Skill Shortages and Advanced Technology Adoption

by

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Abstract

This paper investigates the extent to which establishments in the Canadian manufacturing sector experience occupational skill shortages, and to the extent that they do, whether these shortages appear to act as impediments to advanced technology adoption. Plants adopting advanced technology report shortages, particularly when it comes to professionals, such as scientists and engineers, and to technical specialists. Whether these shortages pose labour-market problems depends very much on the solutions adapted by the establishments experiencing the shortages. This paper finds that labour shortages did not appear to block technology adoption since those establishments that reported shortages were also the most technologically advanced. Although they faced a greater need for skilled labour, they were able to solve their shortages.

Keywords: skill shortages, advanced technology, impediments

1. Introduction

Many forms of technological change are accompanied by changes in skill requirements (Doms, Dunne and Troske, 1997). This is particularly true of the changes associated with the adoption of the new advanced technologies that are being implemented in the manufacturing sector.

During periods of rapid technical change, shortages of particular types of skilled workers emerge. The importance of these shortages depends on their magnitude and the extent to which they reduce the ability of firms to adopt the new technologies. In a previous study, Baldwin and Peters (2001) investigated the extent to which shortages in specific occupations presented impediments to adoption in the early 1990s, when unemployment rates were very high. This study examines the extent to which shortages were more important later in the decade, when labour markets were tighter and when the use of advanced technologies was much more widespread.

Over the past decade, use of advanced technology has increased dramatically, particularly in the years following the recession of the early 1990s. The adoption rates of advanced technologies doubled in the five-year period 1993-98 (Baldwin, Rama and Sabourin, 1999). Growth was fastest for network communications technologies, the technologies linked with higher growth in plant productivity and wages during the 1980s (Baldwin, Diverty and Sabourin, 1995).

Increased skill requirements have resulted from the introduction of advanced manufacturing technology in Canada (Baldwin, Gray and Johnson, 1996). With technological change comes a need for a more highly skilled workforce. Several plant-level studies suggest that we have been undergoing skill-biased technical change. In the United States, Dunne and Schmitz (1995), Siegel (1995) and Alyan (1999) find that higher wages and an increasingly skilled labour force are associated with the use of advanced technologies. In Canada, Baldwin, Gray and Johnson (1996) also find that the average wages of plants using advanced technologies are higher than those not using these technologies and the difference has tended to increase over time. Using data on R&D rather than technology intensity, Machin and Van Reenen (1998) find skill-biased technical change to be an international phenomenon. They report a positive and significant relationship between skill upgrading and R&D intensity for seven countries studied—United States, United Kingdom, Denmark, France, Germany, Japan, and Sweden.

Although these studies point to a relation between technical change and increases in skill levels, they give no indication as to whether or not this poses a problem. In order to answer this question, we must address two issues. The first is the extent to which firms experience skill shortages. The second is whether these shortages are a problem. In an earlier study, Baldwin and Sabourin (1995) find that plant managers report that a lack of skilled workers is one of the principal impediments to technology adoption. However, little empirical evidence exists as to the extent to which plant managers feel there is a "skill shortage" problem in particular occupations. This study investigates this issue.

The document also asks whether these occupational shortages are related to firms' views of whether they face labour-market impediments. Occupational shortages may exist without their being substantial impediments. Firms may find various ways of handling a shortage of labour. A shortage will become an impediment to technology adoption only if its labour supply is highly inelastic or if there are few possibilities for substitution.

The document is structured as follows. Section 2 describes the data source used for the study. Section 3 examines the extent to which occupational shortages exist and the areas in which they are found. Section 4 investigates the actions taken by firms to deal with these shortages. Section 5 deals with the extent to which skill shortages act as impediments to adoption.

2. The Survey

The data source used for this study is the *1998 Survey of Advanced Technology in Canadian Manufacturing*. Conducted by Statistics Canada, it is based on a frame of Canadian manufacturing establishments taken from Statistics Canada's Business Register.[1] The survey was done at the plant level and mainly answered by plant managers. Plants with fewer than 10 employees were not surveyed. The response rate for the survey was 98.5%.[2] The sample size was 4,200 establishments of which 3,760 were in-scope. The survey is included in Appendix A.

The survey includes questions on general firm and establishment characteristics; the adoption of advanced technologies; the occupational skill shortages being experienced by the respondents; whether they implemented training in response to skill shortages; and the obstacles that firms faced when they adopted new advanced technologies; whether certain business practices like concurrent engineering were combined with the use of advanced technologies; the way in which advanced technologies were developed and implemented; the results of technology adoption; and the role of research and development in developing new technologies.

In the technology adoption section of the questionnaire, respondents indicated which of 26 advanced technologies had been implemented. Overall, three quarters of Canadian manufacturing establishments use at least one of the advanced technologies listed on the survey (Sabourin and Beckstead, 1999). The technologies cover six functional technology groups—design and engineering (technologies like computer aided design and engineering); processing, fabrication and assembly (technologies like flexible manufacturing systems and robots); automated material handling; inspection (technologies like computer controlled sensing devices); network communications (technologies like company-wide computer networks); and integration and control (technologies like computer integrated manufacturing). The answers to these questions will be used to divide respondents into groups according to the intensity of advanced technology use.

The skill shortage questions asked managers whether skill shortages arose from the use of advanced technology in four specific areas—management, professionals, technicians and technologists, and skilled trades—as well as how shortages in these areas were handled—by

[1] The food-processing sector was excluded because it had been surveyed separately one year earlier.
[2] For a more complete description of the survey, see Sabourin and Beckstead (1999).

training, raising salaries, or by increased co-operation with educational institutions. These questions will be used to investigate the extent to which managers faced skill shortages.

We also make use of responses to a set of questions on the relative importance of a set of problems that plant managers faced when implementing advanced technologies—from human resource problems to capital costs. These questions allow us to evaluate the importance of human resource problems relative to other impediments. And by cross-referencing answers in this area to responses by plant managers about the extent of occupational skill shortages, we can evaluate the extent to which occupational skill shortages translated into real impediments.

3. Occupational Skill Shortages

3.1 Introduction

Firms that adopt advanced manufacturing technologies (AMTs) require a skilled workforce. When existing skill sets are not adequate, firms can either hire more qualified workers or they can increase the skill levels of existing employees through training. While hiring is essential in many situations, training is clearly an important complement. Previous studies (Baldwin and Sabourin 1997; Baldwin, Gray and Johnson 1996) have shown that AMT users invest more in training than do non-users.

There are times, however, when the supply of particular skill sets falls short of the demand at prevailing wage rates and shortages develop. Shortages may arise because all workers need to develop new skill sets or they may arise from the lack of skill sets that are specific to particular occupations. One of the objectives of this paper is to identify whether skill shortages have developed in those plants at the forefront of the latest changes in technology, and in which occupational areas these shortages are greatest.

3.2 Plant and Industry Characteristics

Skill shortages may not be equally problematic across all occupational categories. Shortages for technicians can develop on the shop floor when the new skill levels are directly associated with machine operation. Or they can develop in supervisory personnel in plants where advanced technologies require more co-ordination of both personnel and practices. Or they may arise in professionals if the new computer-driven advanced technologies demand additional scientific skills.

