Growth of Advanced Technology Use in Canadian Manufacturing During the 1990's

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Abstract

This paper outlines the growth in advanced technology use that has taken place over the last decade in Canadian manufacturing establishments. It presents the percentage of plants that use any one of the advanced technologies studied and how this has changed between 1989 and 1998. It also investigates how growth rates in the 1990s have varied across different technologies in specific functional areas, such as design and engineering, fabrication, communications, and integration and control. In an attempt to discover how changes in technology use are related to certain plant characteristics, the paper then investigates whether the growth in technology use varies across plants that differ by size, nationality and industry. Multivariate analysis is used to investigate the joint effects of plant size, foreign ownership and industry on the incidence of technology adoption and how these effects have changed over the last decade.

***Keywords**:* growth, advanced technology use

Executive Summary

Using data from three separate Statistics Canada surveys that studied advanced technology use in the manufacturing sector, this paper details the growth that has occurred in technology use over the period from 1989 to 1998. It also examines which functional areas (design and engineering, processing and fabrication, communications, and integration and control) had the highest growth in technology use. Finally it investigates how the growth in technology use has varied across plants that differ by size, nationality of ownership and industry type. It finds:

- While growth in advanced technology during the recessionary period from 1989 to 1993 was modest, the rates of growth increased substantially between 1993 and 1998. The fastest rates of growth in the latter period occurred in the communications functional group.

- Communications technologies, which had the fastest growth in technology use during the 1993-98 period, was the area that was associated with superior plant performance (in terms of market share growth, labour productivity growth) in the 1980s.

- The individual technologies that experienced the highest growth were inter-company computer networks, local area networks, CAD/CAM design systems, programmable logic controllers, and knowledge-based software.

- Growth in technology use was large in all size classes; plants in small size classes did not catch up in any significant fashion with plants in large size classes.

- Foreign-owned plants had higher rates of technology adoption than domestically owned plants in 1989 and this gap widened substantially across almost all functional groups during the recessionary period from 1989 to 1993. While the gap did not continue to widen in all areas after 1993, it was not substantially reduced by 1998.

- The poor performance of domestically owned plants relative to foreign-owned plants over this period occured primarily in the medium and smaller size classes.

- Industries that produce innovations with regard to machinery and equipment or intermediate products that are diffused to other sectors tend to make greater use of advanced technologies. Innovation then goes hand in hand with advanced technology use.

1. Introduction

This paper outlines the growth that has occurred in advanced technology use over the last decade, the types of technologies that have experienced the highest rates of growth, and the particular types of plants that have been adopting advanced technologies most rapidly.

Our first objective is to determine whether advanced technology use has grown over the last ten years. Innovation is a key factor behind a firm's economic growth (Baldwin, 1999). Firms that best develop innovative strategies are more likely to be successful. A key element of any successful innovation strategy is the emphasis given to the development and use of advanced technologies. In earlier research, we found that firms using advanced technologies in 1989 enjoyed higher productivity, profitability, and growth levels in the 1980s than those firms not using advanced technologies (Baldwin, Diverty and Sabourin; 1995). Since the use of advanced technologies was associated with superior performance in the 1980s, we would expect technology adoption to have increased in the 1990s. The size of that increase reveals how rapidly Canadian enterprises have been adopting the technologies that are seen to be driving productivity gains in the industrial system.

Our second objective is to determine how growth rates in the 1990s varied across different technologies and to assess whether these differentials correspond to our evidence on the relative impact of these technologies in the 1980s. Our earlier work found that plant success in the 1980s was more closely related to certain types of technology use. The greatest impact of advanced technology use on a plant's success came from the use of inspection and communications technologies. These are technologies at the core of the 'soft' manufacturing revolution—where computer-based information systems combine with advanced machinery (Bylinsky, 1994). During the 1980s, establishments using advanced communications technologies enjoyed the highest rates of labour productivity and wage-rate growth. They also gained market share. Other technologies, especially those in the fabrication group, also were associated with gains in market share, relative labour productivity and relative wage rates.

Our third objective is to discover whether changes in technology use are related to certain plant characteristics. Despite the links between advanced technology use and success, not all firms adopt technologies. Even firms that adopt advanced technologies do so at differing rates. Differences in advanced technology use occur across plant size classes, across industries and across plants that differ by nationality—i.e., domestically controlled versus foreign-owned firms. Larger firms have in the past been associated with higher technology adoption rates (Baldwin and Sabourin, 1995). Foreign firms are seen to possess superior technological capabilities and have previously been shown to be more likely to use advanced technologies (Baldwin and Diverty, 1995). In addition, the scientific environment differs across industries (Jaakkola and Tenhunen, 1993), with certain industries possessing greater technological opportunities than others. In this paper, we investigate how differences in technology use are associated with plant size, nationality of ownership and industry of location. Equally, we ask whether differentials in technology use across plant sizes, nationality types, or industries have changed over the last ten years.

The paper is organized as follows. First, the data sources are described. Second, the paper examines the incidence of advanced technology use over a ten-year period for three separate years—1989, 1993 and 1998. Third, differences in the adoption rates of advanced technologies across plant sizes and between foreign and domestically owned plants are examined. Fourth, an industry breakdown of advanced technology use is provided. Fifth, multivariate regression analysis is used to investigate the joint effects of plant size, foreign ownership and industry on the incidence of technology adoption, and how these effects have changed over the last decade.

2. The Data

The data on advanced technology used for this study are taken from three Statistics Canada surveys of advanced technology use by plants in the manufacturing sector. These Statistics Canada surveys cover technology use in 1989, 1993 and 1998. The 1989 Survey of Manufacturing Technology was conducted as part of Statistics Canada's Monthly Survey of Manufacturing and was based on a sample of manufacturing establishments drawn from the monthly survey frame. Both the 1993 Survey of Innovation and Advanced Technology and the 1998 Survey of Advanced Technology in Canadian Manufacturing were based on samples of manufacturing establishments drawn from Statistics Canada's Business Register. Each of the surveys investigated the incidence of use of a set of advanced technologies. The list of technologies that were considered 'advanced' was developed with the help of a panel of industry experts. The 1989 and 1993 surveys collected information on the same 22 advanced technologies, while the 1998 survey collected information on an updated list of 26 advanced technologies, two-thirds of which were common to the previous two surveys.

In order to compare changes in advanced technology use over time, several modifications were made to the micro data derived from each survey in order to account for methodological differences.

First, while each sample was randomly drawn from a manufacturing establishment population that was stratified by size and industry, the sample frames differ in terms of their coverage of smaller plants. The 1989 survey used a frame that was the least comprehensive in terms of its coverage of small plants, being derived from a frame used for the monthly survey. The 1993 survey used the newer, more comprehensive frame derived from the Business Register and covered the entire universe of large and small manufacturing establishments. The 1998 survey was also based on the Business Register, but deliberately excluded all plants under 10 employees. Since advanced technology use differs considerably across plants of different sizes, adjustments were made to the data provided by the three surveys so as to render the intertemporal comparisons meaningful. The common population chosen covers plants with ten or more employees belonging to the Canadian manufacturing sector.

