Advanced Technology Use and Training in Canadian Manufacturing

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Technology adoption has been both rapid and pervasive in the Canadian economy. In 1993 approximately 92 per cent of Canadian manufacturing shipments were produced in establishments using advanced computer-based manufacturing technologies. This represents an increase of 4 percentage points over the preceding four years. Moreover, the proportion of shipments in plants utilizing 10 or more technologies grew by a dramatic 15 percentage points over the same period — from 23 to 38 per cent (Baldwin and Sabourin, 1995).

The explosion in technology use has fostered a concern about its impact on workers (see Betcherman, 1994, for a summary of studies on this subject). A growing debate has emerged, centring on whether technology adoption increases or decreases workers' skills, the so-called "upskilling/deskilling" debate. Some have argued that new technologies permit the segmentation of tasks into repetitive, mundane, skill-lacking tasks (Keefe, 1991). Others maintain that new technologies permit the automation of mechanical tasks, enabling workers to devote their time to more complicated tasks that require combinations of judgment, dexterity and experience, which cannot be programmed into computers (Bylinsky, 1994). Even if the second view is correct, the question then becomes: What happens to low-skilled workers? Do companies undertake the training necessary to upgrade their skills or do they simply hire qualified personnel?

This article addresses two issues that originate from the debate over the nature of the relationship between skills and advanced technology use. The first is the extent to which human capital — the skills embodied within a firm's employees — complements the investments the firm makes in advanced technologies. This issue is examined by looking at the relationship between the use of technology and, in turn, changes in skill requirements, training and training investments.

The second issue is the degree to which advanced technology use generates a demand for either firm-specific or sophisticated generic skills. Firm-specific skills are those which the firm is more likely to provide in socially optimal quantities without resorting to government subsidies, since most of the benefits of those skills accrue directly to the firm.[1] Conversely, firms may refrain from investing in sophisticated generic skills, as these skills are more easily transferable across firms and are thus subject to an externality problem. Consequently, it is crucial to investigate the type of skills imparted by the training undertaken by firms that use advanced technology.

In addition to the use of advanced technologies, many other factors will influence a firm's decision to train. Whether the firm finds training a relevant and useful activity depends on the other strategies and activities it pursues, as well as on its ability to gain and assimilate knowledge imparted by training activities. Furthermore, these factors will affect the location of training — that is, whether the training is done on or off the plant floor.

The article begins by describing the sources of data utilized in this analysis. We go on to examine the incidence of technology use in Canada and to review the technology/skill controversy. The remainder of the article is devoted to examining the relationship between training and other factors, particularly technology, through the use of multivariate

analysis. The factors influencing the incidence of training are examined first, succeeded by an analysis of the factors that influence the location of training. Training on the plant floor is thought to represent a demand for firm-specific skills, while training off the plant floor is indicative of a demand for sophisticated generic skills. The final section examines evidence on the perceived direct impact of technology adoption on training costs.

The Data

The first survey used, the Survey of Advanced Technology, was conducted by Statistics Canada in 1993, using manufacturing plants and firms of all sizes. Out of a total in-scope sample of 2,877 firms, 2,531 responded — a response rate of 88 per cent. This is well above the 5 to 30 per cent response rate commonly achieved by privately run survey groups. The responses to several questions are utilized in this article.

The first set of questions examined here includes those in which plant respondents were asked to indicate their use or non-use of 22 manufacturing technologies. They were also asked to indicate whether the adoption of various types of technologies increased, reduced or left unchanged their education and training costs, as well as their skill requirements. While the responses to this very basic question are illuminating, they say nothing about which of the dimensions of skill requirements are changing. The "skill" concept will be reviewed more extensively later.

The Survey of Manufacturing Technology conducted by Statistics Canada in March 1989 is also used in this analysis. The sample included 4,200 establishments, of which 3,952 (94 per cent) responded. Establishments in the manufacturing sector were asked to indicate their use of 22 separate advanced technologies (the same technologies as in the 1993 Survey of Advanced Technology). The survey also collected data on whether or not the plant engaged in research and development (R&D). Finally respondents were asked to indicate if any of the establishment's employees had been given formal training in 1989 and whether this training had take place primarily on the plant floor, elsewhere in the firm, or outside the firm.