To determine if skill shortages have developed in certain occupational areas, we examine the percentage of technology users that indicated they experienced a skill shortage in one of four main occupational categories—professionals, management, technicians and technologists, and skilled trades (see Table 1).[3] Our analysis is restricted to technology users only since the skill shortage question is asked in relation to the operation of advanced technology (Appendix A). The professionals category includes mechanical and aerospace engineers; electronic and computer specialists; chemical and chemical process engineers; industrial and manufacturing process engineers; science professionals; and computer scientists. All of these are expected to have achieved a university degree. The management category includes production, design, and human resources management. The technicians and technologists category consists of electronics and computer hardware specialists, science technicians, engineering science technicians, computer programmers, communications network administrators, computer aided design specialists, and instrumentation specialists. The skilled trades' category consists of machinists, machine operators, electrical equipment operators, and process plant operators.

Overall, two-thirds of technology users indicate that they experienced some type of skill shortage during the year immediately preceding the survey. Shortages are greatest for the professional and skilled trade categories, with roughly 40% of technology users experiencing a shortage in each of these areas (Table 1). Close behind are technicians and technologists at 37%, with the fewest shortages reported for management (31%).

In terms of specific occupational categories, shortages are greatest for machine operators, industrial engineers and machinists, with roughly one quarter of plant managers reporting a shortage in each of these areas (Figure 1). Production managers and computer professionals are next, with one-in-five plants reporting a shortage.

These shortages are not spread equally across all plants. The pattern of plant and industry differences in these shortages provides us with information on the nature of the adoption process. It also allows us to ascertain whether the shortages are more likely in those segments that use more or that use less advanced technologies. We know, for example, that large foreign-owned plants are more intensive technology users (Baldwin and Diverty, 1995). Is it also the case then that large establishments are more likely to encounter shortages because of their higher level of demand for skilled personnel? And is being foreign-owned an advantage or a disadvantage when it comes to attracting or developing skilled personnel?

To examine how skill shortages differ across plants, we tabulate the percentage of plants experiencing skill shortages for different occupations by plant size, nationality of ownership, and the degree of technology use (Table 1).

Size is measured by the total number of employees in an establishment, including both production and non-production workers. Establishments are classified to one of three size categories—10 to 99, 100 to 249, and 250 or more employees. Plants are also divided into those that are domestically controlled as opposed to foreign controlled.

[3] See Sabourin and Beckstead (1999) for more details. This question was asked with regard to the operation of advanced technology, so only advanced technology users answered this question.

Table 1. Occupational skill shortages by plant and industry characteristics for advanced technology users (Establishment weighted)

Plant characteristics	Skill shortages				
	Occupational categories				
	Professionals	Management	Technicians and technologists	Skilled trades	Any
	(percentage of establishments)				
Overall	42	31	37	40	64
Employment size:					
Small	38	29	34	41	62
Medium	50	34	40	33	67
Large	67	44	62	41	81
Ownership:					
Canadian	41	31	37	40	63
Foreign	46	31	39	37	69
Number of technologies:					
1 to 4	27	22	27	33	52
5 to 9	48	35	42	44	69
10 or more	57	39	46	46	75
Investment in technology:					
Zero	25	16	20	30	49
1-25%	38	27	33	34	58
26-50%	48	46	44	45	72
51-75%	51	37	54	55	80
76-100%	64	42	60	64	87

Technological intensity is measured in two different ways. First, it is measured in terms of the number of advanced technologies used. Three groupings are employed—1 to 4 technologies, 5 to 9 technologies, and 10 or more technologies. These groupings were chosen since roughly equal numbers of establishments are found in each group. Second, technological intensity is measured as the percentage of total investment on machinery and equipment spent on advanced technologies. Here, four groupings were used—1 to 25%, 26 to 50%, 51 to 75%, and 76 to 100%. Close to half of the plants had invested between 1% and 25% of their total investment in advanced technology. One quarter had not invested in advanced technology at all.

Reported skill shortages increase monotonically with plant size for all but the skilled trades category. Large and medium-sized plants report the greatest shortages for professionals, while for small plants, shortages of skilled trades and professionals are of roughly equal importance. After professionals, technicians are the most often cited category where shortages exist for large and medium-sized plants. They pose less of a problem for small establishments.

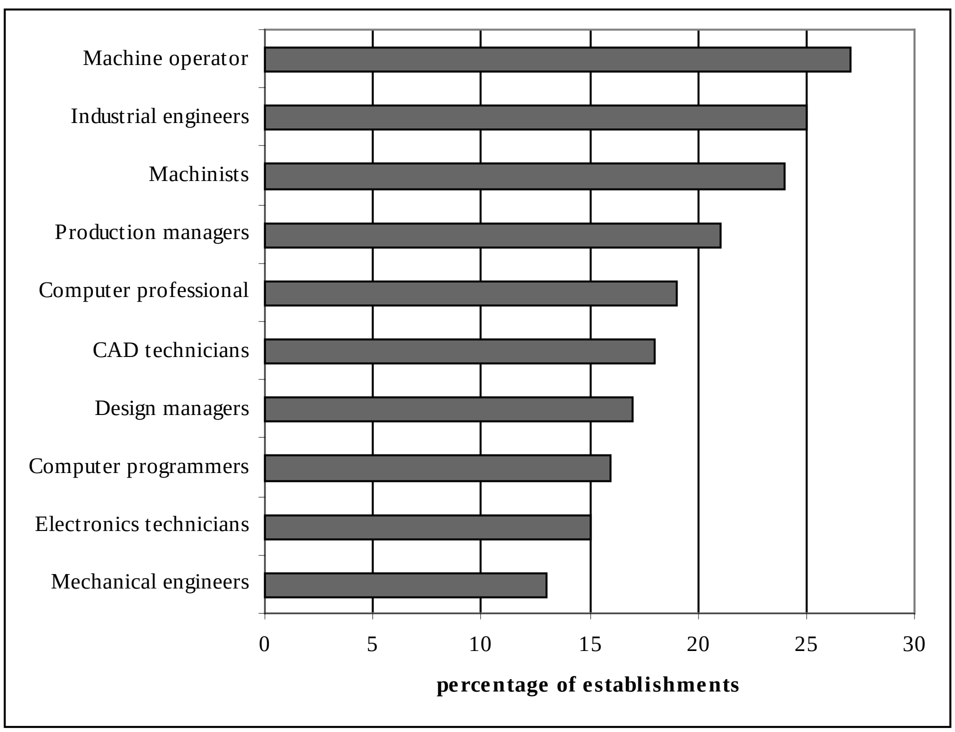
Technological intensity is also positively related to the likelihood of skills shortages. The likelihood that a plant will experience occupational shortages increases monotonically with technological intensity. Plants using more advanced technologies are the most likely to suffer skill shortages of any type. High intensity users have a greater demand for highly skilled workers, particularly professionals, and are, therefore, more likely to suffer a shortage. The difference is largest for the professional category with 30 percentage points difference separating high and low technology users. Differences of between 13 to 19 percentage points are found for the other occupational categories.

