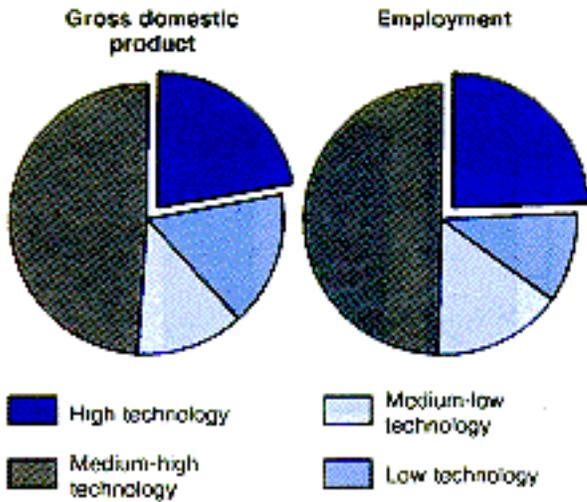
Gross domestic product: system of national accounts in 1981 constant dollars (millions)

	Total business sector	High-technology		Medium-high technology		Medium-low technology		Low-technology	
			%		%		%		%
1977	209,793	44,601	21.3	106,861	50.9	23,435	11.2	34,896	16.6
1978	212,618	46,548	21.9	104,863	49.3	25,250	11.9	35,957	16.9
1979	223,702	49,611	22.2	111,984	50.1	25,741	11.5	36,366	16.3
1980	222,130	50,189	22.6	110,206	49.6	25,614	11.5	36,121	16.3
1981	228,148	52,965	23.2	112,691	49.4	25,727	11.3	36,765	16.1
1982	214,016	50,885	23.8	107,519	50.2	22,823	10.7	32,789	15.3
1983	222,353	52,003	23.4	111,444	50.1	24,207	10.9	34,700	15.6
1984	239,265	59,268	24.8	117,153	49.0	25,208	10.5	37,636	15.7
1985	253,567	62,152	24.5	125,516	49.5	25,721	10.1	40,178	15.8
1986	261,973	64,227	24.5	129,915	49.6	27,337	10.4	40,493	15.5

Source: Input-Output Division, CANSIM

Gross domestic product and employment: distribution by technology group, 1986

High-technology's share of the gross domestic product is about the same as its share of employment.



Source: Input Output Division, CANSIM

Table 3

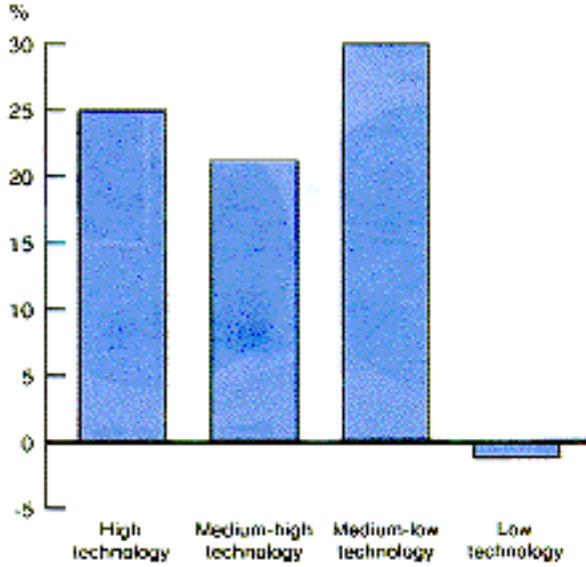
Annual average earnings in current dollars, 1983-1986

	All employees			
	High-technology	Medium-high technology	Medium-low	Low-technology
	\$			
1983	21,557	18,325	19,238	23,170
1984	22,516	18,870	19,922	24,447
1985	23,503	19,650	20,452	25,284
1986	24,146	20,206	20,828	26,033

Source: Data are derived from the Survey of Employment, Payrolls and Hours.

Employment growth rate by technology group, 1977-1986

The high-technology group had the second highest employment growth rate over the 1977-1986 period.