Table 2.1 Advanced Technologies by Functional Group

TECHNOLOGIES	DESCRIPTION
DESIGN AND ENGINEERING	
Computer-aided design and engineering (CAD/CAE)	• Use of computer-based software for designing and testing new products
CAD output to control manufacturing machines (CAD/CAM)	• Computer-aided manufacturing uses the output produced by CAD systems to control the machines that manufacture the part or product
Modelling/simulation technologies or digital data representation	• Used to provide a computer-based visualization of the performance of a computer-aided design, e.g., the simulation of the flow of molten plastic into an injection mold
PROCESSING, FABRICATION AND ASSEMBLY	
Flexible manufacturing systems	• Collections of computer-controlled machine tools, serviced by robots and/or automated materials handling systems overseen by computers
Programmable logic controllers	• Programmable solid state devices that are used as switching devices
Lasers for materials processing	• Used for processes such as, welding, cutting, treating, scribing, and marking
Robots with sensing	• Robots programmed to alter their function based on input from sensors—more sophisticated robots
Robots without sensing	• Robots programmed to undertake simple tasks such as pick and place—less sophisticated robots
AUTOMATED HANDLING SYSTEMS	
Automated Storage/Retrieval Systems	• Use of computer controlled equipment to handle and store goods and materials
INSPECTION	
Other automated sensor based systems used for inspection/testing of inputs/final products	• Automated sensor-based equipment used for inspecting/testing incoming materials or final products
NETWORK COMMUNICATIONS	
Local Area Network for engineering or production use	• Communication networks within a plant used for exchanging information on the 'shop floor', and with design and engineering departments
Inter-Company Computer Network	• Wide area communication networks that connect establishments with their subcontractors, suppliers and customers
INTEGRATION AND CONTROL	
Manufacturing Resource Planning	• Information system used to keep track of machine loading, production scheduling, inventory control and material handling
Computers used for Control in Factories	• These are 'stand alone' machines dedicated to controlling the manufacturing process and other functions
Computer Integrated Manufacturing	• Totally automated factory, where all activities from start to finish are co-ordinated by computers
Supervisory Control & Data Acquisition (SCADA)	• Technology which involves 'real time' monitoring and controlling of production processes
Knowledge-based software	• Software systems that use artificial intelligence or rules based on process knowledge to control manufacturing processes

Second, we had to choose a common list of technologies from each of the surveys that are used to calculate growth over time. Incidence of use is defined in this study as the percentage of establishments that indicated they were using any of the advanced technologies. In order to draw comparisons of advanced technology use over time, only technologies common to all years (17 in total) are included. These technologies are aggregated together into groups corresponding broadly to different functional areas of the production process. There are six functional groups in total. They are design and engineering; processing and fabrication; network communications; integration and control; inspection; and automated materials handling. Two of the functional groups (automated handling systems and inspection) contain only a single technology each and tend to have low adoption rates. While incidence of use in the latter two cases are included in our analysis, the report will focus primarily on technology use within each of the four main groups—design and engineering; processing and fabrication; network communications; integration and control. Table 2.1 lists the 17 technologies common to all the surveys by functional group, where each group corresponds to a different though related part of the production process. A detailed list of all the technologies found in all three surveys is included in Appendix A.

3. Growth in Functional Technology Use

Differences in the incidence of advanced technology use in 1989, 1993 and 1998 (Table 3.1) demonstrate that growth was relatively slow during the first half of the nineties, a period during which the manufacturing sector was suffering from a major economic recession. This was followed during the latter half of the decade by a period of substantial growth in technology use, a period when the economy recovered and grew more rapidly.

In 1989, the adoption rates of each of the four main functional technology groups were relatively similar. One-in-five plants used at least one technology from each of the four major functional groups (Table 3.1). Processing and fabrication technologies led the way with 21 percent of manufacturing establishments using at least one technology from this group. The three other main functional groups were slightly behind with adoption rates of 17 percentage points each.

Growth in advanced technology use during the 1989 to 1993 period was relatively modest. The slow pace of technology adoption in the first half of the decade can be attributed to recessionary pressures on the Canadian economy in the late eighties and early nineties. Despite this, design and engineering technologies managed to achieve a relatively high growth rate of 17 percentage points during this period. Integration and control, and processing and fabrication experienced weak growth over this period with increases in adoption rates of between four and seven percentage points. Virtually no growth was found for network communications during the early nineties.

In contrast to the early 1990s, the latter part of the decade has seen a dramatic increase in the adoption of advanced technologies across all of the major functional groups. Unlike the first period, network communication technologies enjoyed the highest growth in the latter half of the decade. With virtually no growth in the early nineties, the use of communication technologies led the way with an increase of 29 percentage points, highlighting the growing importance of these technologies. Integration and control maintained its strong second position with a growth of 25 percentage points, while processing and fabrication grew at a substantially higher rate (20 percentage points) than it did previously. Growth in the design and engineering group stayed constant at17 percentage points.

Table 3.1 Functional Advanced Technology Use—1989 to 1998 (Establishment Weighted)

TECHNOLOGIES	**Use** (% of establishments)		
	1989	**1993**	**1998**
Design and Engineering	17	34	51
Processing, Fabrication, Assembly	21	25	44
Network Communications	17	18	47
Integration and Control	17	24	49
Automated Materials Handling	5	4	5
Inspection	10	10	13

By the end of the 1990’s there was little variation in use across the four major groups. Roughly half of all plants were using technologies in each group. Design and engineering, integration and control and communication technologies had the highest incidence of use in 1998, with processing and fabrication technologies trailing slightly behind.

These results show that the relative growth rates in the late 1990s (after the recession of the early 1990s) correspond closely to the relative performance or success of the different technologies in the 1980s. Communications grows most quickly, followed by integration and control. It was the use of these technologies that was associated with the most success in the earlier decade. But interestingly, the growth rates of these technologies did not increase until the expansion phase of the business cycle.

4. Growth in Individual Technology Use

During the five-year period from 1989 to1993, growth rates were relatively moderate or low, except for technologies in the design and engineering group. The rising importance of computer-based and communications-based technologies occurs in the second half of the ten-year period from 1993 to 1998. To provide a more comprehensive picture, this section further investigates the growth in technology adoption rates by examining advanced technology use at the individual technology level (Table 4.1).

Table 4.1 Growth in Individual Technology Use—1989 to 1998

TECHNOLOGY	1989	1993	1998	Change from 1989 to 1998
	% of establishments			Percentage points
DESIGN AND ENGINEERING				
Computer-Aided Design/Computer-Aided Engineering (CAD/CAE)	15	30	44	29
Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM)	6	15	36	30
Digital Representation of CAD Output (modelling or simulation technologies)	4	7	17	13
PROCESSING AND FABRICATION				
Flexible Manufacturing Cells/Systems	7	7	15	8
Programmable Logic Controllers	15	18	37	22
Materials Working Lasers	2	4	9	7
Pick & Place Robots	3	5	7	4
Other Robots	3	4	8	5
NETWORK COMMUNICATIONS				
Local Area Network for Technical Data and/or Factory/Production use	12	13	36	24
Inter-Company Computer Network	9	9	29	20
INTEGRATION AND CONTROL				
Manufacturing Resource Planning (MRP II)/Enterprise resource planning (ERP)	8	9	21	13
Computers used for Control in Factories	10	16	31	21
Computer Integrated Manufacturing	3	7	18	15
Supervisory Control & Data Acquisition (SCADA)	5	8	16	11
Knowledge-Based Software	2	2	18	16
AUTOMATED HANDLING SYSTEMS				
Automated Storage/Retrieval Systems	4	4	5	1
INSPECTION				
Other automated sensor based systems used for inspection/testing of inputs/final products	10	10	13	3

Technologies within the network communication group have experienced some of the largest changes in growth rates between the two periods of comparison. With virtually no growth during the 1989 to 1993 period, these technologies experienced some of the highest growth rates for the 1993 to 1998 period. For instance, inter-company computer networks went from no growth in the first period to a 20 percentage point increase in the second period. Local area networks for technical data also experienced a large increase in growth of 24 percentage points—the highest individual increase in technology use of all technologies during the 1993 to 1998 period.

Growth in the design and engineering group was largely due to the rapid rise in the use of both computer-aided design and engineering (CAD/CAE) and computer-aided design and manufacturing (CAD/CAM) equipment. CAD/CAE technologies had the highest adoption rates of any of the individual technologies surveyed across all three survey periods. The use of CAD/CAE by establishments rose by about 15 percentage points in both periods. CAD/CAM experienced moderate increases in the first period (9 percentage points) with large increases in the second period (21 percentage points). The other technology in this group, digital representation of CAD output, experienced a relatively small growth of three percentage points between 1989 and 1993; but by 1998, the use of these technologies had grown steadily. Use of digital representation of CAD output increased by 10 percentage points between 1993 and 1998.

