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Technology Adoption: A Comparison Between Canada and the United States

by

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Abstract

This study examines differences in technology use in Canada as opposed to the United States as well as reasons for these differences. It examines different aspects of technology use—numbers of technologies used, types of technologies used, as well as regional, size and industry variations in their use. It then investigates differences in benefits that plant managers perceive stem from advanced technology use and differences in the factors that managers assess as impediments. While managers in both countries generally place quite similar emphases on items in the list of benefits received and problems that have impeded adoption, there are significant differences that arise because of the smaller size of the Canadian market.

Keywords: technology adoption, training, international comparison

Acknowledgements

We are grateful to Industry Canada for their collaboration on this project. We also wish to thank Georgia Roberts of the Business Survey Methods Division at Statistics Canada for providing advice on methodology.

Highlights

- With their increasing globalization, markets have become more competitive. Firms face greater pressures to reduce costs and increase product quality. One of the major determinants of their ability to compete is their technological competence, as the adoption and diffusion of advanced technologies critically affects their cost structure.

- In order to assess the technological competitiveness of Canadian manufacturing plants, plant managers were asked to rate whether their plants were more or less technologically advanced than their foreign competitors as well as to provide information on the incidence of technology use. According to the results, about 70% of the managers of Canadian manufacturing plants feel their production technologies (whether design and engineering, fabrication and assembly, automated material handling, or inspection and communications) are at least as good as their foreign competitors. Only for inspection and communications technologies is there evidence that more establishments feel they are behind (35%) than ahead (19%) of their foreign competitors.

- Size matters, as large manufacturing establishments tend to be more competitive internationally than either small or medium-sized establishments.

- Plants in high technology industries generally rank themselves as more competitive than plants in low technology industries, particularly for design and engineering; 74% of high technology plants, as opposed to only 62% of low technology plants, feel they are at least as competitive as foreign competitors.

- Even though Canadian plant managers feel their production technologies are broadly comparable to the United States, there are sectors where Canada lags its southern neighbour. In the five industrial sectors—fabricated metal products, industrial machinery and equipment, electronic and other electric equipment, transportation equipment, and instruments and related products—where Canadian technology use can be directly compared to the United States, Canadian plant managers feel that Canada suffers a technological disadvantage. This is borne out by the technology use data. In these sectors, Canadian plants are less likely to use any advanced technology than U.S. plants, although this ‘technology gap’ has decreased over time. Between 1989 and 1993, the ‘gap’ has been halved with 73% of Canadian plants and 81% of U.S. plants using at least one technology.

- Reasons for this can be ascribed primarily to differences in the size of plants and in the size of markets. As technology use increases with size, part of the ‘gap’ can be attributed to the fact that a larger percentage of establishments in Canada are small.

- This is confirmed through comparison of the benefits and impediments associated with technology adoption, as perceived by plant managers, between the two countries. As for size of markets, Canadian plant managers tend to place a greater relative emphasis on *improvements in product flexibility* or *reductions in setup time* than do U.S. plant managers. Both of these benefits are particularly advantageous for plants operating in smaller markets, where filling diversified product lines is more costly and being able to use machinery for different products and being able to reconfigure equipment quickly offer significant benefits.

- Differences in the managers' perception of the relative importance of barriers to technology adoption, between the two countries, also indicate that Canada suffers from a smaller market. In Canada, the *need for market expansion* is given relatively greater weight by plant managers than it is in the United States. U.S. plant managers rank the *need for market expansion* almost at the bottom of the list of impediments while, in Canada, it is ranked at the top of the list.

- The implementation of high technology in the area of fabrication and assembly is more problematic in Canada because of management-labour frictions. For this technology, *worker resistance* is quoted relatively more frequently by Canadian than U.S. plant managers.

- With the acquisition of advanced technology comes increased *education and training costs* in both countries.

- Outside of the differences in importance associated with market size, many of the other problems and benefits associated with technology adoption are the same in both countries.

1. Introduction

The competitiveness of the nation state has received increasing attention, partly because those countries that used to have the highest income per capita have been losing their lead, and with increasing globalization, technological change is transmitted more quickly and the relative competitiveness of nations can change more rapidly. However, the term competitiveness, if it is to mean something other than living standards, has to be operationalized. Krugman (1994) argues that the term is meaningful only if defined in terms of productivity. This, in turn, suggests that we should be concerned with the study of the causes of cross-country productivity differences.

Some have ascribed a major role to technology differences in studies of cross-country productivity levels (Romer, 1994). Others have assumed that technology is the same and have focused on differences in the quality and intensity of inputs. Generally, however, both sides of the debate are conducted without reference to information on the types of technologies actually in use, nor to the reasons that technology intensity may differ across countries.

The debate, on cross-country productivity and technology differences, does not have to be conducted in a vacuum. Both productivity levels and technology use can be measured. In an earlier study, Baldwin and Gorecki (1986) find that Canada lags the U.S. in terms of productivity in the manufacturing sector. In this study, we find that there are measurable differences in the technologies that are employed in the two countries. Understanding the size and the causes of these technology differences is, therefore, central to our understanding of Canada's international competitiveness.

In order to gauge Canada's technological capabilities vis-a-vis its competitors, this paper uses the evaluations of Canadian manufacturing plant managers on the competitiveness of the technologies used. Actual data on technology adoption is then used to confirm these evaluations for the five industry groups—fabricated metal products; industrial machinery and equipment; electronic and other electric equipment; transportation equipment; and instruments and related products—for which there are comparable U.S. data.

Although the majority of Canadian manufacturing plant managers feel their production technologies are at least as good as their foreign competitors, managers in the five industries for which there are comparable U.S. technology adoption data feel they are at a disadvantage. The technology use data confirm this. In these five industries, Canadian firms generally trail their U.S. counterparts in the adoption of advanced technology.[1]

The paper then considers reasons for the differences in technology use between Canada and the United States in these five sectors. Since technology use increases with size, part of the technology gap can be attributed to the fact that a larger percentage of establishments in Canada are small. Size, however, is generally taken as a rough proxy for the net benefits associated with

[1] Results for 1989 are found in a previous study (Statistics Canada, 1991). Comparisons for both 1989 and 1993 were based on establishments with 20 or more employees active in the five major industrial groups used in the U.S. survey.

technology adoption. This study replaces this imperfect proxy with more direct measures of the benefits and problems associated with technology use. Using size alone does not tell us whether the differences in technology use are inexorably tied to size disadvantages that Canadian firms face or whether there are specific problems not related to size that are amenable to policy intervention. In this study, direct measures of cross-country differences in the benefits and problems associated with technology adoption are developed.

2. Data Sources

Two sources of data are used, first to compare rates of technology use, and then to investigate differences in the benefits that technology provides and the problems that impede their adoption. All tabulations in this paper are based on the responses of plant managers in the manufacturing sector.

Technology Use

The Canadian data on technology use come from two surveys conducted by Statistics Canada: the *1993 Survey of Innovation and Advanced Technology* and the *1989 Survey of Manufacturing Technology*.[2] The American data come from the *1993 Survey of Manufacturing Technology* and the *1989 Survey of Manufacturing Technology* conducted by the U.S. Bureau of the Census.[3] Data on the use of advanced technologies by manufacturing establishments is collected by the surveys. The surveys cover 17 individual technologies, all basically related to computer or micro-chip use, belonging to four functional technology groups (Table 1). They are design and engineering, fabrication and assembly, automated material handling, and inspection and communications. In addition, the 1993 Canadian survey explores the views of Canadian plant managers on the competitiveness of their technological capabilities vis-à-vis foreign and domestic competitors.

While there are similarities between the Canadian and American surveys, some differences do exist. First, the American survey covers only establishments belonging to one of five major industry groups—fabricated metal products; industrial machinery and equipment; electronic and other electric equipment; transportation equipment; and instruments and related products—while the Canadian survey covers all major manufacturing industries. Second, the American survey is restricted to establishments of 20 or more employees, whereas the Canadian survey covers all establishments in the Census of Manufactures.

In order to make comparisons, the Canadian dataset was reduced to cover only establishments with 20 or more employees active in the five major industrial groups used in the U.S. survey.[4] The American data also had to be adjusted to account for differences in the treatment of firms

[2] The data for the 1989 survey are published in Statistics Canada (1991). The tabulations based on the 1993 survey were performed by the Micro-Economic Analysis Division of Statistics Canada.
[3] See the U.S. Bureau of the Census (1989) and the U.S. Bureau of the Census (1994).
[4] For this exercise, the concordance reported in Survey of Manufacturing Technology 1989 (Statistics Canada, 1991) was used.

that did not respond to the survey. The Canadian results prorate those who did not respond to a given question in proportion to the respondents. The United States simply reports a not specified category, which includes refusals, incomplete responses, out of business and out of scope cases. For the sake of comparison, the not specified responses in the U.S. survey have been prorated across the other categories in proportion to the relative importance of these other categories.

Table 1. ***Advanced Technologies by Functional Group***

Functional Group	Individual Technology
Design and Engineering	Computer-aided Design and Engineering (CAD/CAE) CAD Output to Control Manufacturing Machines (CAD/CAM) Digital Representation of CAD Output
Fabrication and Assembly	Flexible Manufacturing Cells/Systems Numerically Controlled (NC)/Computer Numerically Controlled (CNC) Machines Materials Working Lasers Pick and Place Robots Other Robots
Automated Material Handling Systems	Automated Storage/Retrieval Systems (AS/RS) Automated Guided Vehicle Systems (AGVS)
Inspection and Communications	Automatic Inspection Equipment for Incoming Materials Automatic Inspection Equipment for Final Products Local Area Networks (LANs) for Technical Data Local Area Networks (LANs) for Factory Use Inter-company Computer Network (ICCN) Programmable Controllers Computers Used for Control in Factories

Benefits and Impediments

The Canadian data on benefits and impediments are derived from the *1993 Survey of Innovation and Advanced Technology*, conducted by Statistics Canada. The U.S. data on the same topic originate from the U.S. survey entitled *Manufacturing Technology: Factors Affecting Adoption 1991*. Both of these surveys explore issues that affect the rate of adoption—factors hindering adoption, benefits from technology acquisition, plans to upgrade existing technologies, and the impact of technology use on education and training costs. It should be noted that, unlike the surveys that collect data on technology use at the more detailed 17 technology level, the surveys on the characteristics associated with technology adoption collect data only for the four functional technology groups outlined above. Only the results for three of the four groups—design and engineering, fabrication and assembly, and inspection and communications—will be presented here. Automated material handling has not been included due to the small numbers of responses obtained in both surveys.

It should also be noted that, while the Canadian survey includes a question on technology use, the American survey does not.[5] Since the questions about the factors affecting adoption are relevant only for plants using a particular technology, it is essential to be able to identify and exclude non-users from the tabulations. For example, when tabulating the benefits and problems associated with design and engineering technologies, it is important that only plants using design and engineering be included. Only for the Canadian data, however, is it possible to clearly distinguish between non-users and non-respondents based on answers to whether a particular technology was used. For the U.S. data, a different approach had to be taken since such a question was not included on the questionnaire. One of the questions on the U.S. survey asked respondents to indicate the extent to which their manufacturing operations depended on the use of advanced technology. Respondents leaving this question blank or answering 'not applicable' were treated as non-users and were removed from all subsequent tabulations.