A similar story is found with regards to investment. With the exception of management, shortages increase monotonically with the amount invested in advanced technology. Sixty percent or more of plants that had invested heavily in advanced technology reported a shortage in all categories except for management, compared to between 30% to 40% of those plants that invested mostly in conventional equipment.

There are smaller differences in shortages reported by domestic and foreign-owned plants. With the exception of the professionals category, foreign-owned and domestic-owned plants are equally likely[4] to report shortages of most types. Only for professionals is there a significant difference, but even then the difference is not large. Forty-six percent of foreign-owned plants report a shortage of professionals compared to forty-one percent of domestic-owned plants.

In conclusion, skill shortages appear to be closely related to technology usage. This is particularly the case for professional occupations. It is not the case that plants that use little in the way of technologies indicate that they suffered most from shortages, thereby suggesting that skill shortages substantially prevented adoption. Rather these patterns suggest that firms that adopt advanced technology need to acquire more skilled labour.

Figure 1. Skilled Personnel Shortages



[4] Although not identical for the technicians and skilled trades' categories, the differences are not statistically significant.

3.3 Multivariate Analysis

3.3.1 The Framework

While the bivariate tabular results reported in the preceding section provide an overview of the relationships that exist between skill shortages and selected plant and industry characteristics, they are limited when it comes to estimating the individual but joint effects of a number of variables. Bivariate analysis does not allow us to determine, for example, to what extent the ownership effect we observe is mainly due to foreign-owned plants simply being larger than domestic plants. In this section, we turn to multivariate analysis to estimate these influences jointly.

Differences in the need to attract skilled labour are hypothesized to be related to differences in plant characteristics (such as plant size, nationality of ownership, R&D performance, and the extent to which advanced technology is being used) and industry characteristics.

The first is whether the plant performs R&D. Plants with R&D facilities are more likely to require a complex skill set and to involve a highly skilled labour force.

The second is whether the plant is engaged in a set of business practices in quality control, materials management and advanced design practices like concurrent engineering that complement the use of advanced technologies. Respondents to the survey indicated whether they used any of a set of twelve practices designed to increase the efficiency of a firm's operation. These practices involve cross-functional design teams, concurrent engineering, continuous improvement, benchmarking, quality certification, just-in-time inventory control, process simulation, and electronic work order management. Many of these practices are process-oriented, but all work with various forms of the advanced technologies that are investigated in the survey. For example, work order management best functions with company-wide computer systems and automated management systems. Concurrent engineering integrates with computer aided design systems.

Three binary variables were constructed to capture the intensity of the use of these practices. The first measures lack of use and takes a value of one if a firm uses none of the practices listed, and a value of zero otherwise. The second measures moderate use taking a value of one if between one and five practices are being used, and a value of zero otherwise. The third binary variable captures heavy use being assigned a value of one if the establishment uses six or more practices, and a value of zero otherwise.

Two industry variables are also included. The first is a proxy for the competitive conditions in an industry. It might be expected that firms in industries that are more competitive would be more likely to bid workers away from one another. Number of competitors is used to measure the degree of competition that a firm faces. Plants are grouped according to whether their manager indicated that they faced five or fewer competitors, six to 20 competitors, or more than 20 competitors and three binary variables are used to capture these competitive categories.

The second industry variable represents the innovative intensity of the industry. Based on a taxonomy developed by Robson et al. (1988), it divides the manufacturing sector into three groups—the core, the secondary and the other group. The core group produces the most innovations and sells a large proportion to other sectors. The "other" sector produces fewer innovations and buys a large proportion of the innovations from the other sectors in the form of machinery or materials. We have previously found that advanced manufacturing technology use is greatest in the core sector, and least in the "other" sector (Baldwin and Diverty, 1995; Baldwin and Sabourin, 1997).

A logistic regression model is used for our analysis with the following specification:

$$S = f(C,I)$$

where S refers to specific occupational skills shortages, C to plant and firm characteristics, and I to industry characteristics.

The binary dependent variable measures the extent to which managers perceive skill shortages to exist in Canadian manufacturing. It takes on a value of one if any skilled shortage exists at all, and zero if it does not. A separate binary variable was constructed for each of the occupational categories— professionals, management, technicians, and skilled trades.

The independent variables include plant size, nationality, technology use, the existence of an R&D unit, and the use of advanced quality and business practices. The industry variables are competitive conditions and innovativeness. The means and standard deviations of the variables used are presented in Table 2.

3.3.2 Empirical Results

The results of the logistic regression models for the probability of a firm experiencing a skill shortage, both at the overall and individual occupational level, are given in Table 3. Weighted[5] logistic estimates are provided for all models. All regressions are estimated against an excluded establishment that is small, Canadian-owned, does not perform R&D, uses some but not many business practices, is in the core sector, faces few competitors, and has a low technological intensity.

The parameter results in Table 3 provide the qualitative effects of the explanatory variables; the quantitative effects are provided in Table 4, which presents the probability of a particular category reporting a skill shortage. The probabilities are initially calculated by estimating the logit function at the sample means of the omitted category.[6] Separate probabilities are only calculated for categories whose coefficients are significantly different from the omitted category.

[5] The weights that are used are the probability sampling weights from the survey.
[6] Probabilities (p) are estimated using the logit equation:

$$P = \exp(\beta x)/[1 + \exp(\beta x)]$$

Skill shortages increase as technology use rises. Plants with the lowest technological intensity—under five advanced technologies—experience the least skill shortages across all occupational categories. Medium and high intensity plants report significantly more skill shortages across all occupational categories, with slightly higher differences for professional and skilled trades. Between 45% and 50% of medium and high intensity plants report shortages in these two areas compared to about a third of low intensity plants (Table 4). Significant differences also exist for the other two occupational groups, although they are less pronounced.

Other measures of technological sophistication are also related to skill shortages. For example, both the use of sophisticated business practices and research and development have a separate effect on skill shortages. The business practices investigated in the survey are complements to advanced technology. Establishments that adopt large numbers of technologies and complementary business practices are those with the most complex innovation and technology strategies. More complex structures are expected to require greater levels of expertise.

Confirming this hypothesis, plants that make use of sophisticated business practices in the area of quality control, materials management and prototyping are more likely to report skill shortages across all occupational categories, except for management. It is noteworthy that differences in shortages are greatest for professionals. Half of the plants employing six or more of the practices listed on the survey encounter shortages of professionals, compared to one out of every five plants employing none.

R&D is another direct measure of scientific sophistication. Plants with R&D facilities report more skill shortages. The coefficient on R&D performance is positive and statistically significant for professionals and management. Being an R&D performer adds about 10 percentage points to the probability of encountering shortages in both of these areas. Once again, this supports the hypothesis that more complex innovation strategies require greater levels of expertise.

Large plants are more likely to report a skill shortage, particularly in the professional and technical skills category even after taking into account technology differences and other aspects of technological sophistication like the use of specific business practices. Large plants are more sophisticated than small plants in more ways than our conditioning variables relating to technology use, R&D performance and the use of sophisticated business practices allow. Slightly more than half of the largest plants suffered shortages in both of these areas compared to only about a third of the smallest ones. Smaller size differentials exist for management skills. In contrast, small plants are more likely to report a skill shortage in the skilled trades category. Small establishments, therefore, appear to have a more difficult time recruiting skilled tradespeople than establishments of other sizes presumably because of their inability to match the wages and benefits packages offered by the larger establishments.