Technologies in the integration and control group have somewhat lower growth rates for the 1989 to 1993 period, ranging from no growth for knowledge-based software to three percentage points for supervisory control and data acquisition to six percentage points for computers used for control in factories. During the second period, however, the technologies in this group experienced substantial increases in growth. Growth was highest for knowledge-based software and computers used for control in factories at about 15 percentage points each, although a broader definition of the knowledge-based software category may account for some of this growth.

There was virtually no growth in processing and fabrication technologies during the 1989 to 1993 period. During the 1993 to 1998 period, however, this changed. Flexible manufacturing systems showed signs of moderate growth during this latter period, increasing by 8 percentage points. Programmable logic controllers led the way with an increase of 19 percentage points during this period.

The technologies within the last two functional groups, inspection and automated handling systems, have achieved little or no growth over the ten year period covered by the three surveys. This, coupled with low adoption rates in 1989, ranks them amongst the least used technologies among all the functional groups in 1998.

5. Growth in Advanced Technology Use by Size Class

It is claimed that advanced technology use and the introduction of innovations benefit from a large firm environment. While the evidence is mixed as to whether innovation increases proportionately with size (Scherer 1992), the evidence that larger firms make greater use of advanced technologies is much stronger (Baldwin and Sabourin, 1995). Previous studies have found pronounced differences in advanced technology adoption rates by plants of differing sizes. Large plants have substantially higher technology adoption rates than do small plants (Vickery and Campbell, 1989; Northcott and Vickery, 1993; Baldwin and Sabourin, 1995). Evidence also suggests that large and small plants differ markedly in their performance (Baldwin 1998) and that one major reason behind this difference in performance may be technology-use differentials.

The literature offers several reasons why large firms tend to have higher technology adoption rates than smaller firms. First, there are asymmetries of information, with larger firms being more informed about new technologies. Small firms are more likely to indicate they suffer from a lack of technical information than are large firms (Baldwin, 1997). Second, larger firms tend to have more financial and technical resources at their disposal to acquire advanced technologies. Third, production processes of larger firms tend to facilitate the implementation of advanced technologies compared to the processes found in smaller firms (Northcott and Vickery, 1993).

As the differences in advanced technology use between small and large plants is a contributing factor to differences in productivity performance, we examine here the extent to which small plants are at a “technological disadvantage” to larger plants. Data from all three survey periods are used in this section to examine how technology adoption rates differ between plants of differing sizes and whether these differences have changed over the last decade.

5.1 Functional Technology Use by Size Class

Advanced technology use increases monotonically with plant size in 1989. Adoption rates of large plants are more than double, and sometimes more than triple those of small plants in the beginning of the period. Large plants also had substantially higher adoption rates than medium-sized plants (Table 5.1).

Table 5.1 Functional Technology Use by Size- 1993 to 1998 (Establishment Weighted)

TECHNOLOGIES	Small			Medium			Large		
	(% of establishments)								
	1989	1993	1998	1989	1993	1998	1989	1993	1998
Design and Engineering	11	28	44	23	37	63	54	72	87
Processing, Fabrication, Assembly	12	15	34	30	34	62	71	70	90
Network Communication	11	10	35	23	24	69	57	60	92
Integration and Control	9	16	38	23	31	66	63	65	90
Automated Materials Handling	3	3	4	6	5	6	16	13	17
Inspection	7	6	8	13	13	18	39	41	45

Note: Small, medium and large plants are defined as having 0 to 99, 50 to 249 and 250+ employees respectively.

Growth in advanced technology use by functional category and by size class for the period from 1989 to 1993 is depicted in Figure 5.1. Technology growth during this recessionary period was primarily restricted to design and engineering, and to a lesser extent, integration and control. It is noteworthy that the difference between the size classes remains relatively constant because the growth of use in each size class is quite similar. During this period, small, medium and large plants experienced growth rates of 18, 14 and 20 percentage points respectively, within the design and engineering group. By 1993, 28%, 37%, and 72% of small, medium and large plants used at least one technology from this group. Growth in the integration and control group was fairly moderate and was restricted to small (7 percentage points) and medium sized plants (8 percentage points). Outside of design and engineering, there was virtually no growth in adoption rates for large plants during this five-year period.

Substantial growth in technology use occurred during the last half of the decade in each functional group and this held for all size classes (Figure 5.2). The functional groups experiencing the fastest growth for this period were network communications and integration and control. Processing and fabrication and design and engineering followed.

Figure 5.1 Technology Growth by Size Class—1989 to 1993 (Establishment Weighted)

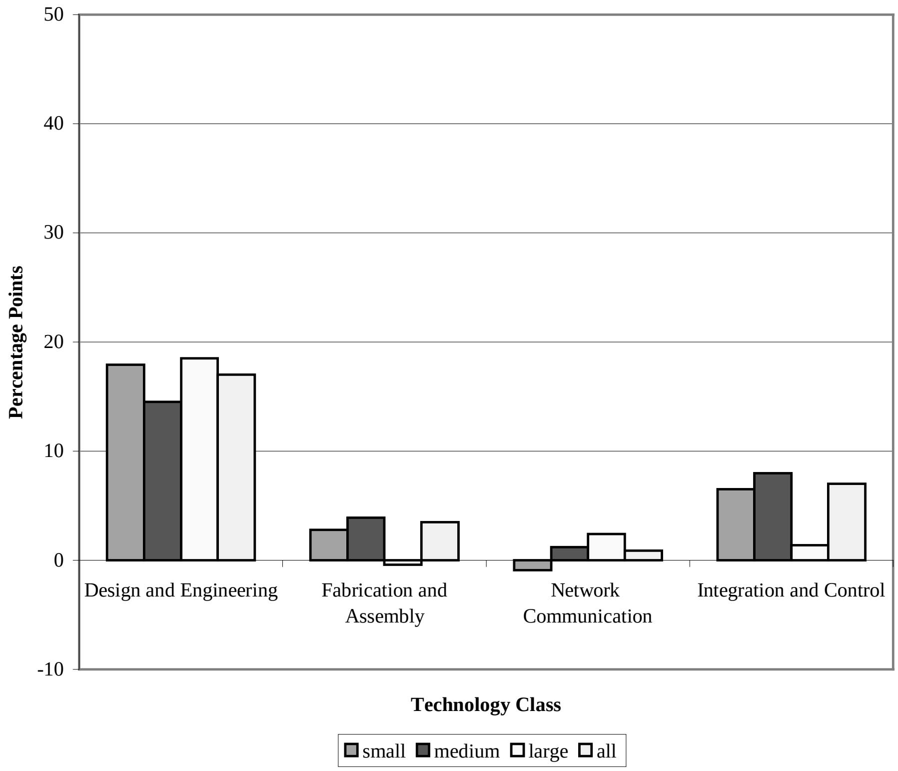
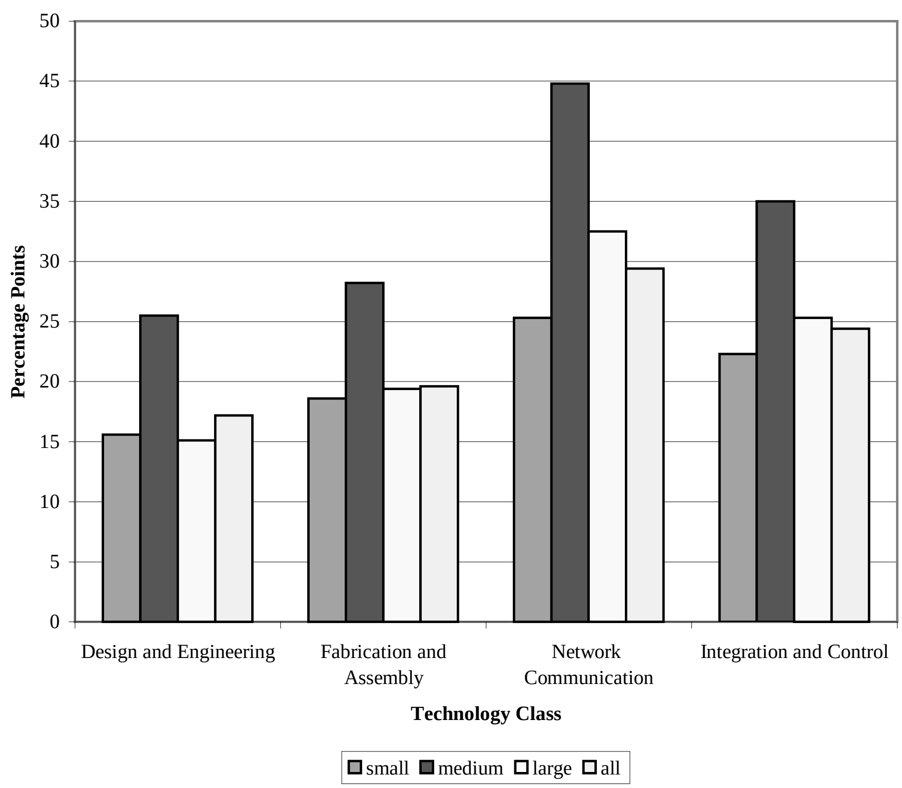