Finally, in order to generate comparable data, the Canadian responses had to be adjusted by imputation to account for item non-response since the U.S. data had already been adjusted for this.

3. Competitiveness of Technology Users

Comparison with International Competitors

Technological competitiveness depends on a host of factors that businesses themselves can best evaluate. The practice of benchmarking—comparing oneself to industry leaders—constantly requires establishments to assess themselves against their foreign competitors. As part of the 1993 Survey of Innovation and Advanced Technology, plant managers were asked to evaluate their production technology against their most significant foreign competitors on a five-point scale: 1 (much less advanced), 2 (less advanced), 3 (about the same), 4 (more advanced), and 5 (much more advanced). This evaluation was performed for each of the four functional technologies—design and engineering, fabrication and assembly, automated material handling, and inspection and communications.

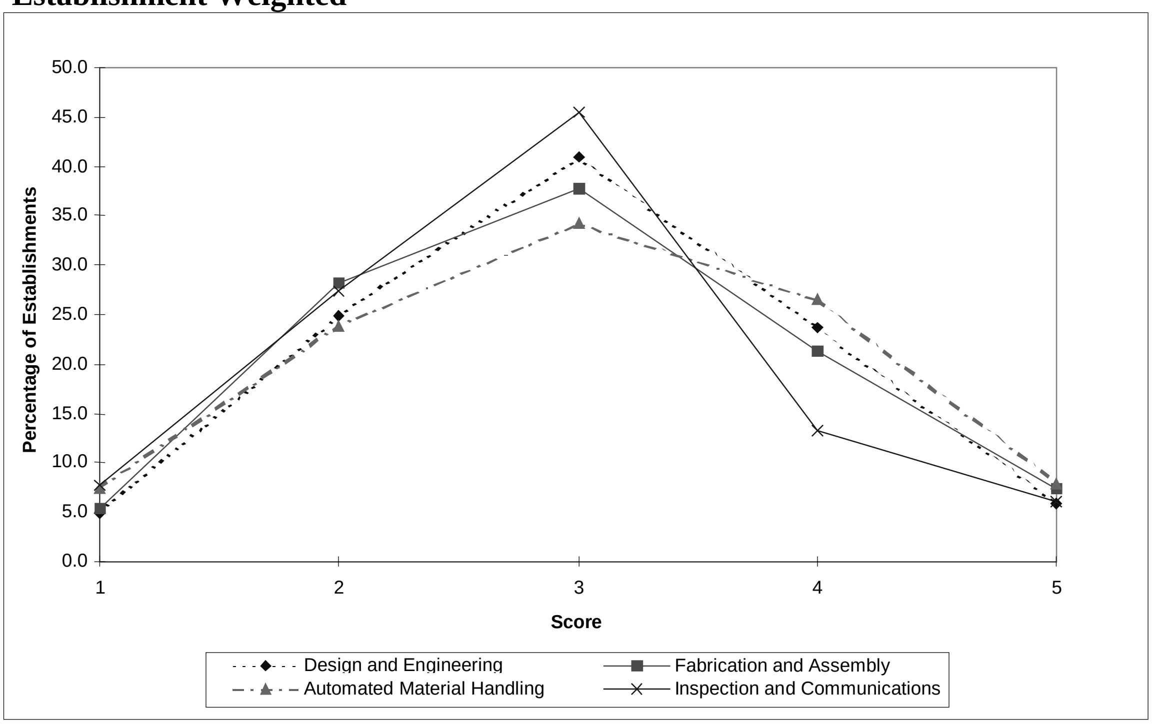
The survey probes how plant managers evaluate their technological competence in general. It requires managers to take into account the many dimensions—both machine use and production practices—that they believe determine technological competence. The answers of plant managers to this question are a more comprehensive measure of technological competitiveness than a comparison based on machine or equipment use alone. Moreover, the answers are available for establishments across the entire manufacturing sector allowing a comparison of international competitiveness that is not restricted to just the five industries for which there are comparable U.S. data on incidence and for which comparisons have been made in the past.[6]

[5] A separate survey is used to collect this information in the U.S. (U.S. Bureau of the Census, 1994).
[6] See Statistics Canada (1991) for a previous study.

On the whole, the evaluations indicate that Canadian plants fare relatively well against their international competitors. The distributions of the scores (Figure 1) are generally symmetric around a score of 3, the same as their competitors. More establishments feel that they are equal to competitors than feel they are either superior or inferior. For example, the percentage that feel they are about the same as their foreign competitors is 41% in design and engineering, 38% in fabrication and assembly, 34% in automated material handling and 46% in inspection and communications.

The distributions of these scores around the mid-point are slightly skewed. Slightly more establishments feel that they are inferior to foreign competitors than feel they are superior, but these differences are generally not statistically significant. For design and engineering technologies, just as many respondents (30%) feel their technologies are superior (scores of 4 and above) as inferior (scores of 2 and below) to their foreign counterparts. For fabrication and assembly, 34% feel inferior and 29% feel superior; while for inspection and communications, 35% feel inferior compared to 19% who feel superior. In the latter case, the difference results from a particularly large percentage evaluating themselves as equal to their competitors, since the sum of those ranking themselves either equal to or superior to their foreign competitors (65%) is quite similar to the other categories—design and engineering (71%), fabrication and assembly (66%), and automated material handling (69%).

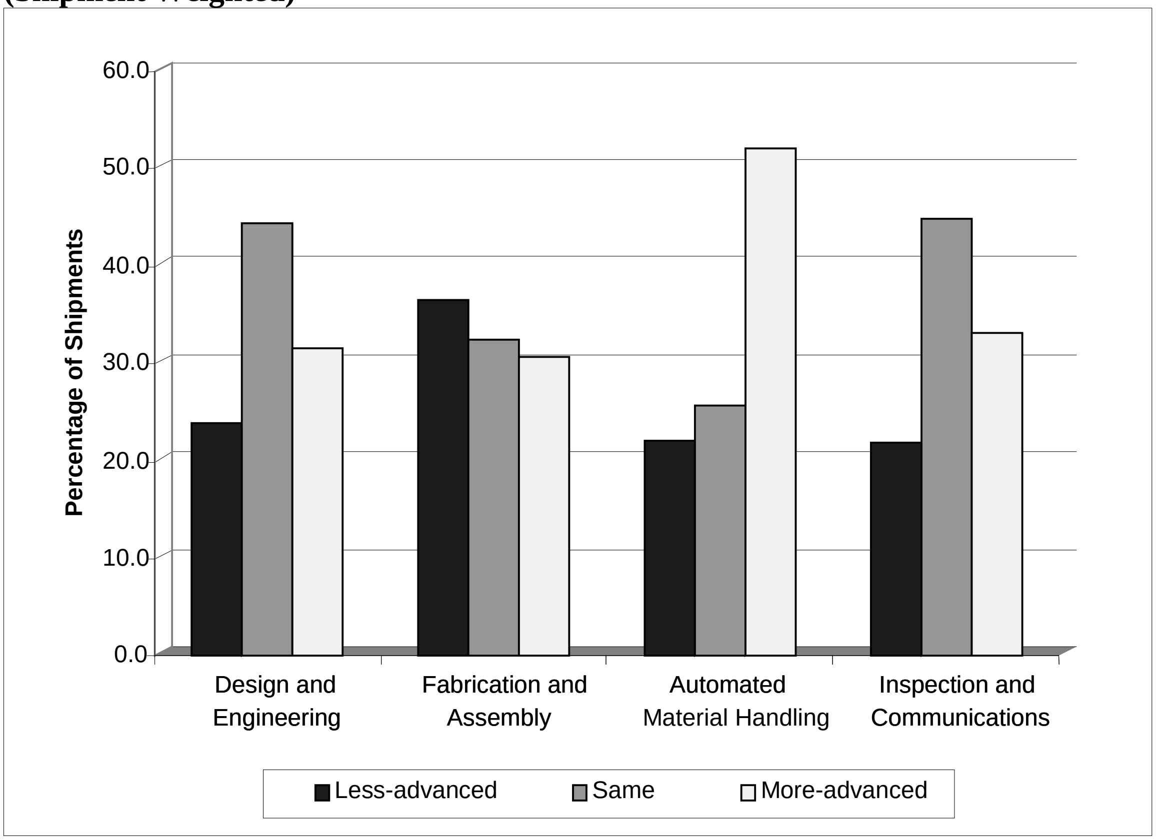
Figure 1. Evaluation Against Foreign Competitors Across All Manufacturing Industries Establishment Weighted



While there is little evidence that more establishments are behind their international competitors than are ahead, it may be the case that shipments are not equally distributed between those plants that are more-advanced and those that are less-advanced than their foreign competitors. If the larger establishments are behind and the smaller ones are ahead, then most production will be located in plants that are uncompetitive.

To assess this possibility, the distribution of shipments by functional group is depicted in Figure 2. Generally, there is a larger percentage of shipments in establishments that are ahead of competitors than are behind: 32% versus 24% in design and engineering; 33% versus 22% in inspection and communications; and 52% versus 22% for automated material handling. Only in fabrication and assembly is the reverse true, as 37% of shipments are in plants that are less competitive and only 31% are in plants that are more competitive. Since these distributions are generally more heavily concentrated in the more-advanced classes when shipment rather than establishment-weights are used, it is the larger plants that tend to be more competitive internationally.