Except for professionals, nationality of ownership has no significant effect on occupational skill shortages. Domestic-owned plants are significantly more likely to have shortages of qualified professionals. Forty percent of domestic-owned plants have “professional” shortages compared to about 31% of foreign-owned plants.

Table 2. Overview of dependent and independent variables for technology users only (Establishment weighted)

Variable	*Description*	*Mean*	*Standard deviation*
1. Dependent variables			
Skill shortage	Skills shortages		
SHORTAGE	- overall	0.60	0.49
PROFESS	- professionals	0.39	0.49
MANAGE	- management	0.29	0.46
TECHIES	- technicians and technologists	0.35	0.48
TRADES	- skilled trades	0.37	0.48
2. Independent variables			
Plant characteristics and activities			
Size	Employment size		
ESTSIZE1	- 10 to 99 employees	0.79	0.41
ESTSIZE2	- 100 to 249 employees	0.14	0.35
ESTSIZE3	- 250 or more employees	0.08	0.26
Business practices	Number of business practices used		
NUPRAC1	- none	0.15	0.36
NUPRAC2	- 1 to 5	0.51	0.50
NUPRAC3	- 6 or more	0.33	0.47
Competition	Number of competitors		
COMPET1	- five or less competitors	0.24	0.43
COMPET2	- six to 20 competitors	0.28	0.45
COMPET3	- over 20 competitors	0.48	0.50
Technology intensity	Number of technologies used		
NUTECH1	- 1 to 4	0.40	0.49
NUTECH2	- 5 to 9	0.33	0.47
NUTECH3	- 10 or more	0.27	0.44
Firm characteristics and activities			
Ownership	Nationality of ownership		
FOREIGN	- foreign owned	0.12	0.32
R&D activity	R&D activity		
RADDOER	- R&D performer	0.63	0.48
Industry characteristics			
Industry	Industrial sector		
CORE	- core	0.19	0.40
SECONDARY	- secondary	0.40	0.49
OTHER	- other	0.41	0.49

The innovation environment of an industry to which an establishment belongs also influences the likelihood that it will experience shortages of qualified personnel. In accordance with our hypothesis that skill shortages emerge in the more innovative industries, establishments in the “other” sector are significantly less likely to encounter shortages in both the professional and technical skills areas than are establishments in the core and secondary sectors.

Another industry characteristic—the competitive environment—has little or no impact on whether a plant reports a skill shortage. It is true that more competition results in a greater probability that shortages of skilled trades will occur but the difference between the most competitive category and the least is not large.

Table 3. Logistic regression model of occupational skill shortages technology users only (Establishment weighted)

	Occupational shortages				
	Professional	Management	Technicians and technologists	Skilled trades	Any
Intercept	-1.03***	-1.50***	-1.02***	-1.06***	-0.11
PLANT CHARACTERISTICS					
Plant size:					
100 to 249 employees	0.26*	0.03	0.11	-0.48***	-0.04
250 or more employees	0.80***	0.36*	0.96***	-0.24	0.55***
Business practices:					
None	-0.79***	-0.18	-0.59**	-0.64**	-0.72***
6 or more	0.37**	0.22	0.19	0.04	0.16
Competition:					
6 to 20 competitors	0.08	-0.10	-0.15	0.32*	0.14
More than 20 competitors	-0.01	0.14	0.02	0.31*	0.24
Technology intensity:					
5 to 9 technologies	0.76***	0.63***	0.61***	0.53***	0.61***
10 or more technologies	0.73***	0.63***	0.49**	0.68***	0.70***
FIRM CHARACTERISTICS					
Ownership:					
Foreign	-0.38**	-0.25	-0.32	-0.22	-0.06
R&D activity:					
R&D doer	0.46***	0.40**	0.26	-0.11	0.28*
INDUSTRY CHARACTERISTICS					
Industry:					
Secondary	-0.21	-0.11	-0.02	0.63***	0.02
Other	-0.56***	-0.26	-0.30*	-0.22	-0.33**
Summary statistics:					
N	3108	3108	3108	3108	3108
LL function	-1859	-1802	-1896	-1929	-1939
χ^2	157.3	59.0	112.0	58.1	104.8

Note: *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

In summary, plants that are more technologically advanced are more likely to report a shortage of skilled workers than are those less technologically advanced. This finding applies whether we measure technological requirements directly with number of technologies implemented or indirectly with types of other activities—such as R&D activity or quality control practices. Even after these measures are taken into account, large plant size, a measure of success that involves other activities than just those measured, is also associated with the reporting of skill shortages.

Table 4. Estimated probabilities for skill shortages logistic regression model (Establishment weighted)

	Occupational shortages				
	Professional	Management	Technicians and technologists	Skilled trades	Any
PLANT CHARACTERISTICS					
Plant size:					
10 to 99 employees	36	30	29	42	55
100 to 249 employees	42	30	29	31	55
250 or more employees	56	38	51	42	68
Business practices:					
None	22	30	21	28	41
Few (1-5)	38	30	32	43	59
Many (6 or more)	47	30	32	43	59
Competition:					
Zero to 5 competitors	39	30	30	35	56
6 to 20 competitors	39	30	30	43	56
More than 20 competitors	39	30	30	42	56
Technology intensity:					
1 to 4 technologies	29	23	24	32	47
5 to 9 technologies	46	36	36	45	62
10 or more technologies	45	36	34	49	64
FIRM CHARACTERISTICS					
Ownership:					
Foreign	31	30	30	41	56
Domestic	40	30	30	41	56
R&D activity:					
R&D doer	43	33	30	41	59
Non R&D doer	32	25	30	41	52
INDUSTRY CHARACTERISTICS					
Industry:					
Core	44	30	33	35	60
Secondary	44	30	33	50	60
Other	31	30	27	35	51

Table 5. Importance of skill shortages as impediments to adoption (Establishment weighted)

Characteristics	**Skill shortages as an impediment**	
	Low importance	High importance
Action taken	69	86
Type of action taken:		
Training	79	87
Improved wages and benefits	60	69
Strengthened educational links	45	54
Searched for skilled personnel	91	97

4. Actions Taken

Firms can deal with skill shortages in a number of different ways. They can choose to introduce training programs for their current employees. Or they may elect to hire new employees possessing the necessary skills. Or they may do both.

In the *1998 Survey of Advanced Technology in Canadian Manufacturing*, firms that reported skill shortages also reported which types of actions were taken in response to these shortages—whether they trained, increased wages or tied themselves more closely to the education system. To analyze whether the severity of the skill shortage was related to the response to the skill shortage question, we examine how the percentage of those taking specific actions varies between those who felt that skill shortages were a major impediment and those who felt it had little importance (Table 5). Firms scoring four or five (out of five) for the skills impediment question are classified as those for which skill shortages are important, while those scoring a one or two are classified as finding them unimportant. Firms scoring a three are omitted from this comparison.