Figure 5.2 Technology Growth by Size Class—1993 to 1998 (Establishment Weighted)



The increasing use of network communication technologies occurred in all size classes. Growth rates were 25, 44 and 32 percentage points in small, medium, and large plants, respectively, during this period. All size classes also experience high growth rates in the three other functional groups, and here medium-sized plants also tended to have the highest growth rates. Growth rates for large and small plants were about the same, except in the communications group, where large plants increased their adoption rates of technologies relative to small plants.

In summary, while growth in the first part of the decade was moderate, it was substantial across all size classes over the latter part of the decade. However, except for the communications group, differences in the adoption rates between small and large plants have not changed during the nineties. The relative increase in the adoption rates of large plants over small plants in the communications group suggests that smaller plants have fallen behind in one of the most important functional groups in the last decade. By contrast, the medium size classes have reduced the gap between themselves and the largest plants in all of the functional groups over the same period.

6. Growth in Technology Use by Ownership

The effect that nationality of ownership has on the adoption of technology use is an important issue for Canada. With the globalization of markets, Canadian-owned businesses are faced with an increasingly competitive environment. This has heightened interest as to whether Canadian-owned firms are able to compete with foreign-owned firms.

Evidence on cross-country productivity differences between Canadian and U.S. firms suggests that Canadian firms lag behind their U.S. counterparts in terms of productivity and advanced technology adoption rates (Baldwin and Gorecki, 1986; Baldwin and Dhaliwal, 1999; and Baldwin and Sabourin, 1998). This paper develops further evidence on whether technology adoption rates between Canadian-owned and foreign-owned plants differ, and how these differences have changed over time.

Multinational firms make up a large portion of the Canadian manufacturing sector, accounting for over 60% of shipments. These foreign-owned firms play a significant role in transferring innovative ideas from one nation state to another (Caves 1982, and Dunning 1993). The transfer of innovative skills is partially accomplished through the adoption of advanced technologies that are first developed abroad. Multinational firms may, therefore, be expected to be among the more intensive users of advanced technologies. This section uses the results from the 1989, 1993, and 1998 technology surveys to examine how the level of advanced technology use differs between Canadian and foreign-owned plants in the Canadian manufacturing sector, and the extent to which these differences, if any, have changed over time.

6.1 Individual and Functional Technology Use by Ownership Structure

There is a marked difference between the technology adoption rates of Canadian and foreign-owned plants at the functional level in all three survey years (Table 6.1). In 1989, differences in technology use between foreign- and domestically owned plants were largest in the areas of integration and control as well as processing technologies.

During the recession between 1989 to 1993, foreign-owned plants increased their use of technologies at a faster rate than domestically owned firms. This supports the view that foreign-owned plants generally react less to local or domestic macro-economic conditions.

Table 6.1 Functional Technology Use by Ownership—1989 to 1998 (Establishment Weighted)

TECHNOLOGIES	1989 Survey		1993 Survey		1998 Survey	
	Canadian Owned	Foreign Owned	Canadian Owned	Foreign Owned	Canadian Owned	Foreign Owned
	% of Establishments					
Design and Engineering	16	23	31	50	50	61
Processing, Fabrication, Assembly	18	37	20	45	41	69
Network Communications	14	30	14	35	44	73
Integration and Control	13	34	19	44	47	66
Automated Materials Handling	4	6	3	7	5	6
Inspection	8	21	8	20	11	27

The growth of adoption rates between 1989 and 1993 for foreign- and domestically owned plants is depicted in Figure 6.1. During this period, the design and engineering and integration and control functional groups experienced the fastest growth in technology adoption in both foreign- and domestically owned plants (Figure 6.1). Nevertheless, the difference between foreign- and domestically controlled plants widened during this period. Adoption rates for Canadian-owned plants in these two groups grew by 15 and 6 percentage points, respectively; adoption rates for foreign-owned plants grew 27 and 10 percentage points, respectively. Little or no growth occurred for either Canadian or foreign-owned plants in the remaining functional groups, with the exception of a eight percentage point increase in the processing and fabrication group by foreign-owned plants.

By 1993, the functional group with the highest rate of technology adoption was design and engineering for both foreign (50%) and domestically owned (31%) plants. The largest disparity in advanced technology use between foreign and domestically owned plants was in processing and fabrication, with 45% of foreign-owned plants using technologies in this group compared to 20% of domestically owned plants. Foreign-owned plants also had higher rates of advanced technology use in integration and control (44 percentage points) and network communications (35 percentage points).

Figure 6.1 Functional Technology Growth by Ownership: 1989 to 1993 (Establishment Weighted)

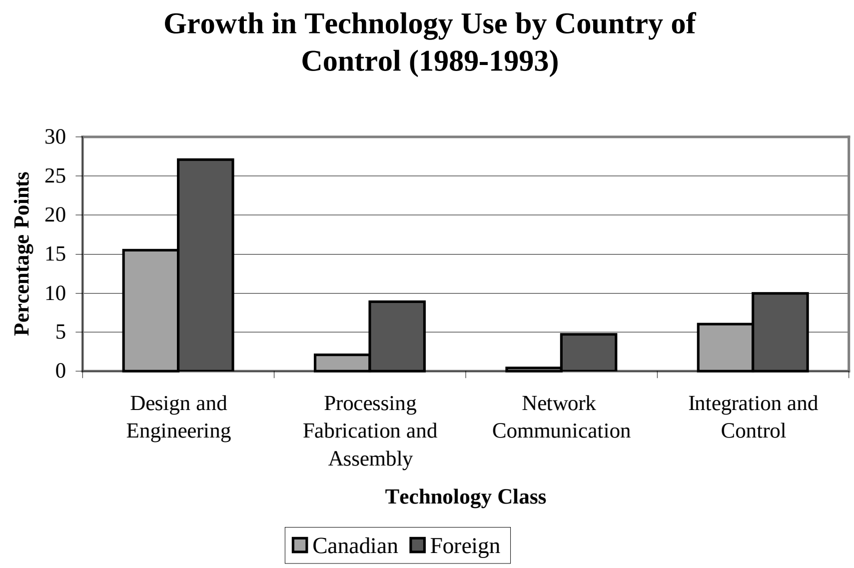
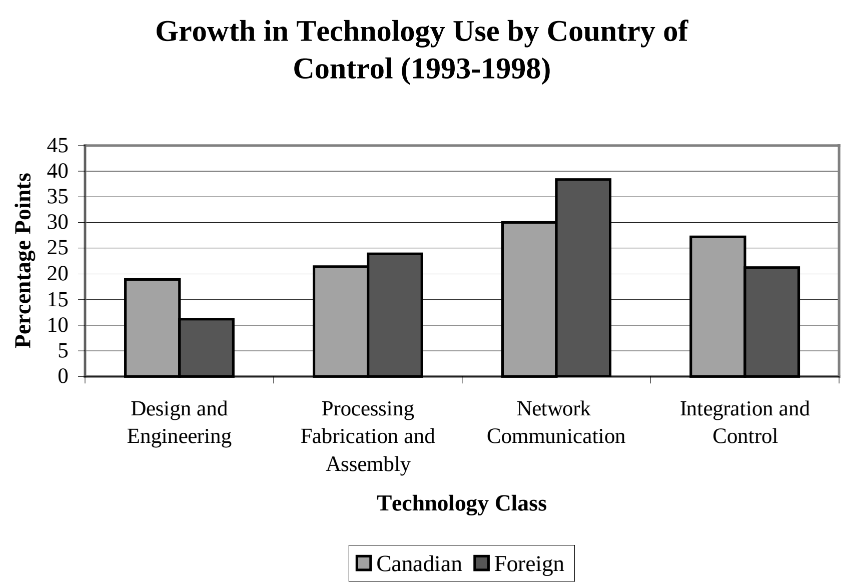


Figure 6.2 Functional Technology Growth by Ownership: 1993 to 1998 (Establishment Weighted)



In the second period, foreign-owned plants continued to have higher growth rates for network communications, as well as for processing and fabrication; but this was not the case for design and engineering and integration and control (Figure 6.2).