In order to evaluate the performance of establishments according to their use of manufacturing technologies, plants' responses to the 1989 Survey of Manufacturing Technology are linked to longitudinal panel data on establishments going back to 1980, taken from the Census of Manufacturers. This source yields information on a plant's employment, shipments and wages. In addition, data on the plant's owning enterprise — nationality, size, diversification and age — are generated from special files maintained by the Micro-Economics Studies and Analysis Division of Statistics Canada.

Because sampling proportions differ across industries, regions and plant sizes in each of the surveys, the answers in the sample need to be weighted to represent the different underlying populations more accurately. Two sets of weights are used in this analysis. The first type — the establishment weight — is a probability weight: each establishment in the sample represents a group of similar Canadian manufacturing establishments (i.e. with the same size and in the same industry and region). Establishment-weighted results present a profile of the average manufacturing establishment; as most manufacturing establishments are small, the establishment-weighted results represent primarily small establishments. The second set of weights, based on shipments, takes into account the fact that different establishments account for different proportions of economic activity. In this case, the weights attached to plants are the shipment values of both their own establishment and similar establishments. As large establishments account for a larger proportion of economic activity than smaller ones, shipment-weighted results present a picture that is more representative of larger establishments and of manufacturing activity in Canada as a whole.

Technology and Skills

The rapid growth in technology use and the potential effect that it can have on workers generate a need for information regarding the relationship between technology and skills, and between technology and training. Similarly, it is important to examine whether different technologies have different impacts.

Before discussing how technology adoption affects skill requirements and training, it is useful to define what technologies are included in the analysis and to review the nature of, and the growth in, that use.

Defining advanced technologies and advanced technology use

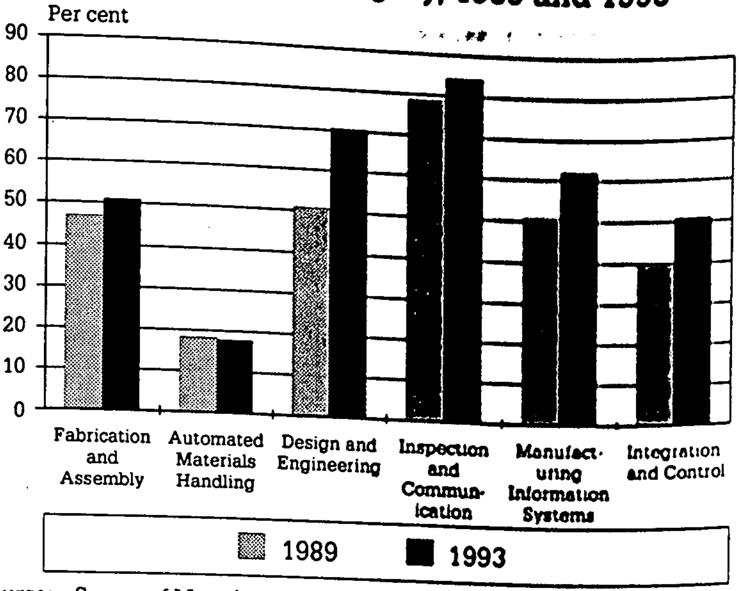
Advanced manufacturing technologies involve the application of computers to various facets of the production process. The 22 manufacturing technologies are grouped into six functional categories, each capturing a different aspect of the process — fabrication and assembly, automated materials-handling systems, design and engineering, inspection and communication, manufacturing information systems, and integration and control. Table 1 presents the technologies and groups used in both the 1989 Survey of Manufacturing Technology and the 1993 Survey of Advanced Technology.

Incidence and pattern of advanced technology use

Advanced technologies are used extensively in the Canadian manufacturing sector. In 1993, some 60 per cent of establishments, accounting for 92 per cent of shipments, used at least one advanced manufacturing technology (see Table 2). Moreover, multiple-technology use was the norm. A mere 5 per cent of shipments were produced by single-technology users, compared to 69 per cent for establishments using at least five technologies. Since the shipment-weighted incidence rate of technology use is higher than the establishment-weighted rate, larger establishments have a greater probability than smaller establishments of adopting advanced technologies.