Of those who experienced a skill shortage, most had taken some type of corrective action. Nine out of ten plants for which lack of skills is seen to be a major obstacle took some action compared to seven out of ten for those plants for which it was not.

Most firms (more than 90%) experiencing shortages increased their search for skilled personnel. Skill shortages, in this sense, were real. The second most important response was to increase training, with between 80% and 90% of plants electing to do so.

Improving wages and benefits package was third. A majority of firms with skill shortages adopted this strategy. Nevertheless, more plants developed training programs than simply adopted higher remuneration packages.

The least important response was to establish stronger links with educational institutions, either because the types of skills that are in short supply cannot be readily generated by the educational system or the costs of this action are too high.

Our results show that plants for which shortages were reported to be a greater obstacle were more likely to take all types of corrective action to deal with these shortages. They were more likely to train, more likely to improve wages and benefits, to strengthen their links with educational institutions, and to actively search for new personnel. Significant differences of close to 10 percentage points separate the two groups right across the board.

To sum up, greater levels of advanced technology adoption lead to higher levels of skill shortages. It is the highly intensive users of technology that are most likely to encounter a shortage. But while these plants are more likely to report a shortage, they are no less likely to adopt advanced technology.

Plants for which skill shortages are seen to be an impediment are more likely to take corrective action once a shortage is encountered. They are also more likely to adopt advanced technologies and to adopt greater numbers of them. This suggests that, although a lack of skilled labour poses a real problem for many plants, it does not necessarily result in reduced adoption rates. Establishments find ways to address these shortages, by training or seeking out qualified workers.

5. Skill shortages as an impediment to technology adoption

5.1 Characteristics

Although employers indicate that occupational shortages are a problem, the severity of the problem has yet to be addressed. There is still the unresolved issue as to whether these occupation shortages acted as an impediment to technology adoption.

Simply reporting an occupational shortage does not mean it has a dramatic effect on technology adoption. The effect of the lack of skilled labour on a firm depends on the elasticity of supply of labour. Firms that report a shortage may have the means to deal with it that are effective and efficient. Others may not be able to do so and a shortage of skills may increase their costs because they have to greatly increase wages or to increase training costs. The latter may reflect serious inadequacies in a firm's own recruitment and training programs.

Firms that are able to deal with skill shortages, either through a training program or a hiring program or both, are less likely to consider the shortages to be a serious obstacle to technology adoption. Firms unable to deal with the shortages, however, either through lack of experience or inadequate resources, are more likely to find them a real problem.

Baldwin and Peters (2001) reported that in the *1993 Innovation and Advanced Technology Survey*, few plant managers reported that they reduced their adoption of advanced technologies as a result of skill shortages. In this section, we address the same issue in a different way by examining whether plants felt skill shortages were very important as impediments.

To gauge the extent to which there are differences in the importance of skill shortages, we make use of the results of responses of plant managers who rated, on a scale of one (low) to five (high), the importance of a set of ten factors as impediments to technology adoption. In what follows, we categorize a plant as suffering an important impediment if it gave the problem a ranking of a 4 or 5.

The impediments were grouped into four major categories—financial costs, labour costs, management problems, and inadequate technical support. The ten factors represent two quite different levels of cost impediments. In the first instance, costs were grouped into general, all-inclusive categories that were non-specific and that should have affected a plant having any one of a number of specific problems. These all-inclusive categories were "financial costs" that involved capital and equipment costs. Firms that faced an upward sloping supply curve should have indicated that costs were an impediment at the margin. Only if the investment decision was overwhelmingly in favour of new technologies and not constrained by incremental increases in equipment costs, would a plant not have indicated that it was impeded by these general cost categories.

At the second level are special costs, which may not be included in equipment costs. These peripheral categories include training costs, technology licencing costs, the costs of persuading workers or management to accept new technologies, the costs of search for new technologies, and the costs of technical support. We would expect most, if not all, respondents to indicate that they faced a constraint from costs in general, while fewer would do so for more specific costs.

The percentage of plant managers that rated a factor as an important impediment to the adoption of advanced technologies is provided in Table 6. The results are divided into categories grouped by level of technological intensity. Three technology groups are used—those plants with 1-4 advanced technologies, 5-9 advanced technologies, and 10 or more advanced technologies. As expected, the largest percentage of plant managers indicated that general costs were an important impediment. The cost of equipment, followed by capital costs, were the two highest rated general costs across all plants. Among technology users of all intensities, about 60% of the managers found high equipment costs to be an important problem. Financing costs were next, with 50% of users rating it as an important impediment. It is also noteworthy that the costs to develop software to run the computer-based advanced technologies are an important impediment. They rank just behind the cost of capital. This is consistent with findings from the *1993 Innovation and Advanced Technology Survey* (Baldwin, Sabourin, and Rafiquzzaman, 1996).

It is significant that there is virtually no difference in the perceived impediments in these areas between non-technology users and technology users. Indeed, if anything, there is a larger proportion of technology users who report that general equipment costs are a significant impediment. We conclude that most firms are constrained at the margin by equipment costs.

Nor are there major differences across the technology using classes in the percentage of plants that report general costs as being a problem. If these impediments served to substantially reduce technology use, we would expect to find firms making less use of technologies to be those who are more likely to report that costs are an important impediment. Since this is not the case, there is little here to suggest that general costs serve as a deterrent to more intensive technology use.

The only cost category where there were significant differences across technology users is the area of market size. If new technologies require long production runs to exploit the economies of volume, an inadequate market size will hamper the implementation of the technologies. It is quite clear that there is a large and significant difference between the high technology and the low technology users in this area, with low technology users reporting that market size was a much more important impediment than more intense technology users. That market size is an important barrier accords with previous findings from the 1993 survey (Baldwin and Sabourin, 1997).

Table 6. Obstacles to advanced technology adoption (Establishment weighted)

OBSTACLES	Non technology users	Low technology users (1-4 technologies)	Medium technology users (5-9 technologies)	High technology users (10 or more technologies)
	(percentage of establishments reporting extreme scores)			
Lack of financial justification due to				
a) small market size	35	37	33	21
b) high cost of equipment	54	63	63	61
c) cost of capital	46	54	49	50
d) costs to develop software	41	37	36	34
e) cost of integration of new technology	47	42	45	39
Human resources				
f) shortage of skills	28	36	40	37
g) worker resistance	14	19	22	15
Management				
h) resistance to introduction of new technology	14	16	15	11
i) inability to evaluate new technology	14	20	20	12
External support services				
j) lack of technical support or service	11	19	19	17

Moving away from the more general to the more specific costs, we find that skill shortages is the most important of the specific costs. Slightly more than a third of plant managers rated it a significant obstacle to adoption. More intense technology users are more likely to report it as a significant obstacle. This difference accords with the learning-by-doing explanation of skill shortages that is reported in related work (see Baldwin and Lin, 2001).

In some instances, firms may learn more about problems after they engage in a particular activity, such as the adoption of advanced technology. Plants are better able to evaluate the problems associated with that activity. The data on differences in the intensity of reporting a significant impediment indicates that technology users have a better understanding of the skill levels required to introduce, operate and maintain a new technology within an organization. They are more likely to suggest that the costs involved in training current employees or searching out new ones are significant.