Network communications had the highest rate of growth of all functional groups in the second period, and here growth was higher for foreign-owned plants. Technology adoption rates for this group increased by 38 percentage points for foreign-owned plants, while they increased by only 30 percentage points for domestically owned plants. Foreign-owned plants also experienced slightly higher growth in the processing and fabrication group (24 percentage points for foreign-owned versus 21 percentage points for domestically owned plants) during this period. By way of contrast, in the second period, domestically owned plants experienced higher growth in the two other major functional groupings—design and engineering and integration and control.

In 1998, the largest disparities between Canadian and foreign-owned plants were in the processing and fabrication and the network communications groups. Moreover, these differences had increased from those existing in 1989. Almost 30% more foreign-owned establishments used technologies from each of these groups than did domestically -owned plants. Even in those areas (design and engineering and integration and control) where adoption rates in domestically owned plants had grown more quickly in the second half of the decade than in foreign-controlled plants, domestic plants still lagged behind those of foreign-owned plants in 1998 (Table 6.1). Moreover, the gap in 1998 was not appreciably different from that existing in 1989.

In summary then, domestic-owned plants either fell behind foreign-owned plants over the course of the decade in the key areas of network communications and processing or did not manage to appreciably close the technology gap in other areas like integration and control as well as design and engineering.

6.2 Ownership Structure Differences By Size Class

Since domestic plants tend to be smaller than foreign controlled plants, and size differences are associated with differences in technology use, we present a breakdown of technology use by ownership within each size class in Table 6.3. To illustrate how these technology use differences have changed over time, we also present a series of graphs showing technology-use differentials between foreign-owned and domestically owned plants for each size class over time (Figures 6.6a-6.6d). Each point on the graphs indicates the difference in technology use by ownership (foreign adoption rates minus domestic adoption rates) for a given size class and survey period. A positive slope indicates the difference between foreign and domestic plants has widened; a negative slope shows the reverse has occurred.

When size is taken into account, differentials between foreign and domestically-owned plants continue to exist, although they are reduced. More importantly, while the gap between foreign- and domestically plants generally widens over the period 1989 to 1998, this does not occur in every size class.

Table 6.2 Growth in the Use of Individual Technologies by Canadian- and Foreign-Owned Plants—1989 to 1998 (Establishment-weighted)

TECHNOLOGY	1989 Survey		1993 Survey		1998 Survey	
	Canadian	Foreign	Canadian	Foreign	Canadian	Foreign
	% of establishments					
DESIGN AND ENGINEERING						
Computer-Aided Design/Computer-Aided Engineering (CAD/CAE)	14	21	27	47	43	57
Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM)	6	6	14	14	36	34
Digital Representation of CAD output (modelling or simulation technologies)	4	5	6	9	17	22
FABRICATION AND ASSEMBLY						
Flexible manufacturing cells/systems	6	13	6	14	14	29
Programmable (Logic) Controllers	13	31	14	38	34	64
Materials Working Lasers	2	2	3	4	8	9
Pick & Place Robots	2	8	3	11	6	15
Other Robots	2	7	3	6	7	13
AUTOMATED HANDLING SYSTEMS						
Automated Storage/Retrieval Systems	4	5	3	7	5	6
INSPECTION						
Other automated sensor based systems used for inspection/testing of inputs/final products	8	21	8	20	11	27
NETWORK COMMUNICATIONS						
Local Area Network for technical data and/or production/factory use	9	22	10	28	33	61
Inter-Company Computer Network	6	20	7	18	26	57
INTEGRATION AND CONTROL						
Manufacturing Resource Planning (MRP II)/Enterprise resource planning (ERP)	6	14	7	21	18	39
Computers used for Control in Factories	7	22	12	33	29	49
Computer Integrated Manufacturing	3	8	6	10	18	22
Supervisory Control & Data Acquisition (SCADA)	4	10	6	16	15	25
Artificial Intelligence/Expert Systems	1	2	1	2	12	24

Over the decade, large plants closed the gap for all but design and engineering, whereas medium-sized plants experienced a widening gap for all but integration and control technologies. Small plants showed mixed results, giving ground in the area of design and engineering as well as integration and control technologies, while losing ground in processing and control and network communications.

In summary, the poor overall performance of the domestic sector described in the previous section must be attributed primarily to the medium and smaller size classes.

Table 6.3 Size Breakdown of Functional Technology Use by Ownership 1989 to 1998 (establishment weighted)

Survey Year	Country of Control by Size	***Functional Technology Group***					
		Design and Engineering	**Processing, Fabrication, Assembly**	**Network Communications**	**Integration and Control**	**Automated Materials Handling**	**Inspection**
		% of establishments					
1989	**Canadian**						
	Small	11	12	9	8	4	6
	Medium	22	26	21	19	5	11
	Large	57	64	52	57	14	40
	Foreign						
	Small	8	15	18	19	1	20
	Medium	26	42	30	36	7	20
	Large	50	76	61	69	17	37
1993	**Canadian**						
	Small	28	13	8	14	2	5
	Medium	35	30	23	27	4	12
	Large	68	62	57	59	15	40
	Foreign						
	Small	33	31	27	33	5	15
	Medium	49	42	28	43	7	14
	Large	77	75	62	69	11	42
1998	**Canadian**						
	Small	45	33	34	38	4	7
	Medium	61	57	67	64	6	16
	Large	85	91	91	91	18	44
	Foreign						
	Small	33	45	56	40	1	15
	Medium	73	82	79	78	6	29
	Large	91	86	95	88	16	49

Tables 6.6a - 6.6d Differences in Technology Use Between Foreign and Canadian-Owned Plants by Functional Group (Establishment Weighted)