The rate of advanced technology use increased dramatically from 1989 to 1993. Over this period, the (shipment-weighted) proportion of plants not using any of the 22 technologies declined from 12 per cent to 8 per cent, while that of shipments in plants using 10 or more technologies increased from 23 per cent to 38 per cent. While some of the increase in technology use is attributed to new users — 8 per cent of shipments in 1993 came from plants not using any technologies, compared to 12 per cent in the earlier period — most is due to plants increasing the number of technologies they used between 1989 and 1993.

Chart 1 Advanced Technology Use by Functional Category, 1989 and 1993



Source: Survey of Manufacturing Technology (1989) and Survey of Advanced Technology (1993). The figures for 1993 have been modified to make their calculation comparable to that of the 1989 figures. Data are shipment-weighted.

While advanced manufacturing technologies have come to affect most output, their use varies considerably across functional groups. In 1993, 73 per cent of shipments came from establishments using inspection and communication technologies. The high adoption rate attributed to this particular group of technologies is due mainly to the use of automatic-control devices — programmable controllers and stand-alone computers used for control on the factory floor — a subgroup of the inspection and communication class, whose shipment-weighted adoption rate was 58 per cent in 1993. The inspection and communication group is followed by design and engineering (63 per cent), manufacturing information systems (53 per cent), and fabrication and assembly (46 per cent). Integration and control technologies were adopted by 42 per cent of plants, while automated materials-handling systems were adopted by just 16 per cent.

The incidence of advanced technology use grew between 1989 and 1993 in all but one of the six functional categories (Chart 1). The growth in shipment-weighted use was most dramatic in the design and engineering, manufacturing information systems, and in-

Table 1 Advanced Manufacturing Technologies by Functional Group Category

Functional Category	Technology
Fabrication and Assembly	Flexible Manufacturing Cells/Systems (FMC/FMS)
	Numerically Controlled (NC) Machines
	Computer Numerically Controlled (CNC) Machines
	Materials Working Lasers
	Pick & Place Robots
	Other Robots
Automated Materials-Handling Systems	Automated Storage/Retrieval Systems (AR/RS)
	Automated Guided-Vehicle Systems (AGVS)
Design and Engineering	Computer-Aided Design and Engineering (CAD/CAE)
	CAD Output to Control Manufacturing Machines (CAD/CAM)
	Digital Representation of CAD Output
Inspection and Communication	Automatic Inspection Equipment - Inputs
	Automatic Inspection Equipment - Final Products
	Local Area Network for Technical Data
	Local Area Network for Factory Use
	Inter-company Computer Network (ICCN)
	Programmable Controllers
	Computers Used for Control in Factories
Manufacturing Information Systems	Materials Requirement Planning (MRP)
	Manufacturing Resource Planning (MRP II)
Integration and Control	Computer Integrated Manufacturing (CIM)
	Supervisory Control & Data Acquisition (SCADA)
	Artificial Intelligence/Expert Systems (AI)

tegration and control groups. Growth in use, however, was weak in fabrication and assembly, as well as in automated materials-handling systems.

Defining skills

Frequent references are made in the literature to the impact of technology on skills, but often without a clear view of what is meant by the term "skill." A useful discussion is found in Spenner (1988), who offers the following two fundamental dimensions: skill as substantive complexity and skill as autonomy/control. Skill as substantive complexity refers to "the level, scope and integration of mental, manipulative, and interpersonal tasks in a job". Skill as autonomy/control refers to "the discretion available in a job to initiate and conclude action, to control the content, manner and speed with which an action is taken."

Spenner (1988) also notes that skill changes at an aggregate level (regional, industrial,

Table 2 Adoption Rate, by Number of Advanced Technologies

Number of Technologies	Proportion of Establishments		Proportion of Shipments	
	1989	1993	1989	1993
0	52	40	12	8
1	12	14	5	5
2 to 4	22	24	26	19
5 to 9	11	17	33	31
10 or More	3	5	23	38
At Least 1	48	60	88	92

Source: Survey of Manufacturing Technology (1989) and Survey of Advanced Technology (1993). The figures for 1993 have been modified to make their calculation comparable to that of the 1989 figures.

etc.) can be broken down into two components — compositional changes and content changes. Compositional changes have to do with who does what kind of work. For example, the demand for computer programming abilities has grown over the past two decades, and a larger proportion of the workforce is now engaged in computer programming. Thus the skill composition of the economy as a whole has changed. The second type of change — content change — refers to what is actually done. As an example, computer programming was not a skill that existed in the early part of this century.