Skill shortages is the only area in which high technology users are more likely to encounter a problem than low technology users. More intense technology users are less likely to find that the cost of integration of new technologies, or the resistance to the introduction of new technologies, or the ability to evaluate new technologies into the plant was a major impediment. This suggests that intense technology users found ways to solve these problems during the implementation process. By way of contrast, human resource problems continued to trouble the more intense technology users.

5.2 Multivariate Analysis

While the extent to which shortages are seen to be a problem by plant managers in the manufacturing sector is related to technology use, it may also be connected to a number of other plant and industry characteristics.

This section asks whether the severity of the perceived impediments due to skill shortages in general is related to the existence of skill shortages in particular occupational classes once these other factors are taken into account. Firms may perceive they have a generic skill problem without their facing a shortage in any particular occupational class (see Baldwin and Peters, 2001).

To examine this issue, we make use of multivariate analysis to estimate the relationship between whether a plant indicated that it faced an important skill-related impediment (generic or occupational) and whether it indicated it suffered from particular occupational shortages. In addition, we consider whether other plant characteristics that were previously found to affect whether a plant faced occupational shortages also affect its perception of the importance of the skill problem as an impediment to technology adoption.

This approach is meant to show which specific occupational skill shortages pose a problem to the firm when it comes to advanced technology adoption. As shown by Baldwin and Peters (2001), impediments may arise either because of specific deficiencies at the occupational level or they may arise more generally in terms of generic skill gaps. We are also interested in ascertaining whether the plant characteristics that were related to the existence of skill shortages (size, nationality, technological intensity) have effects in addition to occupational skill shortages when it comes to the perception of managers that skills offer important impediments to the adoption of advanced technologies.

5.2.1 The Framework

We will investigate whether the importance of skill shortages as an impediment to adoption is related to whether a plant suffers certain occupational shortages. These shortages, in turn, are expected to depend on certain plant and industry characteristics. These characteristics are plant size, R&D activity, the use of advanced business practices, technological intensity, and competitive environment. All of these characteristics may affect the extent to which an occupational shortage provides a significant impediment.

Plant size will affect the extent to which occupational shortages are serious if plants of different sizes vary in terms of their ability to overcome skill deficiencies. Large plants often have formal departments that handle staffing and training issues, while smaller plants do so in a less formalized way. If formal departments are more effective in solving skill deficiencies than the less formalized methods of smaller plants, large plants may regard skill shortages as a less serious problem, even if they are more likely to report shortages in certain occupations.

The same result may occur for technology users. If technology users have already had to deal with skill deficiencies in order to successfully adopt advanced technologies, they may have superior mechanisms in place to resolve deficiencies. In this case, we should expect to find that the importance that is attached to the skill shortage as an impediment will be inversely related to technology use. If technology users are no better equipped to handle shortages, then technology use should have no separate independent effect on the severity of the impediment after the severity of occupational shortages is taken into account.

Other plant characteristics related to technological capabilities, such as the intensity of production processes like concurrent engineering activities, will be positively related to the severity of the impediment if the business practice is a proxy for the value of skilled labour. Firms that have implemented special practices like concurrent engineering may place a higher value on certain skilled occupations and may, therefore, find a shortage in that occupation more of a problem.

An industry characteristics that might be expected to affect whether skill shortages are an impediment is the degree of competition. Establishments facing large numbers of competitors may be more likely to compete for scarce skilled workers.

Logistic regression analysis will be used for our analysis. The dependent variable measures the importance of skill shortages as an impediment to technology adoption. It takes a value of one if skill shortages are reported to be an important obstacle to adoption (scores of 4 and 5 to the impediment question), and zero if it is of little importance (scores of 1 and 2). Plants for which it is of medium importance (score of 3) are omitted from the regression.

The first set of independent variables measures the extent to which occupational shortages are important. These variables are included so that we can ascertain whether certain types of occupational shortages are more critical than others. Four binary variables are included to investigate this effect, one for each of the four main occupational groups—professionals, management, technicians and technologists and skilled trades. Each binary variable takes a value of one if the establishment reported a skill shortage in that area, and a value of zero otherwise.

We also include plant size, technological intensity, and competition, defining each as before.

5.2.2 The Results

The results show a strong relationship between the probability that a plant manager felt that there was a severe impediment to technology adoption from skill shortages and the extent of occupational skill shortages of all types. The effect of shortages in the professional and technical occupational categories is greatest.

The coefficients on both plant size and technological intensity are negative and significant. For a given level of occupational shortages, larger plants and plants with more technologies are less likely to report that they faced impediments from a lack of skills. About 67% of large plants and plants with 10 or more technologies report an impediment compared to 79% of small plants and those with fewer than five technologies. This suggests that it is the smaller, less technologically advanced plants that are at a disadvantage when it comes to attracting or training skilled workers.

A positive but rather weak relationship exists between the importance attributed to skill shortages as an impediment and the likelihood that the plant had implemented one of the advanced business practices. Those that use sophisticated business practices are slightly more likely to encounter a problem for a given level of occupational shortages.

There is also a positive and significant relationship between competition and the likelihood that a firm feels it faces an important impediment with regards to skill shortages. Greater competition leads to an increased likelihood that an occupational shortage creates problems for the firm.

Finally, ownership and R&D activity have no significant effect. While the existence of an R&D unit may be related to the likelihood that a plant faces shortages in certain occupations, for example, professionals, it does not enhance the likelihood that the firm reports a skill shortage impediment.

In summary, after consideration is given to whether a plant faced occupational shortages, it is the small establishments, facing moderate to heavy competition, and using few advanced technologies to begin with, that face the greatest problems. These are the plants that are least likely to be able to solve the problems that they face.

Table 7. Logistic regression results for skill shortage impediments variable (Establishment weighted)

Variables	Coefficients		Probabilities	
	Model 1	Model 2	Model 1	Model 2
Intercept	0.41	-0.25	---	---
OCCUPATIONAL SHORTAGES				
Occupation:				
Professional	---	0.69***	---	74
Management	---	0.46***	---	69
Technical skills	---	0.72***	---	74
Skilled trades	---	0.52***	---	70
PLANT CHARACTERISTICS				
Plant size:				
10 to 99 employees	---	---	57	79
100 to 249 employees	-0.45***	-0.53***	45	69
250 or more employees	-0.24	-0.59***	57	67
Business practices:				
Business practices	---	0.41*	---	78
No business practices	---	---	---	70
Competition:				
5 or less competitors	---	---	48	72
6 to 20 competitors	0.33*	0.33*	57	78
10 or more competitors	0.36**	0.35**	57	78
Technology intensity:				
1 to 4 technologies	---	---	55	79
5 to 9 technologies	0.19	-0.23	55	79
10 or more technologies	0.003	-0.56***	55	68
FIRM CHARACTERISTICS				
Ownerhip:				
foreign	---	-0.04	---	77
domestic	---	---	---	77
R&D activity:				
R&D performer	---	-0.14	---	77
non performer	---	---	---	77
Summary statistics:				
N	3108	3108		
LL function	-1980	-1785		
χ^2	17.4	170.7		

Note: *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

6. Conclusion

Technical change in the Canadian manufacturing sector is being led by the application of advanced technologies. These technologies range from communications and control systems that allow different functional processes to be co-ordinated in new ways, to computer-aided design systems that allow for the integration of the design, engineering and production processes, to flexible manufacturing cells that bring together different parts of the assembly system in new and creative ways (Baldwin, Diverty and Sabourin, 1995).