Figure 6.6a Design and Engineering

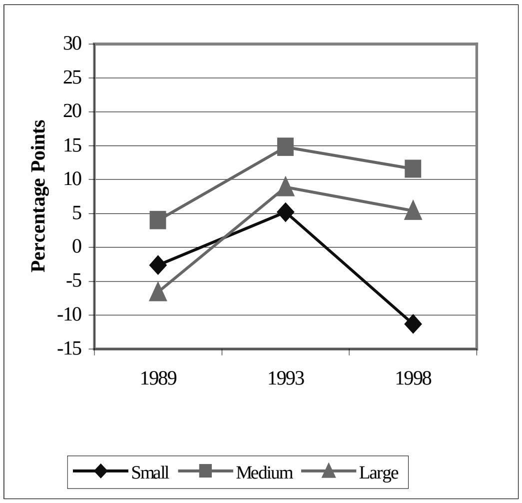


Figure 6.6b Processing and Fabrication

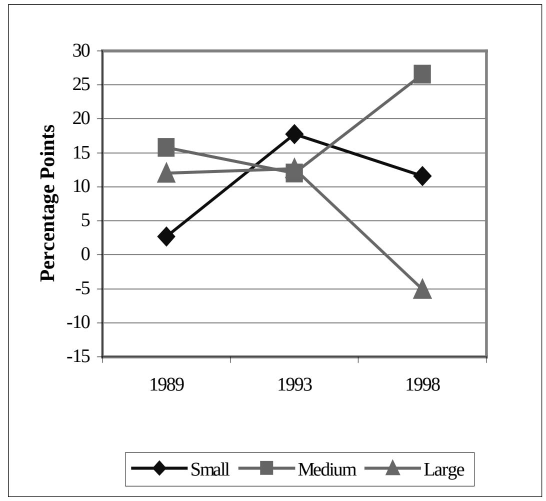


Figure 6.6c Network Communications

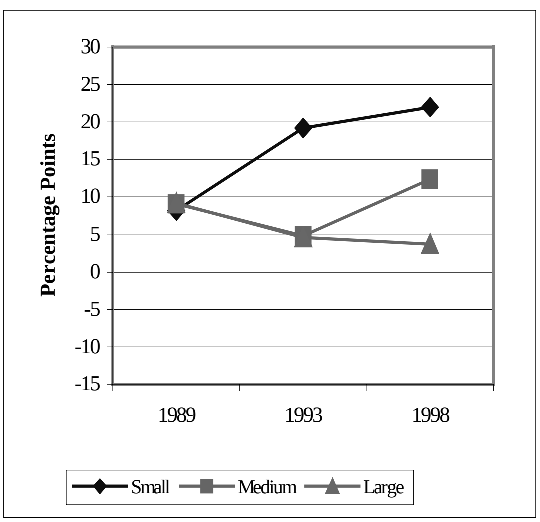
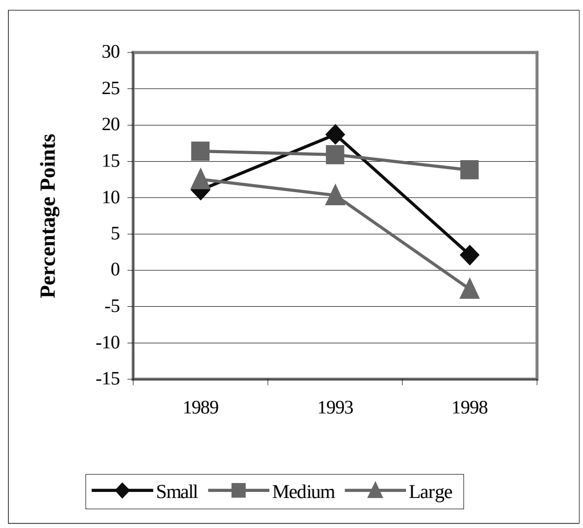


Figure 6.6d Integration and Control



7. Growth in Technology Use by Industry

There are substantial differences in advanced technology use across industries (Jaakkola and Tenhunen, 1993; Baldwin and Sabourin, 1995). Certain industries have greater technological opportunities than others, since the scientific environment in some sectors is more conducive to technology change.

Evidence suggests that firms in industries relying on science-based research are more likely to be innovative (Baldwin, Hanel and Sabourin, 1999). Since the introduction of advanced technology is often associated with an innovation, advanced technology use will be more prevalent in these industries. In this section, we examine whether differences in technology use are related to the innovative environment of an industry and whether the relative importance of advanced technology use by industry has changed over time.

There are many factors that contribute to inter-industry differences in advanced technology use. Differences in plant size, financial capabilities and the applicability of certain technologies all contribute to differences in advanced technology use across industries (Jaakkola and Tenhunen, 1993). For example, industries dominated by larger plants tend to reflect the higher technology adoption rates associated with these larger plants.

For our analysis, we use a taxonomy proposed by Robson et al. (1988) to group industries into one of three industrial sectors, categorized according to their degree of innovativeness. The three sectors are: core, secondary and 'other'. The individual industries in each group are listed in Table 7.1. The core sector is highly innovative, producing mainly innovations or technologies used either in this sector or elsewhere. The secondary sector is less innovative and uses technologies produced both by itself and the core sector. It also diffuses technology to the 'other' sector—though with less intensity than the core sector. The remaining industries make up the 'other' sector. They create new processes by absorbing innovations (both in the form of machinery and equipment and intermediate products) from the core and secondary sectors. The technology adoption rates for each of these three sectors are presented in Table 7.1.

Table 7.1 Growth in Advanced Technology Use by Industry Sector—1989 to1998 (Establishment Weighted)

Industry Sector	Functional Technology Group							
	Design and Engineering		Processing and Fabrication		Network Communications		Integration and Control	
	1989	1998	1989	1998	1989	1998	1989	1998
	% of establishments							
Core	30	63	24	53	21	59	24	57
Secondary	18	61	26	51	16	49	19	52
Other	14	39	16	35	14	41	13	42

In 1989, industries within the core sector had moderately higher adoption rates than secondary industries, but substantially higher adoption rates than 'other' industries in all functional groups. The most pronounced differences occurred within design and engineering and integration and control, where twice as many plants in core sector industries were using at least one of these technologies than industries in the 'other' sector.

The use of advanced technologies rose substantially from 1989 to 1998 across all industry sectors for all functional groups (Table 7.1). The differences between the core and 'other' sector widened over this period.

As the extent of the change in advanced technology use within each sector during this ten-year period differs across industries and technology groups, we investigated whether there were systematic changes within the overall population in the importance of advanced technology use. To do so, we ranked each of the 21 individual industries using their incidence of use in each of the functional groups for 1989 and 1998. These functional group rankings were then averaged across the four groups to yield an overall ranking for 1989 and for 1998. These two yearly rankings were then added to determine an overall rank for the ten-year period. These rankings are provided in Table 7.2.

Generally industries that ranked in the upper tertile for advanced technology use across all groups in 1989, also ranked in the upper tertile in each of the functional groups (for a detailed listing of industrial technology use rankings by functional group by year, refer to Appendix B). The highest-ranking industries in 1989 were the transportation equipment, primary metals, paper and allied products, tobacco, beverage, electric and electronic products, machinery and refined petroleum industries. The clothing, wood, furniture and fixtures, other manufacturing, textile and leather and allied products industries had the lowest technology adoption rates in 1989.

By 1998, there was relatively little change in the overall rankings within the upper, middle and lower tertiles (Table 7.2). The Spearman correlation between the 1989 and 1998 rankings of all 21 industries is 0.63.

Nevertheless, there have been some shifts in industry rankings within functional groups from 1989 to 1998, indicating possible shifts in the relative importance of certain production processes. The three industries that experienced the greatest shifts in functional technology use are the beverage, rubber and refined petroleum industries. The beverage industry experienced a large shift away from the use of design and engineering technologies (falling from ninth to eighteenth) towards communication (growing from seventh to first) and integration and control technologies (growing from tenth to second). The refined petroleum and rubber industries saw their ranking fall relative to other industries with regards to the use of technologies in three of the major functional groups. The overall rankings for the rubber industry fell from seventh to tenth, but the refined petroleum industry fell from sixth to thirteenth during the ten-year period.

Table 7.2 Industry Ranking by Technology Use

INDUSTRY	1989 Rank	1998 Rank	Overall Ranking
Core			
Electrical and Electronic Products	6	1	3
Machinery	6	6	6
Chemical and Chemical Products	8	10	9
Refined Petroleum	6	13	11
Secondary			
Primary Metal	2	2	1
Transportation	1	7	3
Rubber	7	10	8
Plastic Products	11	8	10
Fabricated Metal Products	12	9	12
Non-Metallic Minerals	10	12	13
"Other"			
Tobacco	4	1	2
Paper and Allied Products	3	3	4
Beverage	5	4	5
Primary Textiles	9	5	7
Printing and Publishing	13	14	14
Wood	15	15	15
Other Manufacturing	17	11	16
Textile	18	15	17
Furniture and Fixtures	16	16	18
Clothing	14	17	18
Leather and Allied Products	19	16	19

In summary, there has been large growth in advanced technology use across each industry sector over the last decade. Despite inter-industry shifts between functional technology groups, industries that were among the leaders in advanced technology use in 1989 continued to be so in 1998.