Figure 2. Distribution of Shipments by Competitive Ranking Against Foreign Competitors (Shipment Weighted)

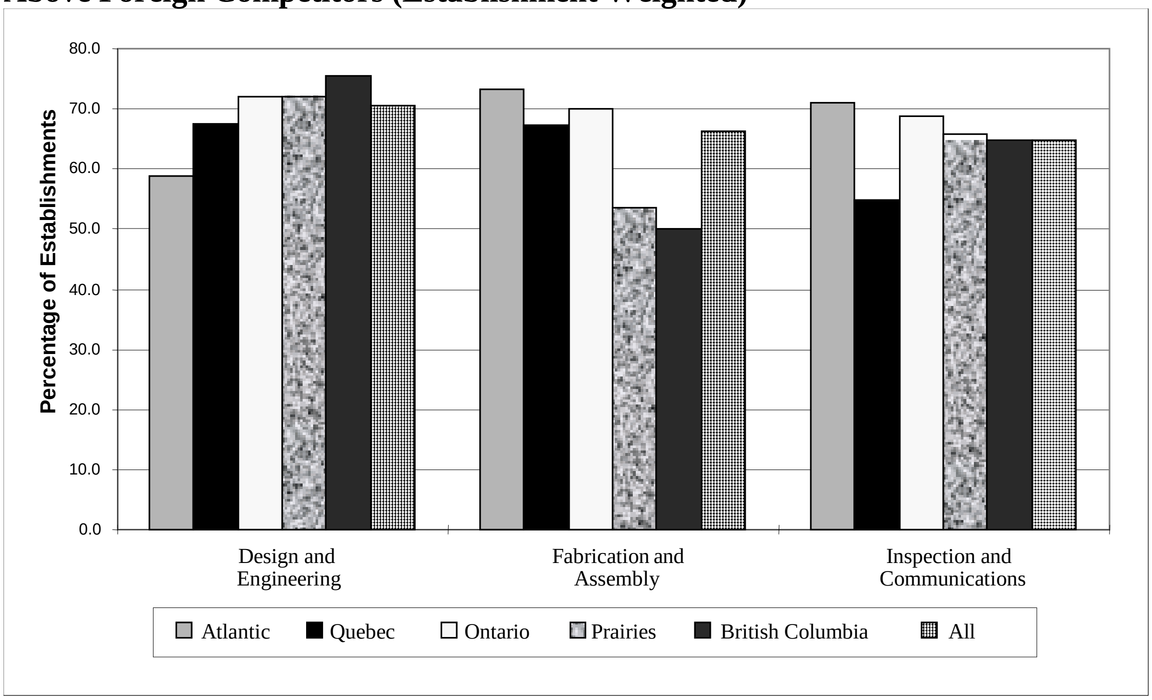


Regional Comparison

Canada's regional economies differ from coast to coast—both with respect to the industrial base and the productivity of establishments. Therefore, it is important to ascertain whether there are any large discernible differences in the technological competitiveness of establishments in different regions.

In order to examine this issue, the percentage of establishments that ranked themselves equal to or above foreign competitors is plotted in Figure 3 by region and by functional technology group.[7]

Figure 3. Regional Differences in Technological Competitiveness Percentage Equal To or Above Foreign Competitors (Establishment Weighted)



Differences across regions are relatively minor. The percentage of establishments that rank themselves equal to or superior to their foreign competitors in Ontario is always greater than the national average. Quebec lags Ontario in each technology group. Its gap is particularly large in inspection and communications technologies, an area that has been growing rapidly (Baldwin and Sabourin, 1995) and that is associated with particularly large wage gains in plants that use these technologies (Baldwin, Diverty and Sabourin, 1995). There is no discernible pattern in Atlantic Canada. This region lags other regions with regards to design and engineering but leads other regions in fabrication and assembly as well as inspection and communications. Atlantic Canada's adoption rate may be lower than the rest of the country but, when technology is

[7] Automated material handling has not been included due to small numbers of responses.

adopted, it is generally as competitive as the rest of Canada. The Prairies and British Columbia are about as competitive as the rest of Canada in design and engineering but they lag substantially in fabrication and assembly.

Industrial Comparison

Technology use varies considerably across industries: some (like electronics) are founded upon intensive use of advanced technologies, while others (like textiles and clothing) are much less likely to use advanced technologies. Since it is the high technology sector that has recently led growth, it is important to know whether Canadian plants have a particular advantage or disadvantage in high- as opposed to low- technology industries.

In order to explore differences in the competitiveness of establishments in different industries, establishments are classified as either high, medium, or low technology. The basis for this classification scheme is found in Table 2. Industries are ranked according to their use of at least one advanced technology. Also included in the table are the adoption rates by functional technology group for each of the 15 industries. Industries that rank high in using at least one technology also rank high in using specific types of technologies. On the basis of the use of at least one technology,[8] three groups were constructed. Industries with a high technology adoption rate—electronic products, paper, machinery, primary metals, and transportation equipment—are assigned to the high technology group; those with a more moderate usage rate—"other" manufacturing industries, petroleum and chemicals, non-metallic minerals, rubber and plastic, and fabricated metal products—to the medium technology group; and those with a low adoption rate—food processing, printing and publishing, wood, textiles and clothing, and furniture and fixtures—to the low technology group.

Establishments in high technology industries are generally at least as competitive as establishments in medium and low technology industries (Figure 4, Table 3). The percentage of establishments in high technology industries that rank themselves as equal to or superior to their foreign competitors is always higher than for those establishments in low technology industries. This difference is greatest (12 percentage points) for design and engineering technologies. For all but inspection and communications technologies, high technology establishments are also at least as competitive as medium technology establishments.

[8] Food processing and fabricated metal products have almost identical usages of at least one technology at 33.4% and 33.2%, respectively. Fabricated metal products was included in the medium technology group, while food processing was included in the low technology group, based on their functional technology adoption rates.

Table 2. ***Technology Use by High, Medium, and Low Technology Industry Groups Establishment Weighted***

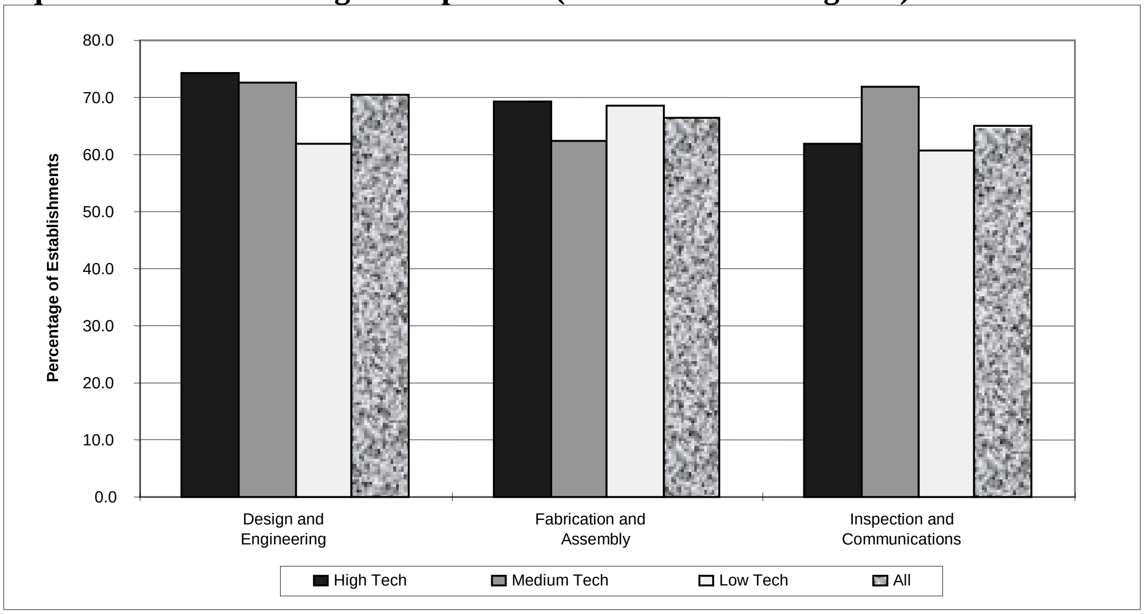
Industry Group	Industry	Technology Use			
		At Least 1 Technology*	Design and Engineering	Fabrication and Assembly	Inspection and Communications
		(Percentage of Establishments)			
High Tech	Electronic Products	74.0	66.0	27.6	41.6
	Paper	50.6	39.0	12.9	37.9
	Machinery	48.1	42.8	28.1	25.1
	Primary Metals	47.7	37.9	23.3	30.5
	Transportation Equipment	46.0	37.4	28.2	27.7
Medium Tech	Other Manufacturing	41.8	27.9	13.9	16.0
	Petroleum and Chemicals	39.8	22.1	12.8	31.1
	Non-metallic Minerals	37.6	15.5	16.7	21.3
	Rubber and Plastic	34.4	21.6	11.8	18.9
	Fabricated Metal Products	33.2	25.1	23.9	11.6
Low Tech	Food Processing	33.4	10.4	11.1	25.1
	Printing and Publishing	30.7	21.5	11.7	16.2
	Wood	19.7	9.7	11.2	14.9
	Textiles and Clothing	19.7	14.2	7.7	7.9
	Furniture and Fixtures	18.4	13.3	12.2	7.4

* Use of at least one technology is based on a list of 22 technologies found on the questionnaire.

Table 3. ***Distribution of Foreign Competitiveness Scores by Industry Group Establishment Weighted***

Functional Group	Industry Group	Score		
		1 & 2	3	4 & 5
		(Percentage of Establishments)		
Design and Engineering	High Tech	25.7	40.1	34.1
	Medium Tech	27.3	47.3	25.4
	Low Tech	38.1	34.5	27.4
	ALL	29.6	41.0	29.5
Fabrication and Assembly	High Tech	30.8	46.9	22.3
	Medium Tech	37.6	39.2	23.3
	Low Tech	31.5	25.6	42.9
	ALL	33.6	37.7	28.7
Inspection and Communications	High Tech	38.0	41.2	20.8
	Medium Tech	28.2	55.6	16.3
	Low Tech	39.4	39.4	21.3
	ALL	35.1	45.5	19.4

Figure 4. Industrial Differences in Technological Competitiveness Percentage Equal to or Above Foreign Competitors (Establishment Weighted)



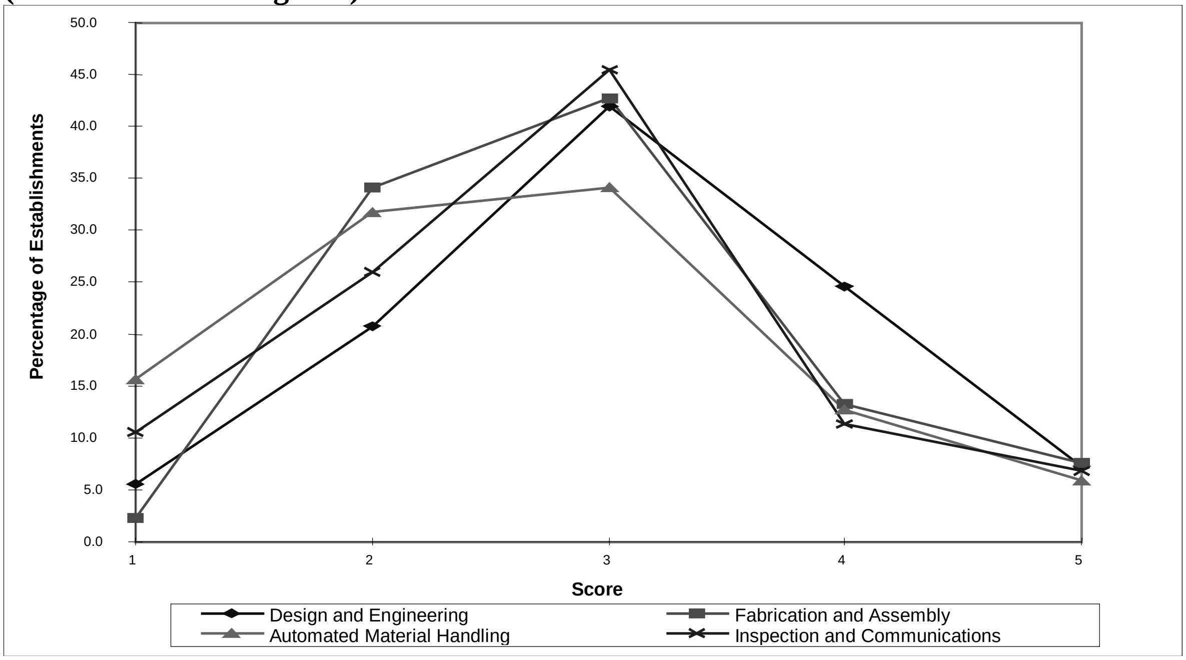
4. Incidence of Technology Use

Comparable U.S. Sectors

The validity of the findings based on plant managers' evaluations can be confirmed by comparing technology use within Canada to that of the United States. But before proceeding to the actual comparisons of Canada and United States technology use, it is important to determine how representative the evaluations made by plant managers in these five industries are of all manufacturing industries. Except for design and engineering technologies, more respondents felt that their technologies are inferior than superior to their foreign counterparts—36% versus 21% for fabrication and assembly and 37% versus 18% for inspection and communications technologies. The difference is most pronounced for automated material handling technologies, where about one-half (47%) consider themselves behind, compared to only 19% who feel they are ahead. Only for design and engineering technologies do more respondents claim their technologies are superior (32%) than inferior (26%) to their foreign competitors.