As with other major technological revolutions, the changes that are occurring in the factory are being felt in the labour force. New skills are required to work the new machines and new skills are required to manage the production process.

As a result, skill shortages have developed in plants that have been adopting new advanced technologies. They are greatest in the professional areas—for electronic and computer specialists; chemical and chemical process engineers; industrial and manufacturing process engineers; science professionals; and computer scientists—and in the area of technical specialists—electronics and computer hardware specialists, science technicians, engineering science technicians, computer programmers, communications network administrators, computer aided design specialists, and instrumentation specialists.

Shortages in these professions are larger in those plants that most actively adopt a strategy that involves either an advanced technology or an innovation strategy. Plants that are more technologically intensive, are more R&D intensive, and are more innovative are all more likely to have experienced skill shortages in these occupations. In addition, large plants are more likely to experience these shortages than small plants.

Others have suggested that the type of shortages outlined herein should give us cause for concern. Gingras and Roy (2000) find no evidence that Canada is suffering from a broad-based shortage of skilled labour. They conclude that while there may be a growing labour shortage, there is no aggregate shortage of skilled workers. The ACST Expert Panel on Skills (2000) also finds no evidence of a persistent shortage of technical skills. Rather, they find a frictional shortage due to labour mobility.

While the focus is often on the emergence of new skills and shortages therein, we have been cautious about suggesting that shortages act as major impediments to technological adoption. Baldwin and Peters (2001) found that occupational shortages were less severe in the early years of the 1990s, when labour markets were experiencing a recession and when advanced technology use was not as widespread.

By the late 1990s, advanced technology use had grown substantially and this paper demonstrates that many manufacturing plants reported that they were experiencing occupational shortages. These shortages were greatest in the areas of professionals and skilled technicians. But it is important to note that they were also high in other areas.

This result is partly due to the dynamics of change. At any point in time, some plants are growing and others are declining (Baldwin, 1995). The plants that have managed to incorporate advanced technologies into their production process are most likely to grow (Baldwin, Diverty and Sabourin, 1995). Growing plants have to expand their labour force and need to add new workers and new skills at the same time.

Skill shortages then should be more severe for plants that are more innovative in terms of production processes—those plants that have managed to implement new technologies. And this process should be particularly intensive as manufacturing processes shift to incorporate the new generation of computer driven technologies—as the production system goes through a paradigm shift.

Whether this transitional period is faced with particularly severe labour-market problems will depend on the solutions that are adapted by firms experiencing skill shortages. The human resource problem that firms face can be solved in a number of different ways. And firms that do so most effectively will have a cost and competitive advantage over their compatriots.

We have seen that firms in the early 1990s not only had fewer specific occupational shortages than later in the 1990s, but they did not tend to view them as being very serious. Firms in the early 1990s found a number of ways to mitigate the problem—from outsourcing to training. In the late 1990s, they reported more shortages and they utilized training somewhat more than previously. Moreover, those who reported occupational shortages tended to indicate that labour skill problems were an important impediment to technology adoption.

Nevertheless, labour shortages were not the sort of impediment that blocked technology adoption. Indeed, those plants that indicated they faced more shortages were the ones that were more technologically sophisticated. Skill shortages had developed as plants adopted new technologies and learned about their skill requirements. Moreover, after conditioning on the amount of skill shortages faced, these plants (those that were more technologically sophisticated) were less likely to indicate that they faced an impediment from skill shortages—probably because they had a superior human resource strategy.

The competitive system then rewards those who can solve problems arising from expansion and growth. One of those problems is finding skilled labour. Firms that are successful will face more problems due to their success and the pressures that are placed upon them to expand. Those who solve their problems will in turn expand further. The fact that they face these problems should not be interpreted to mean that the problems associated with success are endemic to the population of firms as a whole.

APPENDIX A: 1998 Survey of Advanced Technology Questionnaire

Section A. General Questions

A1. Please indicate the geographic region of the head office of your controlling firm.

Canada	
U.S.A.	
Europe	
Pacific Rim	
Other foreign	

A2. Please indicate the average number of employees working in your plant.

Less than 50	
50 to 99	
100 to 249	
250 or more	

A3. Please indicate in which of the following markets your plant's primary product is sold.

Canadian markets	
U.S. markets	
European markets	
Pacific Rim markets	
Other foreign markets	

A4. Please indicate how many firms (both domestic and foreign owned) offer products directly competing with your plant's primary product.

None	
1 to 5	
6 to 20	
Over 20	

A5. Please rate the importance of the following factors in your firm's business strategy.

	IMPORTANCE				
	low				high
	1	2	3	4	5
Products and Marketing					
a) Developing new products					
b) Entering new markets					
Technology					
c) Reducing manufacturing costs					
d) Developing new manufacturing technology					
e) Using new materials					
Human Resources					
f) Using teams (e.g., cross functional, quality improvement)					
g) Ongoing technical training					

Section B. Advanced Technologies

B1. Please indicate whether you are currently using, plan to use (within two years), or have no plans to use the following advanced technologies in your plant.

TECHNOLOGIES	In use	Plan to use within 2 years	No plans to use/Not applicable
Design and Engineering a) Computer Aided Design/Engineering (CAD/CAE) b) Computer Aided Design/Manufacturing (CAD/CAM) c) Modelling or simulation technologies d) Electronic exchange of CAD files			
Processing, Fabrication and Assembly a) Flexible Manufacturing Cells or Systems (FMC/FMS) b) Programmable Logic Control (PLC) machines or processes c) Lasers used in materials processing (including surface modification) d) Robots with sensing capabilities e) Robots without sensing capabilities f) Rapid Prototyping Systems (RPS) g) High speed machining h) Near net shape technologies			
Automated Material Handling a) Part identification for manufacturing automation (e.g. bar coding) b) Automated Storage and Retrieval System (AS/RS)			
Inspection a) Automated vision-based systems used for inspection/testing of inputs and/or final products b) Other automated sensor-based systems used for inspection/testing of inputs and/or final products			
Network Communications a) Local area network (LAN) for engineering and/or production b) Company-wide computer networks (including Intranet and WAN) c) Inter-company computer networks (including Extranet and EDI)			
Integration and Control a) Manufacturing Resource Planning (MRP II)/Enterprise Resource Planning (ERP) b) Computers used for control on the factory floor c) Computer Integrated Manufacturing (CIM) d) Supervisory Control and Data Acquisition (SCADA) e) Use of inspection data in manufacturing control f) Digital, remote controlled process plant control (e.g. Fieldbus) g) Knowledge-based software			

B2. Over the last three years, what percentage of your plant's investment in machinery and equipment was spent on advanced equipment (as listed in question B1 above)?

Zero percent	
1% to 25%	
26% to 50%	
51% to 75%	
76% to 100%	

B3. How would you compare your plant's production technology with that of your most significant competitors?