8. *Multivariate Analysis*

Model Selection

Technology adoption is related to various plant characteristics such as plant size, ownership structure and sector of activity. The previous sections examined the relationship between each of these factors taken separately and advanced technology use. In this section we will investigate their joint effects using multivariate analysis. In order to explore whether the effects of these factors have changed during the nineties, technology adoption logit regressions are estimated using micro data from the three surveys and the following model specification:

$$T_i = f(S_i, O_i \ I_i)$$

where T_i refers to the incidence of advanced technology use, S_i to plant size in period i, O_i to plant ownership structure in period i and I_i to industrial sector in period i.

Dependent Variable

The dependent variable is a dichotomous variable measuring incidence of advanced technology use. Incidence of use is measured for all technologies taken together and for technologies within each of the four main technology groups. The overall incidence of technology use variable measures whether a plant uses at least one technology from the 17 advanced technologies common to all three surveys. It takes a value of one if a plant is using at least one of these technologies, zero otherwise. We also estimate incidence of use at the functional group level—design and engineering, processing and fabrication, network communications and integration and control. Four dependant variables were calculated in order to capture incidence of advanced technology use within each of these technology sub-groups. Each is defined to have a value of one if at least one of the technologies within that group is being used, and a value of zero otherwise.

Explanatory Variables

We investigate the effects of the three variables previously examined in our bivariate analysis—plant size, country of control and industrial sector on advanced technology use. We also examine whether these effects have significantly changed over time.

Establishments are classified as belonging to one of three size categories—small (10 to 49 employees), medium (50 to 249 employees) and large (250 or more employees). Three binary variables are used to capture these size effects. Country of control effects are measured by a binary variable taking a value of one if the plant is foreign-owned and zero otherwise. Three binary variables corresponding to the three industrial sectors, taken from the Robson et al. (1988) taxonomy discussed previously, are used to capture industry effects.

Estimation Procedures

In order to examine size, ownership and industry effects on advanced technology use in the Canadian manufacturing sector over a ten-year period from 1989 to 1998, the following pooled logistic regression equation is estimated:

$$T = \beta + \beta_1 * \text{SIZE} + \beta_2 * \text{FOREIGN} + \beta_3 * (D_{98} * \text{SIZE}) + \beta_4 * (D_{98} * \text{FOREIGN}) + \beta_5 * \text{INDUSTRY} + \varepsilon$$

where T refers to the pooled dependant variable measuring the use of at least one technology. SIZE, FOREIGN and INDUSTRY refer to the pooled explanatory variables of size, ownership and innovative sector. D_{98} is a dummy variable that takes a value of one if the corresponding observation is from the 1998 data set and zero if the observation is from the 1989 data set. D_{98}*SIZE and D_{98}*FOREIGN capture whether the effects of size and ownership have changed over the period. The industry variable is used as a control variable. The descriptive statistics associated with the pooled dependant and independent variables for the entire data set are presented in Table 8.1.

The coefficients β_1 and β_2 represent the size and ownership effects, respectively, for the base year (1989). The coefficients β_3 and β_4 represent the interaction or shift effects for these variables, that is, they capture whether size and ownership effects have changed from 1989 to 1998. The 1998 size and ownership effects are determined by adding the base year (1989) and the shift or interaction coefficients. For example, the 1998 size effect is captured by adding the coefficients $\beta_1$and β_3. The coefficient β_5 captures industry effects. Although evidence of industry shifts over time was found, these effects were generally not found to be statistically significant, and hence industry interaction terms were not included.

Empirical Results

The results of the logistic regression models for the probability of using at least one technology are presented in Table 8.2. Weighted estimates are provided for all of the models. All regressions are estimated against an excluded plant that is small, Canadian-owned and in the core sector.

The parameter results in Table 8.2 provide the qualitative effects of the explanatory variables. In order to present quantitative effects, probability estimates are provided in Table 8.3. The probabilities are calculated by estimating the logit equation at the sample means.[1]

Plant size is positive and statistically significant for all of the functional groups in the base year. Larger plants are more likely to use at least one of the 17 technologies than are smaller plants (column 1, Table 8.2). The probability of adopting at least one of the technologies for large plants is more than double that for small plants (Table 8.3). Close to 90% of large plants have adopted at least one technology compared to only about 40% of small plants. Similar effects are found at the functional group level (columns 2 to 5, Table 8.2). The size effects are greatest for processing and fabrication and integration and control, where the probability of using at least one technology ranges from 65 to 70 percent for large plants compared to only about 15 percent for small plants.

The effects of foreign ownership present a somewhat similar story. Foreign ownership matters. The foreign ownership coefficients are positive and statistically significant for all but the design and engineering group in the base year. Overall, foreign-owned plants have a 61% probability of adopting at least one technology compared to 50% for Canadian-owned plants in 1989. At the functional level, the largest difference in the probability of using at least one technology between foreign and Canadian-owned plants is found for the integration and control group. Foreign-owned plants are almost twice as likely to adopt at least one technology from this group than their Canadian-owned counterparts. The coefficients for design were negative and statistically significant, indicating that Canadian-owned plants are more likely to adopt design and engineering technologies than foreign-owned plants—perhaps because this function is carried out abroad by the foreign parent.

[1] Probabilities are estimated by: P = exp((x)/[1 + exp((x)].

Table 8.1 Overview of Dependent and Independent Variables for Technology Incidence Regression (Establishment Weighted)

Variable	Description	Mean	Standard Deviation
1. Dependent Variables			
Incidence of use	Incidence of Technology Use		
USER	- across all functional groups	0.61	0.49
DESUSE	- design and engineering	0.36	0.48
FABUSE	- processing and fabrication	0.40	0.49
COMUSE	- network communications	0.29	0.46
CTLUSE	- integration and control	0.35	0.48
2. Plant Characteristics			
Establishment Size	Employment Size		
ESTSIZE1	- 10 to 49 employees	0.61	0.48
ESTSIZE2	- 50 to 249 employees	0.32	0.47
ESTSIZE3	- 250 + employees	0.07	0.25
Ownership	Country of Control		
FOREIGN	- Foreign owned	0.15	0.36
3.Industry Characteristics			
Innovative Sector	Innovative Industrial Sector		
ISECT1	- Core Industries	0.16	0.36
ISECT2	- Secondary Industries	0.33	0.47
ISECT3	- Other Industries	0.52	0.50

Table 8.2 Logit Model of Size and Ownership Effects on Technology Use (Establishment Weighted)

Variables	FUNCTIONAL GROUPS				
	All Groups	**Design**	**Fabrication**	**Communications**	**Control**
Intercept	-0.15***	-1.11***	-1.65***	-1.62***	-1.78***
Base Year 1989					
esize2	1.03***	0.87***	1.24***	0.92***	1.05***
esize3	2.30***	2.04***	2.61***	2.30***	2.46***
foreign	0.43**	-0.35*	0.42**	0.35*	0.70***
Shift Effect 1998:					
sh_size1	1.22***	1.42***	1.38***	0.93***	1.47***
sh_size2	1.77***	1.36***	1.39***	1.46***	1.56***
sh_size3	3.28***	1.62***	2.00***	1.62***	1.64***
sh_foreign	-0.35	0.14	0.33	0.18	-0.50*
Control Variable					
isect2	-0.27	-0.24	-0.29	-0.26	-0.05
isect3	-0.67***	-1.01***	-0.29**	-0.63***	-0.39***
Log-likelihood	-4190	-4066	-4134	-3751	-4007
N	7265	7265	7265	7265	7265

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Turning to shifts over time, the coefficients on the size interaction terms are positive and highly statistically significant for all functional groups, indicating that each size class has a greater likelihood of adopting at least one technology in 1998 than it did in the previous period. However, the differences in incidence of use between large and small plants that were found in 1989 persist in 1998 and the magnitude of these differences has remained about the same for all but the communications group. In the communications group, the difference in the probability of use between large and small plants has actually grown by 13 percentage points.