Thus, plant managers in these five industries generally feel they are less competitive internationally than the average manufacturing plant (Figure 5), particularly for fabrication and assembly, and automated material handling technologies. These sectors then are not representative of overall Canadian competencies in technology and should not be used to infer competitiveness for the manufacturing sector as a whole. Nevertheless, a comparison of technology use can be employed to confirm the benchmarking estimates derived from managers of manufacturing plants.

Figure 5. Evaluation Against Foreign Competitors for Five Industries (Establishment Weighted)



This next section examines the extent to which these evaluations translate into lower technology use in Canada as opposed to the United States in these same five industries. Comparisons of the incidence of Canadian and American technology use are done at several levels. First, differences in the use of any advanced technology are examined. Second, differences in multiple technology use are examined. Finally, the paper compares the use of 17 individual technologies.

Use of at Least One Technology

In 1989, 74% of American establishments used at least one technology, more than the 58% of Canadians that used any one of the 17 advanced manufacturing technologies in the same year (Table 4). The Canadian disadvantage did not exist across all size classes. In large establishments, virtually all (98%) use at least one advanced technology in both countries. For medium-sized establishments, Americans tended to be slightly more likely to use at least one technology (89% versus 81%). The largest difference occurred in small establishments, where 67% in the U.S. possessed at least one technology while only 50% did so in Canada.

In both countries, technology use is directly connected with plant size. Larger establishments are much more likely to use at least one technology than are small establishments. Because of this, a country like Canada that has a greater proportion of small establishments will have a lower overall technology adoption rate even if each size class adopts technologies at the same rate.

By 1993, the overall “technology gap” had been halved from 16 percentage points in 1989 to only 8 percentage points in 1993.[9] Moreover, the difference in technology use has, within each size class, either decreased or remained about the same.

Growth in the incidence of use of advanced technologies between 1989 and 1993 has been greater in Canada than in the United States for the five sectors that can be compared. Canada reports a growth of 15 percentage points over this period (from 58% to 73%) compared to 7 percentage points (from 74% to 81%) for the United States.

Table 4. ***Use of at Least One Technology by Employment Size, 1989 and 1993 (Establishment Weighted)***

Employment Size (Number of Employees)	Use of at Least One Technology			
	1989		1993	
	Canada	United States	Canada	United States
	(Percentage of Establishments)			
20 to 99	50	67	70	75
100 to 499	81	89	85	94
500 or More	98	98	94	97
All Sizes	58	74	73	81

Number of Technologies Used by Employment Size

Since the use of multiple technologies has become the norm, comparisons of technological competence need to ask how Canada fares in terms of combining several technologies within its manufacturing plants.

In 1989, Canadian establishments not only were less likely than the United States to use any advanced technologies, but they were also less likely to combine several different technologies within the plant. Only 15% of Canadian plants used five or more advanced technologies, while 25% of U.S. plants did the same; similarly, just 26% of Canadian plants used two to four advanced technologies, while 34% of U.S. plants did the same.

By 1993, these differences had changed (Table 5). The percentage point difference for the use of five or more technologies remains constant at about 10 percentage points, but little difference now separates Canadian and American plants in the use of two to four technologies. Slightly more Canadian establishments (19%) than American establishments (14%) use only one technology.

Small American establishments use multiple technologies somewhat more than do small Canadian establishments in 1993: 20% of American and 14% of Canadian small plants use five or more technologies, while 38% of U.S. and 33% of Canadian small plants use between two and

[9] Because of the sampling and non-sampling error, the reduction in the gap cannot be said to be statistically significant.

four technologies. By contrast, medium-sized establishments in both countries resemble one another in their tendency to use at least two technologies. Eighty percent of medium-sized Canadian establishments and 87% of American ones use at least two technologies. Similarly, an equally large percentage (about 95%) of large establishments, in both Canada and the United States, use two or more advanced technologies. Moreover, nine out of every ten large manufacturing establishments use at least five advanced technologies, regardless of country.

Table 5. ***Number of Technologies Used by Employment Size, 1989 and 1993 (Establishment Weighted)***

Employment Size	Number of Technologies							
	0		1		2 to 4		5 or More	
	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.
	(Percentage of Establishments)							
1989								
20 to 99	50	33	18	18	24	34	8	14
100 to 499	19	11	15	12	36	37	30	40
500 or More	2	2	2	2	25	13	71	83
All Sizes	42	26	17	16	26	34	15	25
1993								
20 to 99	30	25	23	17	33	38	14	20
100 to 499	15	6	5	7	47	34	33	53
500 or More	6	3	0	2	5	10	89	86
All Sizes	27	19	19	14	34	36	20	31

Use of Individual Technologies

In this section, differences between Canada and the United States in the use of 17 different individual technologies are examined. These 17 technologies belong to our four different functional technology groups (design and engineering, fabrication and assembly, automated material handling, and inspection and communications).

In 1989, Canadian use of almost all of the individual technologies was less than that of American establishments (Table 6). In computer-aided design and engineering (CAD/CAE) technologies, Canadian use was 80% the level of American use. In computer-aided manufacturing systems based on CAD output (CAD/CAM), it was only 66% of the American use. In fabrication and assembly systems, Canadian use was behind American use in all areas, but particularly so in the use of numerically controlled and computer numerically controlled (NC/CNC) machines. In inspection and communications, Canada was a less frequent user of automatic inspection systems, local and wide area networks, programmable controllers, and computers used for factory control. The one area where Canada did not lag behind the United States in 1989 was in automated handling equipment.

In both Canada and the United States, there has been a marked growth in the use of design and engineering technologies since 1989. In fact, computer-aided design and engineering has the highest growth of any of the technologies surveyed. Growth rates of 22% for this technology have been achieved in both Canada and the United States. Currently, Canada reports an adoption rate of 56% for CAD/CAE, just behind the United States at 64%. Growth in the use of each of the other two technologies in this group (CAD/CAM and digital representation of CAD output) has been higher in Canada than in the United States, so that there is now no significant difference in the use of these technologies.

Little growth is found for many of the fabrication and assembly as well as automated material handling technologies. The only exception is numerically controlled and computer numerically controlled machines in both countries.

In both Canada and the United States, there is no growth in the use of automatic inspection equipment. Among communications technologies, the newer technologies—LANs for technical data, LANs for factory use, and inter-company computer networks—experienced moderate growth in the United States and little or no growth in Canada. The more mature technologies such as programmable controllers, and computers used for control in factories have grown in Canada but remained about the same in the United States.

Comparisons between the two countries reveal that by 1993 the adoption patterns of advanced technologies, with the exception of communications technologies, were quite similar in Canada and the United States. For the newer communications technologies (LANs for technical data, LANs for factory use, and inter-company networks), American establishments have widened the gap between themselves and their Canadian counterparts between 1989 and 1993. Over the same period, however, Canadian plants have narrowed the gap for older communications technologies such as programmable controllers and factory control computers.

For 10 of the 17 technologies listed, Canadian establishments have adoption rates similar to the United States. For the other seven technologies—CAD/CAE, NC/CNC machines, LANs for technical data, LANs for factory use, inter-company networks, programmable controllers, and factory control computers—Canadian establishments have lower adoption rates than do those in the United States. All but two of these are communications technologies. The subjective evaluation of plant managers are, therefore, confirmed by data on actual use of technologies.

Table 6. ***Use of Individual Technologies in Canada and the United States (Establishment Weighted)***

Technology	Use			
	Canada		United States	
	1989	*1993*	*1989*	*1993*
	(Percentage of Establishments)			
Design & Engineering				
Computer-aided Design and Engineering	34	56	42	64
CAD output to Control Manufacturing Machines	12	27	18	28
Digital Representation of CAD	6	13	11	13
Fabrication & Assembly				
Flexible Manufacturing Systems	9	11	12	14
Numerically Controlled and Computer Numerically Controlled Machines	27	34	45	51
Materials Working Lasers	2	4	5	6
Pick and Place Robots	5	9	8	10
Other Robots	4	7	6	5
Automated Material Handling				
Automated Storage/Retrieval Systems	2	4	3	3
Automated Guided Vehicle Systems	2	1	2	1
Inspection & Communications				
Inspection Equipment for Inputs	7	7	11	11
Inspection Equipment for Outputs	10	11	14	14
Local Area Networks for Technical Data	15	17	21	32
Local Area Networks for Factory Use	11	11	18	24
Inter-company Computer Networks	11	11	16	20
Programmable Controllers	23	25	35	34
Computers Used for Control in Factories	17	20	30	30

Investment Plans

Another measure of the importance of advanced technologies can be derived from plans for future investment in advanced technology. Both Canadian and U.S. surveys requested managers to indicate whether they were intending to upgrade their technologies and how extensive these upgrades would be. When newer technology offers distinct advantages over existing technology, plant managers will choose to upgrade. The more advantages that new technology is perceived to have, the more dramatic will be the upgrades.