COMPETITORS	less advanced				more advanced	
	1	2	3	4	5	N/A
a) Other producers in Canada						
b) Producers in the U.S.						

B4. For what purposes does your plant use communications networks (Internet, Intranet, Extranet, VAN)? Check all that apply.

	YES	**NO**	*N/A*
a) ordering products			
b) tracking production flow			
c) on-line maintenance			
d) tracking sales and inventory			
e) tracking distribution			
f) sharing technology information			
g) accounting and financing			
h) human resources purposes			
i) management planning system			
j) marketing/customer information			
k) financial transactions (e.g., banking)			
l) consumer information			
m) production status information			
n) general reference (e.g., phone numbers)			
o) other			

Section C. Business Practices

C1. Are the following practices or techniques regularly used in your plant?

	YES	**NO**	*N/A*
a) cross-functional design teams			
b) concurrent engineering			
c) continuous improvement (including TQM)			
d) benchmarking			
e) plant certification (e.g., ISO9000)			
f) certification of suppliers			
g) just-in-time inventory control			
h) statistical process control			
i) electronic work order management			
j) process simulation			
k) distribution resource planning			
l) quality function deployment			

Section D. Development and Implementation of Advanced Technologies

D1. Have any advanced technologies (as listed in question B1) been introduced into your plant?

___ Yes ___ No

If NO, then please go to question G1.

D2. If YES, by which method does your plant introduce advanced technologies?

	YES	**NO**
a) by purchasing off-the-shelf equipment		
b) by licensing new technology		
c) by customizing or significantly modifying existing technology		
d) by developing brand new advanced technologies (either alone or in conjunction with others)		

D3. Please indicate which of the following sources play an important role in providing ideas for the adoption of advanced technology in your plant. Please check all that apply.

	YES	**NO**	*N/A*
INTERNAL to your firm			
a) research			
b) experimental development			
c) production engineering			
d) corporate head office			
e) related plants			
f) technology watch program			
g) production staff			
h) design staff			
i) sales and marketing			
j) other			
EXTERNAL to your firm			
k) trade fairs, conferences, publications			
l) patents			
m) consultants/service firms			
n) suppliers			
o) customers			
p) related firms			
q) universities			
r) governments, institutes, associations			
s) other producers in your industry			
t) other			

Section E. Skill Requirements

E1. Have your plant employees received any training pertaining to the adoption of advanced technology in the last three years?

___ % Yes ___ % No

If NO, then please go to question E3.

E2. If YES, please indicate in which of the following areas training was provided. Please include both on-site and off-site training. Check all that apply.

	YES	NO	N/A
a) basic literacy/numeracy			
b) computer literacy			
c) technical skills			
d) quality control skills			
e) safety skills			
f) other			

E3. In the operation of advanced technology, for which types of skilled personnel have you experienced shortages at your plant during the past year? Please check all that apply.

	YES	NO	N/A
Professionals with university degree:			
a) mechanical/aerospace			
b) electronic/computer			
c) chemical/chemical process			
d) industrial/manufacturing process			
e) science professionals			
f) computer scientists			
Management:			
g) production management			
h) design management			
i) human resources management			
Technicians/Technologists (Community College/CEGEP):			
j) electronics/computer hardware			
k) science technicians			
l) engineering science technicians			
m) computer programmers			
n) communications network administration			
o) computer aided design			
p) instrumentation			
Skilled Trades:			
q) machinist (including tool, die mould)			
r) machine operator			
s) electrical equipment operator			
t) process plant operator			
Other:			
u) other			

If you are NOT experiencing any skill shortages at your plant, then please go to question F1.

E4. Have you taken any steps at your plant to deal with these shortages?

___ % Yes ___ % No

If NO, then please go to question F1.

E5. If YES, what steps have you taken? Check all that apply.

	YES	NO	N/A
a) provided training			
b) improved wages and benefits			
c) established stronger links with educational institutions (e.g., research scholarships, hired summer students)			
d) searched for skilled personnel			
e) other			

E6. In order to deal with these skill shortages, did you search for personnel

	YES	NO
a) within your region		
b) outside your region (in Canada)		
c) outside Canada		

Section F. Results of Adoption

F1. Rate the importance of the following effects related to the adoption of advanced technology by your plant.

EFFECTS	*IMPORTANCE*					
	low				high	don't know
	1	2	3	4	5	
Improvement in productivity due to						
a) reduced labour requirements per unit of output						
b) reduced material consumption per unit of output						
c) reduced capital requirements per unit of output						
d) reduced set-up time						
e) reduced rejection rate						
Product improvement						
f) new product features						
g) reduced time to market						
h) improvement in product quality						
Plant organization changes						
i) increased production flexibility						
j) increased skill requirements						
Plant efficiencies						
k) increased equipment utilization rate						
Market performance						
l) increased market share						
m) increased profitability						
Other						
n) other						

Section G. Obstacles to Adoption

G1. Rate the importance of the following factors as obstacles to advanced technology adoption by your plant.

OBSTACLES	*IMPORTANCE*				
	low				high
	1	2	3	4	5
Lack of financial justification due to					
a) small market size					
b) high cost of equipment					
c) cost of capital					
d) costs to develop software					
e) cost of integration of new technology					
Human resources					
f) shortage of skills					
g) worker resistance					
Management					
h) resistance to introduction of new technology					
i) inability to evaluate new technology					
External support services					
j) lack of technical support or service (from consultants or vendors)					
Other					
k) other					

Section H. Research and Development Activity

H1. Please indicate whether or not your firm has been involved in any of the following R&D activities over the last three years. Please exclude quality control, routine testing, style changes, minor adaptations and market research.

	YES	**NO**
a) does your firm do R&D in-house?		
b) does your firm do R&D jointly with another firm?		
c) does your firm contract out R&D?		

If you answered NO to all three parts of question H1, then please go to question I1.

H2. Please indicate the frequency of R&D in your firm.

	YES	**NO**
a) R&D are performed on an ongoing basis		
b) R&D are performed on an occasional basis		

H3. What is your firm's R&D program responsible for?

	YES	**NO**
a) creating original products		
b) creating original production equipment or new process technology		
c) substantially adapting technology acquired from others		
d) introducing off-the-shelf equipment or process technology		

Section I. Electronic Communication

I1. Does your firm use e-mail?

___Yes   ___No

I2. Does your firm use the internet?

___Yes   ___No

If no, go to question 15.

I3. If YES, please indicate for what purposes your firm uses the internet.

	YES	NO
a) searching on the World Wide Web		
b) selling your goods and services		
c) advertising/marketing your goods and services		
d) purchasing goods and services		
e) secure electronic transactions		
f) sharing research and development (R&D)		
g) other (please specify)		

I4. Does your firm have a home page on the World Wide Web?

___Yes   ___No

I5. Does your firm use electronic data interchange (EDI)?

___Yes   ___No

If NO, then please go to the end of the questionnaire.

I6. If YES, what type of communication network setup does your firm use for EDI? Check all that apply.

	YES	NO
a) Value added network (VAN)		
b) Internet		
c) Extranet		

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