The 1998 shift effects for foreign ownership are generally not significant, thereby indicating that domestic plants did not consistently close the gap that existed in 1989. Integration and control is the only group with statistically significant coefficients on the foreign interaction terms. The coefficient is negative, indicating that the effect of being foreign-owned diminished by 1998. That is, Canadian-owned plants were "closing the gap" with their foreign-owned counterparts for this group of technologies. The effect of foreign-ownership on advanced technology use in 1998 has not significantly changed from 1989 for the rest of the functional groups. These results are reflected in the probabilities presented in Table 8.3.

The coefficients attached to the industry sectors indicate that 'other' industries have a lower likelihood of using advanced technologies than do core industries, on average. This is most evident for design and engineering and integration and control, where about 50 percent of plants in 'other' industries use technologies from each of these groups, compared to 73 and 64 percent of core industries, respectively. The coefficients for the secondary sector were negative but not statistically significant, indicating that there were no real differences in the likelihood of the core and secondary sectors using at least one technology.

Table 8.3 Estimated Probabilities of Using at Least One Technology

Variables	User	Functional Groups			
		Design and Engineering	Processing and Fabrication	Communications	Integration and Control
Establishment Size					
1989 - ESIZE1	39	16	15	13	13
ESIZE2	65	29	38	28	31
ESIZE3	87	59	70	60	64
1998 - ESIZE1	69	43	41	28	38
ESIZE2	91	62	71	62	66
ESIZE3	99	88	95	88	90
Ownership					
1989 - FOREIGN	61	17	31	24	32
DOMESTIC	50	23	23	18	19
1998 - FOREIGN	88	45	65	51	56
DOMESTIC	82	54	55	42	51
Industry					
ISECT1	92	73	74	64	71
ISECT2	92	73	74	64	71
ISECT3	86	49	68	48	62

9. Conclusion

The use of advanced technologies over the last decade has grown rapidly as firms have increasingly incorporated these technologies into various stages of the production process. However, the growth in advanced technology use in the first half of the 90's was relatively slow. The slow pace of technology adoption in the first half of the decade can be attributed to recessionary pressures on the Canadian economy in the late eighties and early nineties. Only technologies within the design and engineering group achieved substantial growth during this period, most of which was contributed by growth in computer-aided design and engineering technologies. Over the second half of the decade, functional technology use grew across all major groupings with communications technologies leading the way. These communications technologies are central to the soft-manufacturing revolution and in the 1980s were associated with higher growth in plant productivity and wages.

Individual differences in plant characteristics such as the size of the plant, the country of control of the plant and the industry to which the plant belongs are related to advanced technology use during this period.

Over the last decade, technology use continues to be higher in larger than in smaller plants. But medium-sized plants experienced the highest rates of growth, distancing themselves from small plants, and closing the gap with large plants. Size differences between large and small plants remained about the same in most cases, and in the case of technologies in the communications group, have increased. Generally, small plants have not made up any ground on large plants over the last decade.

Plants whose ownership resides outside of Canada are more likely to use technologies than domestically owned plants and the magnitude of the difference in general has not declined. But some of these differences are related to size and once size is considered, there are differences in the rate at which different sized domestically controlled plants have been closing the gap with foreign controlled plants. In large plants, the difference has generally declined. This is not the case for medium and small plants. That the overall domestic adoption rates continue to be lower than foreign adoption rates in all of the major functional groups then is the result of relatively poorer performance in small and medium-sized plants.

Industry variation in advanced technology use is widespread, and the industries that were initially the most intensive users of technology continue to be so. The industries that have been the top leaders in advanced technology use fall in the core and secondary sectors, which produce innovations used elsewhere—the transportation equipment, primary metals, electric and electronic products, machinery and refined petroleum industries. "Other" industries such as the clothing, wood, furniture and fixtures, other manufacturing, textile and leather and allied products industries were among the least intensive users of technologies over the last ten years. While several industries such as the beverage, rubber and refined petroleum industries experienced major shifts in functional advanced technology use, the overall rankings of the industries on advanced technology use did not change much over the ten-year period from 1989 to 1998.

Appendix A: Breakdown of Adoption Rates for the Technologies Included in Each Technology Survey

TECHNOLOGY	1989 Survey in Use	1993 Survey in Use	1998 Survey in Use
	% of establishments		
DESIGN AND ENGINEERING			
CAD/CAE	15	30	44
CAD/CAM	6	15	36
Digital Representation of CAD output (modelling or simulation technologies)	4	7	17
Electronic exchange of CAD files	---	---	34
PROCESSING AND FABRICATION			
Flexible mfg cells/systems	7	7	15
Programmable (Logic) Controllers	15	18	37
Numerically Controlled Machines	10	16	---
Materials Working Lasers	2	4	9
Pick & Place Robots	3	5	7
High speed machining	---	---	17
Rapid prototyping systems (RPS)	---	---	5
Near net shape technologies	---	---	7
Other Robots	3	4	8
AUTOMATED HANDLING SYSTEMS			
Automated Storage/Retrieval Systems	4	4	5
Part identification for manufacturing automation (e.g. bar coding)	---	---	18
Automated guided vehicle systems	3	1	---
INSPECTION			
Automated vision-based systems used for inspection/testing of inputs/final products	---	---	11
Other automated sensor based systems used for inspection/testing of inputs/final products	10	10	13
NETWORK COMMUNICATIONS			
Local Area Network for Technical Data and/or Factory/Production use	12	13	36
Company-wide computer networks (including Intranet and WAN)	---	---	35
Inter-Company Computer Network	9	9	29
INTEGRATION AND CONTROL			
Materials Requirement Planning (MRP)	14	16	---
Manufacturing Resource Planning (MRP II)/Enterprise Resource Planning (ERP)	8	9	21
Computers used for Control in Factories	10	16	31
Computer Integrated Manufacturing	3	7	18
Supervisory Control & Data Acquisition (SCADA)	5	8	16
Use of inspection data in manufacturing control	---	---	26
Digital remote-controlled process plant control (e.g. field bus)	---	---	5
Artificial Intelligence/Expert Systems	2	2	18

Appendix B: Overall and Functional Technology Use Rankings by Industry—1989 and 1998

INDUSTRY	1989 Rank					1998 Rank				
	Design	**Fabrication**	**Communication**	**Integration**	**1989 Rank**	**Design**	**Fabrication**	**Communication**	**Integration**	**1998 Rank**
CORE										
Electrical and Electronic Products	1	15	6	7	**6**	1	6	2	5	**1**
Machinery	2	9	9	9	**6**	2	7	10	7	**6**
Chemical and Chemical Products	11	10	8	8	**8**	19	12	7	9	**10**
Refined Petroleum	13	7	4	5	**6**	12	17	18	14	**13**
SECONDARY										
Primary Metal	4	1	5	6	**2**	3	2	4	6	**2**
Transportation	3	5	2	3	**1**	5	9	8	8	**7**
Rubber	16	11	3	2	**7**	9	11	12	15	**10**
Plastic Products	19	8	12	13	**11**	10	4	11	10	**8**
Fabricated Metal Products	6	13	20	14	**12**	4	10	13	11	**9**
Non-Metallic Minerals	18	4	16	12	**10**	15	14	16	12	**12**
“OTHER”										
Tobacco	10	3	1	11	**4**	7	1	5	1	**1**
Paper and Allied	5	6	11	1	**3**	6	5	6	4	**3**
Beverage	9	2	7	10	**5**	18	3	1	2	**4**
Primary Textiles	8	12	14	4	**9**	11	8	3	3	**5**
Printing and Publishing	12	16	10	17	**13**	17	20	9	16	**14**
Wood	15	14	15	16	**15**	14	13	21	17	**15**
Other	14	20	17	21	**17**	8	15	14	18	**11**
Textile	17	18	19	20	**18**	21	16	15	13	**15**
Furniture and Fixtures	20	17	13	19	**16**	13	18	19	21	**16**
Clothing	7	19	18	15	**14**	20	21	20	20	**17**
Leather and Allied Products	21	21	21	18	**19**	16	19	17	19	**16**

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