Spenner's comments are of assistance in describing the range of factors that can be considered when analyzing changes in skills. In this article, no distinction is made between the different dimensions of skills. The data do not make it possible to differentiate the effects of technology adoption on the demand for substantive complex skills from those pertaining to skills related to autonomy/control. Similarly, whether technology generates a demand for new types of skills or for a greater number of people with higher skills is not clear. Plant managers were only asked whether skills in an aggregate sense had changed as a result of the implementation of advanced manufacturing technologies. The concept of skills used in answering this question no doubt involved degrees of both complexity and/or autonomy/control, but which of these dominated was outside the purview of the survey. This is a first-stage analysis that is focused on whether there are any broad relationships between aggregate skills at the plant level and technology. Analyses of relationships between technology and different dimensions of skill are left for future study.

The technology/skill controversy

As firms adopt new advanced manufacturing technologies, their skill requirements change. What these changes entail for workers, however, has been a subject of controversy. On the one hand, the introduction of new technology has been equated with a large-scale deskilling of the workforce. Proponents of this view argue that technology is used as a substitute for skilled workers and is responsible for lowering the average skill level of the workforce. Technological change, involving computerization, automation and job redesign, makes it possible to separate the conceptualization of work from its execution. Ultimately, technology adoption is said to result in an overall loss in conceptual tasks and control on the part of the worker (Braverman, 1974; Spenner, 1988; Keefe, 1991).

On the other hand, technology adoption has been associated with increases in skill levels. As Spenner (1988) puts it,

> the division of labour evolves along the lines of greater differentiation and efficiency in industrial societies. Technological change increases productivity, requiring a broader variety of skills and higher average skills from the workforce. Automation eliminates

Table 3 Impact of Technology Adoption on Skill Requirements

Technology	Shipment-Weighted		Establishment-Weighted	
	Increased	Reduced	Increased	Reduced
Fabrication and Assembly	56	16	23	9
Automated Materials-Handling Systems	59	5	7	3
Design and Engineering	54	8	27	5
Inspection and Communication	47	6	15	2

Note: Totals do not add to 100 because of omission of the no change category.
Source: Survey of Advanced Technology (1993).

routinized work, jobs increasingly involve higher levels of substantive complexity and autonomy-control.

The introduction of technology leads to more flexible forms of production, which, it is argued, can only be achieved through a highly skilled workforce. Technology adoption is thought to heighten the demand for skills along both dimensions, increasing the demand for conceptual skills as well as giving greater autonomy to workers. Training, preparation and learning emerge as core elements of newly created work (Bell, 1973; Matzner *et al.*, 1990; Keefe, 1991).

There are two reasons for believing that a positive technology/skill relationship exists within the Canadian manufacturing sector. First, the pattern of technology adoption by Canadian manufacturers, discussed above, suggests that firms are increasingly turning towards "soft manufacturing," which creates a demand for skilled workers. "Soft manufacturing" refers to a manufacturing environment in which software and computer networks are more important than production machines (Bylinsky, 1994). In soft manufacturing, firms use advanced manufacturing technologies to tailor their products to buyer needs, and at the same time improve the speed of delivery and achieve economies of scale. The introduction of these technologies makes it possible to replace workers with machines for repetitive and dangerous tasks, while enabling them to be tasked to concentrate on problem-solving and improving the quality of their products and services.

Second, the Survey of Advanced Technology (1993) provides direct evidence of a positive technology/skill relationship. In this survey, managers of plants using technologies from each of the four functional groups were asked if the introduction of that technology resulted in "increased skill requirements," "reduced skill requirements" or "no change in skill requirements." The results are unambiguous: plant managers observed that the introduction of the technology increased their skill requirements more often than it reduced them (Table 3).[2] Plants accounting for 47 to 59 per cent of shipments indicated that skill requirements increased, while only 5 to 16 per cent of shipments were in plants experiencing a skill decline.[3]

The percentage of plants indicating that skill requirements increased is greater for shipment-weighted averages than for establishment-weighted calculations. Thus it is the larger plants that experience the greatest increases in skill requirements associated with technology acquisition. There are a number of reasons for this. Large plants tend to use more advanced technologies per plant. They tend to combine technologies across functional groups more often. They are more likely to employ the most sophisticated integration and control technologies. Large plants also tend to be greater users of leading-edge technologies within each functional group (Baldwin and Sabourin, 1995).