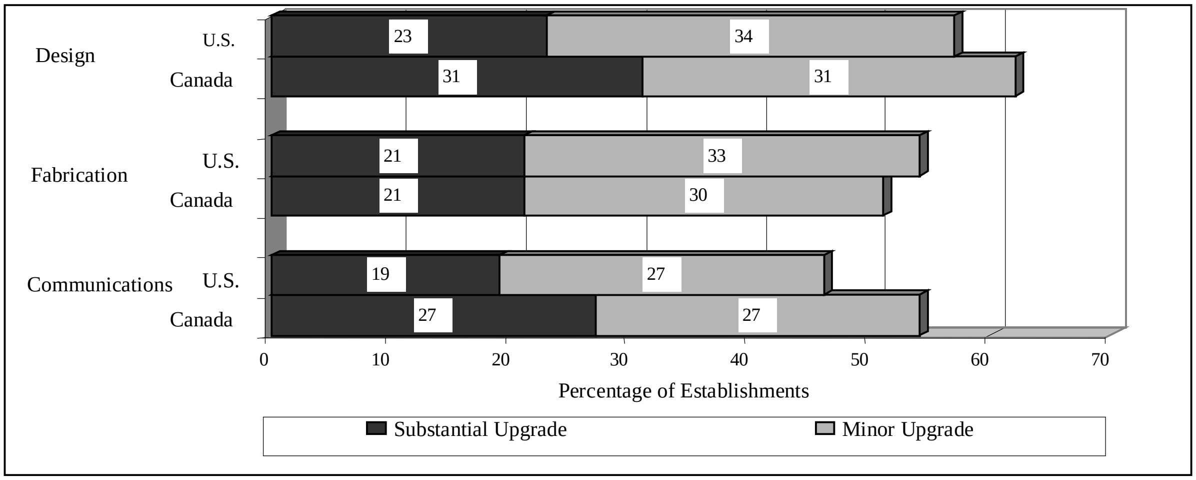
Table 7. ***Plans to Upgrade Existing Advanced Technology (Establishment Weighted)***

Plans	Design		Fabrication		Communications	
	Canada	U.S.	Canada	U.S.	Canada	U.S.
	(Percentage of Establishments)					
Total Replacement	7	3	1	1	6	2
Major Upgrade	24	20	20	20	21	17
Minor Upgrade	31	34	30	33	27	27
Under Consideration/No Plans/Not Applicable	38	43	49	46	46	54

In general, equally as many plants envisaged upgrades as those that did not. In both Canada and the United States, about 60% of plants planned to upgrade their design and engineering technologies, while close to 50% planned some upgrades of their fabrication and assembly, and inspection and communications technologies (Table 7).

Upgrades vary from substantial upgrades of equipment to minor modifications of existing setups. Substantial upgrades include both total replacement and major upgrades. Patterns of upgrades are similar between the two countries with few significant differences (Figure 6).

Figure 6. Plans to Upgrade Existing Advanced Technology (Establishment Weighted)



5. *Factors Affecting Adoption*

Introduction

Differences in the adoption rates between the two countries in these industries are due, in part, to the fact that Canada has a higher proportion of small establishments, which tend to be less likely to adopt advanced technology. This section explores other possible reasons for these differences.

In deciding to adopt advanced technology, plant managers may be expected to weigh expected benefits against the associated costs of implementation. If the internal rate of return earned by the introduction of the technology exceeds the cost of capital, adopting the technology is financially justified. Thus, differences in either expected benefits or implementation costs between the two countries could explain the observed differences in adoption rates.

This section examines various factors that could affect differences in adoption rates between Canada and the United States. First, the importance of the benefits arising from technology adoption is explored. Then differences in the factors impeding technology adoption are investigated. Finally, the impact of technology adoption on education and training costs is examined.

Benefits and Effects of Technology Adoption

Both the Canadian and American technology adoption surveys explored the benefits and effects that occurred when advanced technologies were adopted. However, the lists were not exactly the same. Twice as many benefits are listed in the Canadian survey as in the U.S. survey—16 for Canada compared to eight for the United States. Of these, six are common to the two surveys—improvements in product quality, reductions in labour requirements, increased equipment utilization rate, lower inventory, reduced setup time, and greater product flexibility—as indicated by the shaded areas in Table 8. The percentage of respondents indicating that a particular benefit or effect accrued to the plant as a result of adopting advanced technologies in each functional area is presented in Figure 7 for the most important benefits and effects.

The benefits are divided into two groups—depending on whether the benefits are *tangible* or *intangible*. Previous researchers (OECD, 1991; Baldwin, Sabourin and Rafiquzzaman, 1996) have emphasized that the evaluation of benefits is made particularly difficult when benefits are difficult to quantify. *Tangible* benefits, such as productivity improvements, are those that firms are better able to estimate prior to investment, while *intangible* benefits, such as product quality improvements, are more difficult to quantify and predict.

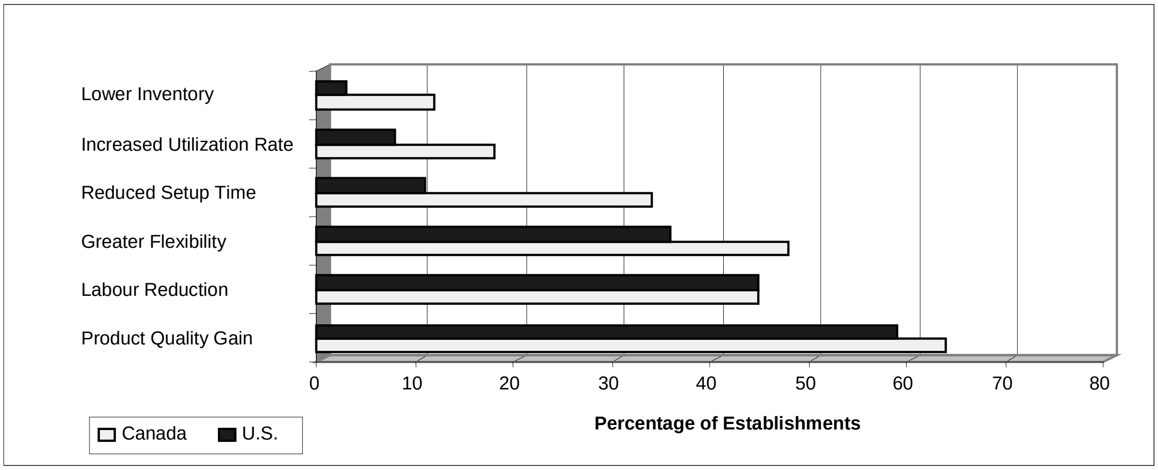
When comparing the Canadian and U.S. results, it should be noted that the Canadian survey asked respondents to check off any benefits that were received from technology adoption, whereas the U.S. survey asked them to list only the three most important. As a result, the responses to any individual category might be expected to be higher for Canada. In order to control for this, rankings of the relative importance of benefit categories are calculated (Table 8). Comparisons between the two countries are better done based on these rankings. For example, even though 80% of Canadian plants reported product quality gains as a result of using advanced fabrication and assembly technologies, both ranked it first in terms of importance.

Among the six comparable categories, *improvements in product quality* are the most important—that is, the most frequently cited—in both Canada and the U.S. across all functional groups. Depending on the functional group, between 60% to 80% of plants in both countries claimed to have received product quality gains from technology adoption. It is particularly important for fabrication and assembly for Canadian plants (80%), while it is of equal importance across all functional groups for U.S. plants (about 60%).

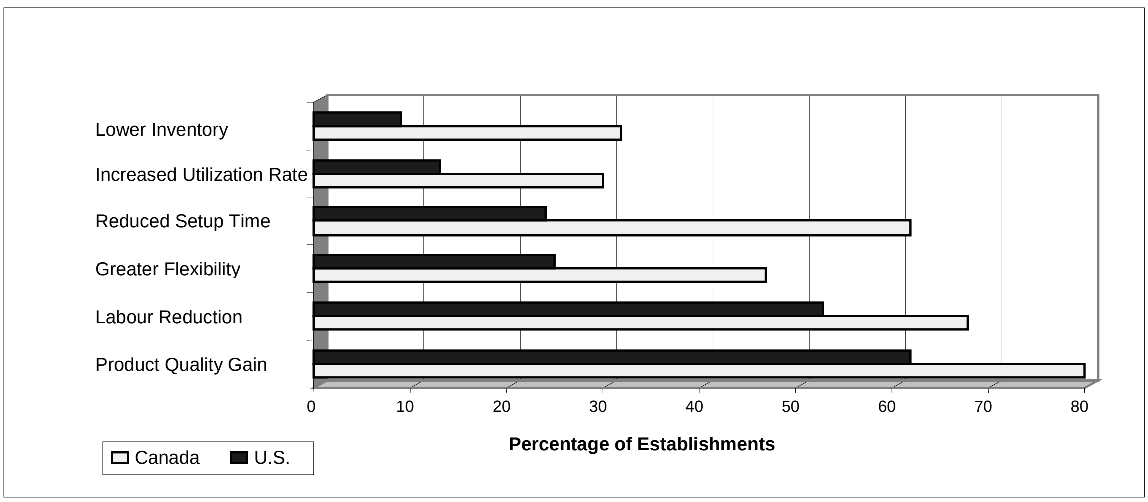
Second in importance for the United States is the effect category *reductions in labour requirements*. This is a category that is closely tied to *improvements in productivity*—a category that was used in the Canadian but not in the United States survey. As the major factor contributing to gains in productivity, *reductions in labour requirements* is consistently ranked high in both countries—second in the United States and second or third in Canada among the group of common benefits. It ranges in importance from about 30% for inspection and communications, to 45% for design and engineering for both Canadian and U.S. plants. For fabrication and assembly, 68% of Canadian plants rank it important, which is slightly higher than the 53% of U.S. plants that do so. In both countries, productivity gains due to labour reductions come just after quality improvements.

Figure 7. Most Important Benefits and Effects From Technology Acquisition (Establishment Weighted)

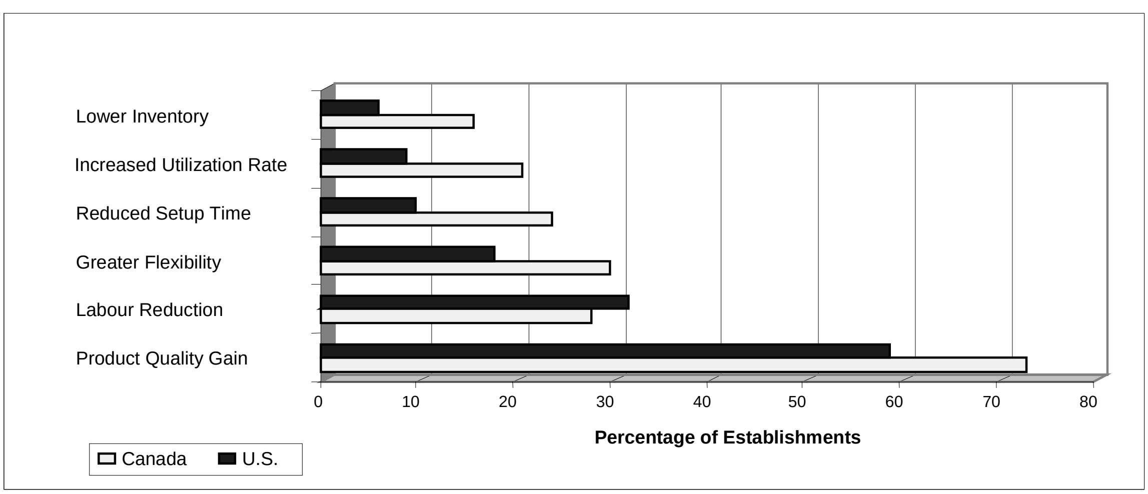
Design and Engineering



Fabrication and Assembly



Inspection and Communications



Greater product flexibility is another important benefit found in both countries for all functional groups. The ability to produce a range of different products or parts with the same piece of equipment is particularly important for design and engineering (48%), as well as fabrication and assembly (47%) for Canadian plants, and design and engineering (36%) for U.S. plants. This flexibility ranks second in importance for the design and engineering technologies as well as the inspection and communications technologies in Canada—ahead of the third place ranking given by U.S. respondents. This difference accords with the view that Canada suffers from short production runs and that these technologies allow greater flexibility, since these characteristics receive greater weight in the smaller country.