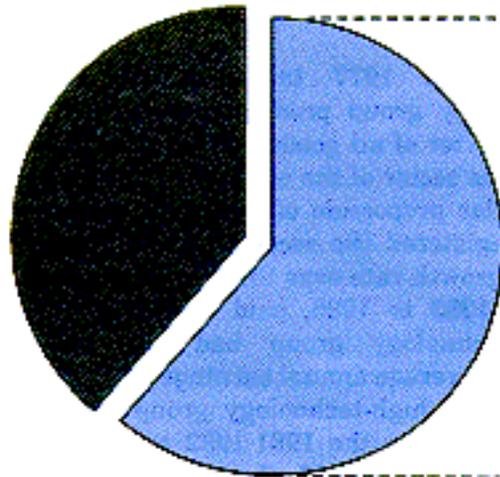


Source: Input Output Division, CANSIM

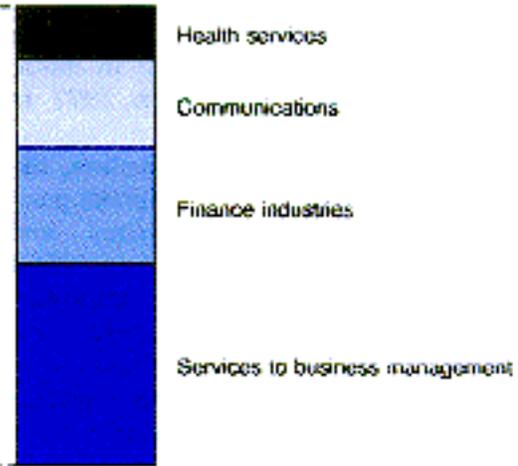
Employment distribution in high-technology industries, 1986

The majority of jobs in the high-tech group were in the service sector.

Goods sector



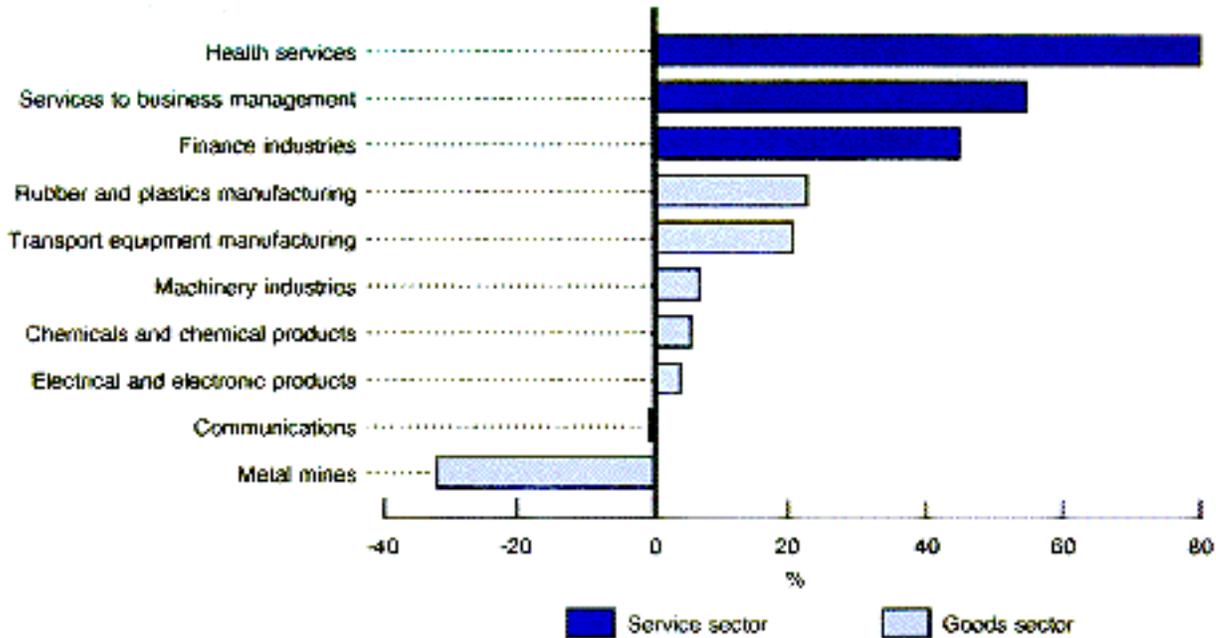
Service sector



Source: Input Output Division, CANSIM

Employment growth rate of high-technology industries, 1977-1988

In the high-technology group, service industries generally had a higher employment growth rate.



Source: Input Output Division, CANSIM