Technology and Training

A Model of Training

If technology is skill-enhancing, producers would be expected to improve the skill sets of their workforce by hiring more highly skilled workers and by providing more training. Our objective here is to corroborate the evidence arising from plant managers' own view that human capital requirements are enhanced in technologically advanced firms, by examining the relationship between the incidence of training across plants and the use of advanced technologies.

The responses to the 1989 Survey of Manufacturing Technology indicate that the intensity of technology use and the intensity of training are highly correlated. The use of just one advanced manufacturing technology raises the incidence of formal training from 77 per cent to 90 per cent of manufacturing plants (establishment-weighted); virtually all manufacturing plants using five or more technologies engage in formal training (Table 4).

It is important to recognize, however, that training is just one of the many areas where the firm must make a decision. Therefore, the relationship between training and technology use needs to be examined within the context of a plant's or a firm's other activities and strategies, through the use of multivariate analysis.

Determinants of Training

There are several ways to measure training activity. The first is to measure the incidence of training — whether the plant has engaged in any training. Conversely, the type of training, formal or informal, can be investigated. More detailed information on training may also be investigated, such as the number of workers trained or the amount of, or expenditures devoted to, training.

The analysis in this article adopts the first approach. The training variable used here is a dichotomous variable that equals 1 if any of the plant's employees received formal training, regardless of the location of that training, and 0 otherwise. This binary variable covers only the decision to train and imparts no information on the *intensity* of training.

The incidence of training was chosen as the dependent variable for both practical and theoretical reasons. First, the 1989 Survey of Manufacturing Technology only investigated whether or not the plant engaged in formal training and the location of the training.[4] While this limits the extent to which other measures can be used, previous work that examines the determinants of training using measures of both incidence and intensity (Baldwin and Johnson, 1995a) has shown that the *decision* to train is more closely related to a firm's overall strategies and activities than is the intensity of training. Once the decision to train has been made, the number of workers trained depends almost solely on the numbers of workers within occupational categories in the firm, and the amount spent on training depends almost entirely on the number of workers trained. In other words, the other strategies, activities and characteristics of the firm are less important in determining the intensity of training than is the occupational mix, with some groups of workers having a higher propensity for training than others (Baldwin and Johnson, 1995a).[5]

Table 4 Incidence of Formal Training by Advanced Technology Use, 1989 (Establishment-Weighted)

	Number of Advanced Technologies in Use (Per Cent of Establishments)			
	0	1	2 to 5	6 or More
No Training Provided	23	10	7	1
Training Provided	77	90	93	99

Source: Survey of Manufacturing Technology (1989)

Establishment Activities

The foregoing discussion demonstrates that the use of advanced manufacturing technologies is an activity associated with ongoing increases in the skill level of workers. As a consequence, the number of advanced technologies in use is hypothesized to be positively related to the probability of training, since more intensive technology use implies more complex production processes and, hence, a need for more adaptable, skilled workers. Technology use is captured here with four 0/1 binary variables, representing four categories of use — no advanced technologies used; use of one technology, of between two and five technologies, and of five or more technologies.

The plant's research and development activities are also expected to influence the decision to train. There are several reasons for this. A plant that performs or supports R&D is more likely to be receptive to change requiring greater adaptability from its workers. It is also more likely to be continually introducing new concepts in the form of either new products or new processes. Firms performing R&D also tend to have better-educated workers; and better-educated workers are more likely to receive training (OECD, 1991). Consequently, performers of R&D are more likely to train. This factor is captured by a variable that equals 0 if no research and development is performed for the plant, and 1 if it is, regardless of whether that research is done within the plant or elsewhere within the firm, or contracted outside the firm.