Both countries generally rank *reduced setup time* fourth among the common factors. *Reduced setup time* and *greater product flexibility* are related. Indeed, Canadian plants rank *reduced setup time* higher in fabrication and assembly than they do *greater product flexibility*. In Canada, *reduced setup time* receives its highest importance in fabrication and assembly technology (62%), where it rivals *reductions in labour requirements* (68%). It is also important for design and engineering (34%) and inspection and communications (24%), but much less so.

The final two common benefits—an *increased equipment utilization rate* and *lower inventory*—come last in both countries, though they are about in the middle of the longer Canadian list.

Looking at just the Canadian list, the two highest rated benefits, among Canadian plants, are *improvements in product quality*—an intangible benefit—and *improvements in productivity*—a tangible benefit (Table 8). *Improvements in product quality* is the leading benefit for fabrication and assembly (80%), and inspection and communications (73%), while *improvements in productivity* is rated highest for design and engineering (73%). These two categories always rank either first or second in each functional technology grouping.

Outside of the six common factors, there is one particular factor that is consistently ranked high by Canadian plants. *Increased skill requirements* is at the top of the list, just behind *improvements in product quality* and *productivity*, for both design and engineering as well as inspection and communications. It ranks slightly lower for fabrication and assembly. This is consistent with research that indicates that wages are highest in plants that use advanced inspection and communications as well as design and engineering technologies but no higher for those using advanced fabrication and assembly technologies (Baldwin, Gray and Johnson, 1997).

A second non-common factor that is relatively important for Canadian plants is *increased capital requirements*. Ranked just behind *increased skill requirements* for design and engineering, it is of equal importance for inspection and communications and slightly ahead for fabrication and assembly. Between 40% to 60% of Canadian plants increased their capital requirements as the result of technology adoption. It is most important for fabrication and assembly (58%) and least important for design and engineering (41%).

Table 8. ***Benefits and Effects of Advanced Technology Acquisition (Establishment Weighted)***

Effect	Design and Engineering				Fabrication and Assembly				Inspection and Communications			
	Canada		U.S.		Canada		U.S.		Canada		U.S.	
	% Est.	Rank	% Est.	Rank	% Est.	Rank	% Est.	Rank	% Est.	Rank	% Est.	Rank
TANGIBLE:												
Improvement in Productivity	73	1	---	---	73	2	---	---	60	2	---	---
Reduction in Labour Requirements	45	5	45	2	68	3	53	2	28	8	32	2
Reduction in Material Use	27	8	---	---	24	12	---	---	20	11	---	---
Reduction in Energy Use	10	11	---	---	19	13	---	---	8	14	---	---
Increased Equipment Utilization Rate	18	9	8	7	30	11	13	6	21	10	9	6
Increased Capital Requirements	41	6	---	---	58	5	---	---	47	3	---	---
Reduced Capital Investments	5	13	---	---	6	15	---	---	1	16	---	---
Lower Inventory	12	10	3	8	32	10	9	8	16	13	6	7
INTANGIBLE:												
Improvement in Product Quality	64	2	59	1	80	1	62	1	73	1	59	1
Increased Skill Requirements	50	3	---	---	48	7	---	---	46	4	---	---
Reductions in Product Rejection Rate	34	7	---	---	57	6	---	---	39	5	---	---
Reduced Setup Time	34	7	11	6	62	4	24	4	24	9	10	5
Reductions in Lead Time	---	---	27	4	---	---	20	5	---	---	11	4
Greater Product Flexibility	48	4	36	3	47	8	25	3	30	7	18	3
Improved Working Conditions	24	8	---	---	46	9	---	---	31	6	---	---
Marketing Advantage	---	---	22	5	---	---	11	7	---	---	18	3
Reduced Environmental Damage	10	11	---	---	24	12	---	---	18	12	---	---
Reduced Skill Requirements	8	12	---	---	10	14	---	---	5	15	---	---

Note: The shaded areas in the table indicate the factors common to both surveys.

Factors Hindering Acquisition of Advanced Technology

Impediments to technology acquisition are factors that increase the costs of adoption, thereby decreasing the net return earned from adoption. Firms that are on the margin of adopting advanced technologies will be influenced by increases in costs; while firms that receive a rate of return well above their cost of capital would be expected to adopt advanced technologies even if costs change marginally.

In the first instance, impediments include the overall costs of equipment. Impediments that are commonly investigated extend beyond overall costs to specific cost problems such as labour training, organizational change, software development, or lack of technical support. The inclusion of both the general cost categories and the specific cost categories leads to a problem in the interpretation of the results. After all, if overall costs are deemed to be constraints, is it not true that every cost component should also be important? How then should a manager's evaluation of a particular category like skill shortages be interpreted?

Every manager has to decide where to devote resources and how much to devote to them. At any point in time, a manager will decide whether resources should be spent on a particular problem based on an evaluation of the benefits to be received. In a well-articulated maximization problem that can be represented by a programming model, relaxation of a constraint such as a skill shortage will be associated with an improvement in overall profits—the value of the dual in the programming model. While difficulties associated with assigning values to intangible benefits will make such a model difficult to apply, managers nevertheless apply alternate decision rules in deciding which problems are most capable of solution to the benefit of the operations of their plant. The importance of a particular cost category should be regarded as the plant manager's evaluation that the benefits to be received from reducing the problem, or the diminution of profits that result from its lack of resolution, are large.

The Canadian and U.S. surveys cover almost the same topics—overall cost, lack of financial justification, education and training costs, worker resistance or uncertainty, time and cost to develop software, lack of technical support, increased maintenance expense, and need for market expansion.[10] The exception is cost of technology acquisition, which appears only in the Canadian survey. Two of these require a special explanation. Market expansion should be interpreted as a cost-inhibiting factor having to do with equipment constraints. Some equipment may require sufficiently long production runs that its use is not profitable for plants with small markets. Financial justification involves the evaluation of revenue and cost streams. When revenue or cost streams are influenced by intangible items, it may be difficult to invoke sophisticated financial measures and more simple rules of thumb based on evaluation of cost items will be used. It is, therefore, of interest to compare the percentage of plant managers who

[10] A recent OECD report (1991) lists lack of skilled personnel, organizational problems, problems with software, and economic difficulties, such as lack of finance and economic downturns, as the major problems establishments encounter in adopting technology.

indicate that costs, as opposed to financial justification, is the problem because differences therein will indicate the extent to which evaluation problems are particularly difficult.[11]

Once again, it should be noted that the Canadian survey asked plant managers to check off any item that was an impediment to technology acquisition. The U.S. survey asked only that the three most important items be checked. Therefore the absolute values—the percentage of firms finding a category important—are not directly comparable. For example, *overall cost* is the main factor hindering technology acquisition in both countries, but a greater percentage of plants in Canada than the United States indicate that it is important (Table 9). In evaluating the importance of factors other than overall cost, it is important to compare their importance relative to that of overall cost since this partially corrects for the differences in the number of items checked off in the two surveys. *Relative importance (r. i.)* is the percentage of plants for which a secondary factor is important, expressed as a fraction of those for which overall cost is important.

In Canada and the U.S., and across all technology groups, *overall cost* matters most as an impediment. But there are differences in its importance that are common across both countries. Cost is more of a concern for design and engineering as well as fabrication and assembly technologies. It is somewhat less important for inspection and communications technology where only a third of Canadian establishments and a fifth of U.S. ones felt it was important.

Lack of financial justification is second to overall cost in importance for both Canadian and U.S. plants in almost all cases. *Overall cost* and *lack of financial justification* should be related. But in both countries, a greater percentage of plants indicate that costs were too high than indicate the investment was not financially justified. In both countries then, decisions are more likely to be related to a decision-rule based on costs than on a fully articulated financial decision-rule. But Canadian plants do not appear to be less able to perform sophisticated financial decision-making since the relative importance of financial justification is higher in Canada than in the U.S. for two of the three functional groups—design and engineering, and fabrication and assembly (Figure 8). For the third, inspection and communications, a similar emphasis is found in the two countries. For Canadian plants, the relative importance ranges from 0.59 in inspection and communications to 0.73 in fabrication and assembly. By comparison, it ranges from 0.46 in fabrication and assembly to 0.58 in inspection and communications for U.S. plants.

According to Canadian plant managers, *cost of technology acquisition* is the third most important impediment, after *overall cost* and *financial justification*. The cost of technology acquisition includes all costs related to knowledge acquisition—payments for licenses, patents, trade secrets, and technical support (Baldwin, Sabourin, and Rafiquzzaman, 1996). Little variation is found across functional groups in the importance of this category, ranging as it does from 0.47 for fabrication and assembly to 0.57 for design and engineering. Unfortunately, this factor did not appear on the U.S. questionnaire, so no comparison can be made between Canada and the United States in this instance.

[11] See Baldwin, Sabourin and Rafiquzzaman (1996) for a lengthier discussion of this issue.

Generally the next highest common factor in Canada, after financial justification, is the *need for market expansion*. It is particularly important for design and engineering (0.43) and fabrication and assembly (0.38), and less so for inspection and communications (0.29). This supports the claims that the small Canadian market is restrictive, at least for these five industries. In contrast, the *need for market expansion* is generally near the bottom of the list of impediments for U.S. plants.

Table 9. ***Factors Hindering Acquisition of Advanced Technology (Establishment Weighted)***

Factors	Design and Engineering		Fabrication and Assembly		Inspection and Communications	
	Canada	U.S.	Canada	U.S.	Canada	U.S.
	(Percentage of Establishments)					
Overall Cost	42	25	45	26	34	19
Cost of Technology Acquisition	24	---	21	---	18	---
Cost of Education and Training	20	13	12	12	9	10
Worker Resistance or Uncertainty	8	5	17	6	7	5
Time to Develop Software	15	11	13	7	14	7
Cost to Develop Software	11	7	11	5	7	5
Increased Maintenance Expense	6	5	14	9	1	3
Need for Market Expansion	18	3	17	5	10	3
Lack of Financial Justification	27	12	33	12	20	11
Lack of Technical Support	10	8	12	8	10	5
Other	6	5	10	4	8	3

Unlike Canadian plants, U.S. plants consider the *cost of education and training* to be equally as important as the *lack of financial justification*. The *cost of education and training* is relatively less important in Canada than in the United States, falling just behind the *need for market expansion* for fabrication and assembly as well as for inspection and communications. It is, however, relatively just as important in the area of design and engineering in Canada.

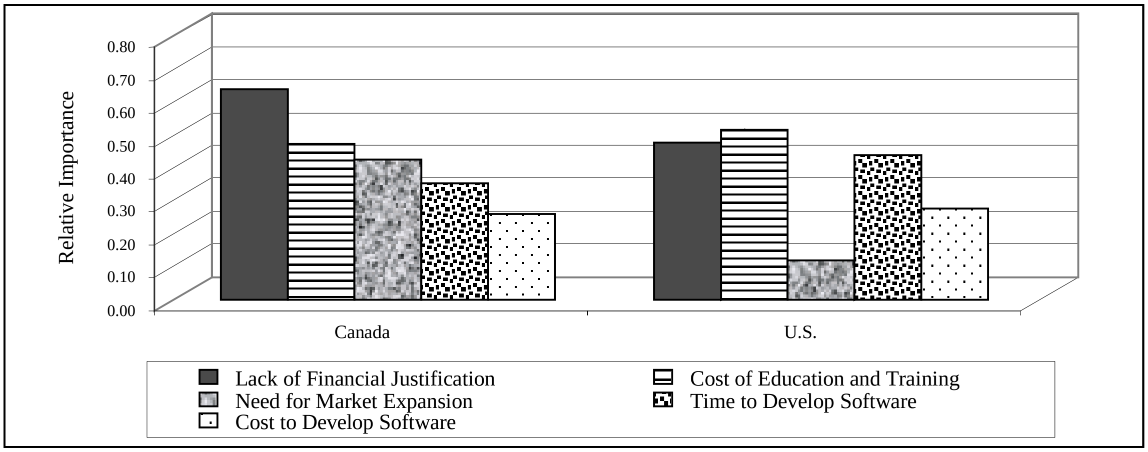
While the *cost of education and training* is relatively less important in Canada, it should be noted that Canadian plant managers did note that one of the most important effects of the introduction of advanced technologies was an increase in skill levels. However, in this section that considers the relative importance of impediments, education and training costs are relatively less important in Canada than in the United States.

Time to develop software and *cost to develop software* both have about the same relative importance in the two countries. It is the case, however, that *time to develop software* has a higher ranking in inspection and communications, where this impediment ranks third in both countries. *Time to develop software* is always more important than *cost to develop software*. The importance of *lack of technical support* is relatively similar in both countries as well.

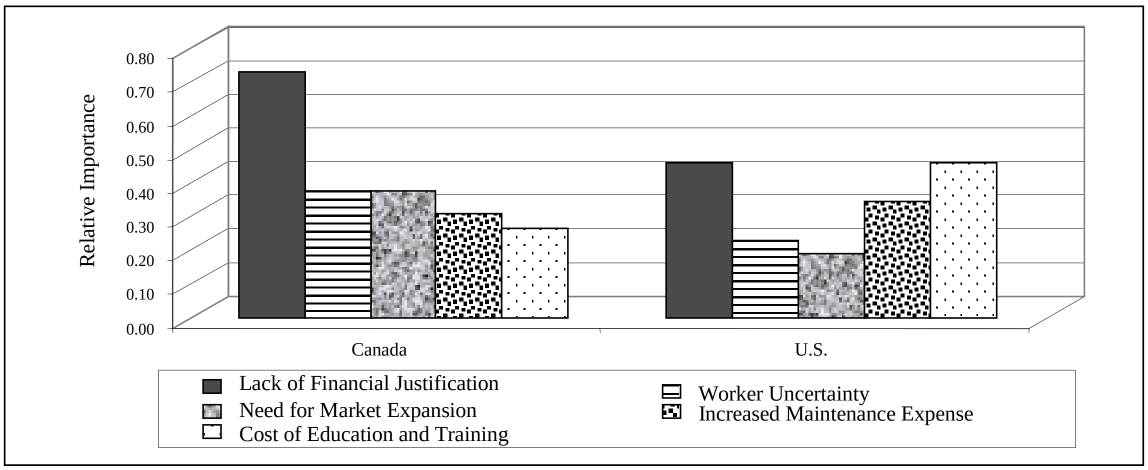
Worker resistance is generally at the bottom of the list of problems in both countries—with one exception. In Canada, it is relatively important for fabrication and assembly technology (0.38).

Figure 8. Relative Importance of Major Impediments to Technology Acquisition[12] (Establishment Weighted)

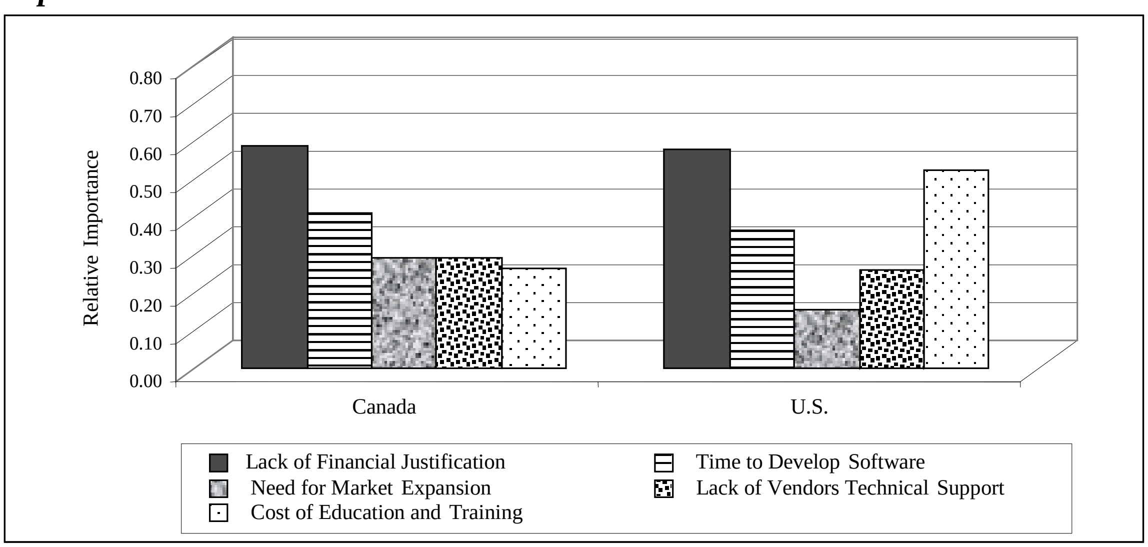
Design and Engineering



Fabrication and Assembly



Inspection and Communications



[12] Of the impediments investigated, overall cost and cost of technology acquisition have not been included. Overall cost has not been included since by construction it equals one. Cost of technology acquisition has not been included since it is not found on the U.S. questionnaire.

In summary, the most significant difference in the two countries is the greater emphasis that is placed by Canadian plant managers on the *need for market expansion*. Concomitantly, U.S. managers place relatively greater importance on the *costs of education and training*. While the absolute percentage of plants in Canada that perceive education important is about the same as in the United States, compared to other problems it is relatively less important in Canada. This is particularly so for the adoption of fabrication and assembly technologies, *where market expansion*, and *worker resistance* are more important and in inspection and communications technologies, where the *time to develop software* is perceived to be more important.

Impact on Education and Training Costs

The introduction of computer-based technology into the production process has led to a concern over changing job skills. A recent study (Baldwin, Gray and Johnson, 1995) of Canadian manufacturing establishments has shown that plants adopting advanced technology require more highly skilled labour. It goes on to show that these plants are more likely to have formal training programs, which has led to an increase in their training costs.

The previous sections focused on the skill issue—but always placed skills in context by asking plant managers how skill issues compared to others. In the benefits section, Canadian plants indicated that increased skill requirements were one of the most important effects associated with the introduction of advanced technologies. However, in the impediments section, Canadian plant managers responded that increased costs of education were less important relative to problems associated with the need for market expansion than did U.S. plant managers. While the previous sections have the advantage that they set the skills issue in the context of other problems, they have the disadvantage that they can only provide a relative assessment. Managers in Canada and the United States may see the skills issue quite the same in absolute terms but quite different in relative terms. Therefore, this section examines how the managers responded to a question that focused only on the effects of the adoption of advanced technologies on training and education costs—whether it decreased, had no effect, caused a marginal increase, a moderate increase, or a significant increase in these costs. This question not only allows us to focus directly on the skills issue but, to the extent that managers in both countries use a similar scale to measure the impacts, it also permits us to assess differences in the intensity of the response.

Table 10. ***Impact on Education and Training Costs (Establishment Weighted)***

Impact	Design		Fabrication		Communications	
	Canada	U.S.	Canada	U.S.	Canada	U.S.
	(Percentage of Establishments)					
Increased Significantly	38	18	27	14	18	10
Increased Moderately	23	26	24	25	21	19
Increased Marginally	16	26	14	26	25	26
No Change	14	16	11	18	18	23
Decreased	1	1	3	1	1	1
Not Applicable	8	13	21	16	17	21

The Canadian and U.S. responses are similar in that the majority of plant managers in both countries indicate that the adoption of advanced technologies increased education and training costs (Table 10). The relative percentages in Canada and the United States are 77% and 70% for design and engineering, 65% and 65% for fabrication, and 64% and 55% for inspection and communications. Thus, Canadian plant managers do not lag those in the United States with regards to their assessments of the effect that advanced technologies have on skill levels. Indeed, the reverse is true.

In the previous section, it was found that education and training costs were relatively more important as an impediment for design and engineering technology. It was much less important for fabrication and assembly, and inspection and communications. The data here confirm this. Consistent with this, both Canadian and U.S. plant managers reported the greatest impact on education and training costs for design and engineering technology. A greater percentage of Canadian plant managers experienced an increase in education costs in design and engineering (77%) than did so in either fabrication and assembly (65%) or inspection and communications (64%). More importantly, thirty-eight percent of Canadian plant managers encountered *significant* increases in education and training costs after acquiring design and engineering equipment while a smaller percentage did so in either fabrication or communications. Finally, irrespective of which functional category is examined, the percentage of Canadian plant managers that experienced a significant increase in education costs is well above that of U.S. managers.

Similar percentages of plants in both countries report moderate increases in training costs, across technology groups and countries. Between 20% to 25% of establishments had a moderate increase. Marginal increases in training costs are reported with greater frequency by U.S. plant managers for design and engineering, as well as fabrication and assembly technology. For inspection and communications, Canadian plant managers reported marginal increases just as often as did U.S. plant managers.

Less than one-fifth of plants in Canada and one-quarter of plants in the United States reported no change in education and training costs with the introduction of advanced technology, at least for these five industries. The percentage of plants reporting a decline in training costs is minimal in both countries.

In conclusion, a direct comparison of the effects of technology on training costs suggests that Canadian plants experience the same type of impediments as do those in the United States. If anything, these problems are probably slightly higher in Canada than those experienced by the United States.

In the previous section, we noted that the responses to the impediments question, when taken alone, allowed only a comparison of the relative importance of each factor for Canada and the United States using ordinal scales. If the responses to the impact on education costs question are used to define the points on the two relative scales that are equivalent, then the relative ranking can be transformed into absolute scales that are comparable.[13] If education and training costs have about the same importance in the two countries, it is not unreasonable to conclude that all those categories that are relatively more important than education and training in Canada pose greater problems to Canadian than U. S. plant managers. For example, in fabrication and assembly, these would include lack of financial justification, need for market expansion, worker resistance and increased maintenance expense (see Table 9). This greater emphasis on a wider range of impediments might serve to explain why Canadian adoption is lower than U. S. adoption.

Conclusion

The competitiveness of firms in manufacturing depends upon many different factors, including the skill of its work force, its organizational structure, and the extent to which it employs advanced technologies. Technological competence begins with the use of the most advanced equipment. Recent surveys have developed measures of the degree to which manufacturing plants possess machines that embody the computer-driven technologies that are changing the nature of manufacturing and the extent to which Canadian plants are competitive with those of foreign producers.

Canadian plant managers indicate that, on the whole, the technological competence of their plants is just as good as or better than their foreign competitors. Moreover, the high technology industries do particularly well. There are, however, areas of technology use, where the picture is not as healthy. Inspection and communications do not fare as well as others for the population as a whole.

Plant managers' evaluations for five industries where technology use data are available for the United States indicate that they feel Canada suffers a disadvantage in these industries. Technology-use data bears out these evaluations. In the late 1980s, Canadian technology use in these five industries lagged that of the United States. At that time, Canadian plants were less likely to be users of any of these technologies. As well, they lagged the United States in the use of multiple technologies and in the use of many of the individual technologies. By 1993, Canada had closed some of the technology gap in these five industries.

Much of the technology gap can be attributed primarily to differences in the size of markets. Canadian plant managers tend to place a greater relative emphasis on *improvements in product flexibility* or *reductions in setup time* as benefits of technology adoption and the *need for market expansion* as an impediment to technology is given relatively greater weight than it is in the United States. U.S. plants rank the *need for market expansion* almost at the bottom of the list of impediments while, in Canada, it is ranked at the top of the list.

[13]The assumption of equivalence with regards to education and training costs and a similarity in the ordinal rankings transforms the ordinal into cardinal rankings.

Improved product flexibility and *reduced setup time* are particularly advantageous for plants operating in smaller markets, where filling diversified product lines is more costly. In these situations, being able to use machinery for different products and being able to reconfigure equipment quickly offer significant benefits.

Plant managers in the United States generally give considerably higher relative weight to the *cost of education and training* as an impediment than do managers in Canada. At first glance, this suggests that Canadian managers may have less of a problem in this area. But careful examination of the issue by a direct comparison of responses in the two countries to questions dealing just with the training cost issue suggests that there is little difference between the two countries in the absolute weight given to this issue. In fact, when training costs alone are examined, Canadian plant managers suggest that the severity of the increase in training costs is greater than in the United States. If this is indeed the case, it suggests that other factors—such as *lack of financial justification* and *need for market expansion* that are relatively more important than *training costs*—are much more of a problem in Canada. This would help to explain why Canada lags the U.S. in technology adoption.

Finally, it should be noted that the implementation of high technology in the area of fabrication and assembly is more problematic in Canada because of management-labour frictions. For this technology, *worker resistance* is quoted relatively more frequently by Canadian than U.S. plant managers.

Outside of these differences in plant managers' perceptions of the benefits and problems of technology adoption, there are a large number of similarities. *Improvements in quality* and *improvements in productivity/reductions in labour* are the two most important effects in both countries. *Education and training costs* are important in both countries. *Increased equipment utilization* and *lower inventory costs* are relatively unimportant as benefits. In the same vein, many of the impediments, like the *time* and *cost to develop software* are similar in relative importance. But then this is as it should be. The differences in technology use that have been delineated here are not enormous. We should expect the attitude of plant managers to be relatively the same in the two countries, and with the exception of their perceptions on the need to expand markets, they are.

Appendix A: Standard Errors

The standard errors for each table in the publication are provided here. The standard errors for the U.S. results are taken from U.S. Bureau of the Census (1993) while the Micro-Economic Analysis Division of Statistics Canada generated the standard errors for the Canadian results.

The standard errors are lower for the U.S. results than for the Canadian results. Much of this difference is likely due to differences in the sample sizes. The U.S. sample size is roughly 10 times larger than the Canadian one, mostly because of differences in target populations. The U.S. survey was restricted to establishments with 20 or more employees in one of five major industry groups,[14] while the Canadian survey covers establishments of all employment sizes active in all major manufacturing industries. In order to make comparisons, the Canadian sample had to be drastically reduced.

Table B.1. Standard Errors for Table 4

Use of at Least One Technology by Employment Size (Establishment Weighted)

Employment Size (Number of Employees)	Use of at Least One Technology			
	1989		1993	
	Canada	United States	Canada	United States
	(Percentage of Establishments)			
20 to 99	5	na	4	na
100 to 499	3	na	1	na
500 or More	9	na	1	na
All Sizes	4	na	4	na

Table B.2. Standard Errors for Table 5

Number of Technologies Used by Employment Size (Establishment Weighted)

Employment Size	Number of Technologies							
	0		1		2 to 4		5 or More	
	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.
	(Percentage of Establishments)							
1989								
20 to 99	5	na	4	na	3	na	4	na
100 to 499	4	na	2	na	5	na	7	na
500 or More	2	na	1	na	7	na	6	na
ALL SIZES	4	na	3	na	3	na	3	na
1993								
20 to 99	4	na	4	na	4	na	2	na
100 to 499	1	na	1	na	1	na	2	na
500 or More	1	na	1	na	1	na	1	na
ALL SIZES	4	na	4	na	4	na	2	na

[14]The five industry groups are fabricated metal products, industrial machinery and equipment, electronic and other equipment, transportation equipment and instruments and related products.

Table B.3. Standard Errors for Table 6

Use of Individual Technologies in Canada and the United States (Establishment Weighted)

Technology	Use	
	Canada	United States
	1993	1993
	(Percentage of Establishments)	
Design & Engineering		
Computer-aided Design and Engineering	3.0	0.7
CAD Output to Control Manufacturing Machines	2.8	0.6
Digital Representation of CAD	2.0	0.4
Fabrication & Assembly		
Flexible Manufacturing Systems	1.7	0.4
Numerically Controlled and Computer Numerically Controlled Machines	2.9	0.7
Materials Working Lasers	1.3	0.3
Pick and Place Robots	1.7	0.3
Other Robots	1.1	0.2
Automated Material Handling		
Automated Storage/Retrieval Systems		
Automated Guided Vehicle Systems		
Inspection & Communications		
Inspection Equipment for Inputs	1.4	0.4
Inspection Equipment for Outputs	1.7	0.4
Local Area Networks for Technical Data	2.0	0.6
Local Area Networks for Factory Use	1.8	0.5
Inter-company Computer Networks	1.5	0.5
Programmable Controllers	2.5	0.6
Computers Used for Control in Factories	2.3	0.6

Table B.4. Standard Errors for Table 7

Plans to Upgrade Existing Advanced Technology (Establishment Weighted)

Plans	Design		Fabrication		Communications	
	Canada	U.S.	Canada	U.S.	Canada	U.S.
	(Percentage of Establishments)					
Total Replacement	1.6	0.2	0.6	0.2	1.4	0.2
Major Upgrade	3.5	0.7	3.8	0.7	3.1	0.6
Minor Upgrade	3.7	0.8	3.9	0.8	4.2	0.7
Under Consideration/No Plans/Not Applicable	3.9	0.9	4.8	0.9	4.2	1.0

Table B.5. Standard Errors for Table 8

Benefits and Effects of Advanced Technology Acquisition (Establishment Weighted)

Effects	Design and Engineering		Fabrication and Assembly		Inspection and Communications	
	Canada	U.S.	Canada	U.S.	Canada	U.S.
	(Percentage of Establishments)					
<u>*TANGIBLE :*</u>						
Improvement in Productivity	3.4	---	4.3	---	3.3	---
Reduction in Labour Requirements	3.9	0.9	4.7	1.0	3.0	0.8
Reduction in Material Use	3.6	---	2.8	---	2.0	---
Reduction in Energy Use	2.0	---	4.0	---	2.4	---
Increased Equip. Utilization Rate	2.7	0.4	3.0	0.6	2.9	0.5
Increased Capital Requirements	4.0	---	3.1	---	2.9	---
Reduced Capital Investments	1.4	---	1.6	---	0.6	---
Lower Inventory	1.9	0.3	2.9	0.4	2.5	0.4
<u>*INTANGIBLE :*</u>						
Improvement in Product Quality	3.9	1.0	2.3	1.0	2.3	0.9
Increased Skill Requirements	3.9	---	4.5	---	3.0	---
Reductions in Product Rejection Rate	3.9	---	4.7	---	3.0	---
Reduced Setup Time	3.8	0.6	4.5	0.8	3.2	0.5
Reductions in Lead Time	---	0.8	---	0.7	---	0.5
Greater Product Flexibility	3.9	0.8	4.8	0.7	2.8	0.6
Improved Working Conditions	3.1	---	4.5	---	3.0	---
Marketing Advantage	---	0.7	---	0.6	---	0.7
Reduced Environmental Damage	2.6	---	4.6	---	2.0	---
Reduced Skill Requirements	2.1	---	2.1	---	1.4	---

Table B.6. Standard Errors for Table 9

Factors Hindering Acquisition of Advanced Technology (Establishment Weighted)

	Design and Engineering		Fabrication and Assembly		Inspection and Communications	
	Canada	U.S.	Canada	U.S.	Canada	U.S.
	(Percentage of Establishments)					
Overall Cost	3.9	0.7	4.8	0.8	3.5	0.7
Cost of Technology Acquisition	3.3	---	4.0	---	2.8	---
Cost of Education and Training	3.6	0.6	3.3	0.6	2.4	0.5
Worker Resistance or Uncertainty	2.2	0.3	3.6	0.4	1.9	0.4
Time to Develop Software	3.1	0.5	3.0	0.4	2.4	0.4
Cost to Develop Software	2.8	0.4	2.7	0.3	2.0	0.3
Increased Maintenance Expense	1.7	0.3	3.3	0.5	0.6	0.3
Need for Market Expansion	3.5	0.3	3.6	0.4	2.7	0.3
Lack of Financial Justification	3.5	0.6	3.9	0.5	2.7	0.5
Lack of Technical Support	2.8	0.5	3.0	0.4	3.3	0.3
Other	1.1	0.4	1.7	0.3	1.5	0.3

Table B.7. Standard Errors for Table 10

Impact on Education and Training Costs (Establishment Weighted)

Plans	Design and Engineering		Fabrication and Assembly		Inspection and Communications	
	Canada	U.S.	Canada	U.S.	Canada	U.S.
	(Percentage of Establishments)					
Increased Significantly	3.9	0.6	4.5	0.6	3.7	0.5
Increased Moderately	3.1	0.8	2.9	0.8	2.9	0.7
Increased Marginally	2.4	0.7	2.3	0.8	3.1	0.7
No Change	3.1	0.7	3.0	0.7	3.6	0.8
Decreased	0.9	0.1	1.4	0.1	0.3	0.2
Not Applicable	2.0	0.3	4.2	0.3	3.7	0.4

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