Establishment Characteristics

The characteristic variables capture factors that make certain plants more receptive to training than others. These variables are: the innovativeness of the industry, the level of foreign ownership of the plant, the difficulty the plant experiences in hiring workers with the requisite skills, plant and firm size, the age of the plant, the diversification of the firm and the region of operation of the plant.

The decision to train should be related to the availability of skilled workers. If a plant cannot fill positions through external sources, it will be more likely to engage in training. The model controls for this factor through the use of a binary hiring variable, with a value of 1 if the plant had difficulty in hiring skilled personnel to work with the plant's technologies, and of 0 otherwise.

The importance of technology adoption has already been mentioned. However, in addition to technological innovation in the firm, the degree of *product* innovation in the industry is also important. Those who produce more innovations are likely to demand continually changing skills among their employees, and thus to require training. Indeed, Baldwin and Johnson (1995b) have found that firms that are innovative in a broad sense train more. In order to test whether technology use and product innovativeness have separate additive effects, both variables are therefore included. As data at the firm level are not available on product innovation, a binary variable that classifies the industry in which the plant is located as more or less innovative is included. The classification is derived from Robson *et al.* (1988), who investigate differences in innovative tendencies of two-digit industries. They find that two-digit industries fall into three basic groups, of which the first two, defined here as the innovative industries, produce the majority of innovations. Many of these innovations are also used by the less innovative industries. The more innovative industries consist of electrical and electronic products, chemicals and chemical products, machinery, refined petroleum and coal, transportation equipment, rubber products, non-metallic mineral products, plastics, fabricated metals and primary metals. The less innovative industries are textiles, paper, wood, clothing, leather, beverages, food, furniture and fixtures, and printing and publishing.

A measure of the number of industries in which an establishment's parent enterprise operates is included to capture the effects of diversification. Multi-plant enterprises have multiple contact points that enable them to develop an information advantage. The broader knowledge base in diversified firms may confer spillover benefits for training. Alternatively, diversified firms, because of their complex management structures, may require higher levels of training at the plant level. For example, employees at the plant level in highly diversified firms may have to take greater responsibility than in single-in-

dustry plants in order to compensate for a lack of concentrated, industry-specific expertise at the head office. The model controls for this effect by including a binary variable that is equal to 1 if the firm operates in more than one industry, and to 0 if it does not.

Training is a strategy that complements others and should be found in firms that have developed competencies resulting in growth. Output growth of the plant during the 1980s is included here as a proxy for recently developed competencies that are associated with success. Plants that have experienced little recent growth may be in that position because they are resistant to change; if so, they are also less likely to train. Growing plants may not only be more receptive to change, they may also have a greater need to train as their workers take on new functions associated with dealing with a larger, and perhaps more diversified, market. In this analysis, growth is measured by a binary variable that categorizes plants based on the size of the change in shipments over the period of study. The variable equals 0 if the plant experienced negative or small growth, and 1 if it experienced moderate or rapid growth.[6]

The age of the plant is another characteristic hypothesized to be associated with the incidence of training. Older plants have more experience on which to draw and might be expected to have better information about where training would be most useful. In this case, training would be part of a mature culture. On the other hand, younger plants may have newer technologies. Newer technologies may be more sophisticated and require higher skill levels. If so, workers in young plants will require more training. A binary variable is used to capture age effects — 1 for plants born after 1970, and 0 otherwise.

Foreign ownership captures a set of competencies hypothesized to be positively correlated with a firm's decision to train. Multinationals are the vehicle through which hard-to-transfer scientific knowledge is moved from one country to another (Caves, 1982). They perform this function either because of scale economies associated with their larger size or because of an inherent advantage associated with information that is uniquely held by these firms. They might therefore be expected to receive more benefits from training programs. To capture the advantages of foreign-owned plants, a binary variable is included, equalling 1 if a manufacturing plant is foreign-controlled, and 0 otherwise.

Size has also been linked to training for a variety of reasons. It has been argued that large firms have access to cheaper capital to finance investment in training (Hashimoto, 1979); that large firms can reduce the risk and, therefore, the cost of investment in training by pooling risks (Gunderson, 1974); and that large firms enjoy a greater payoff from training because their size and their exploitation of economies of scale have led to task specialization, and thus to a greater benefit arising from training (Doeringer and Piore, 1971). Alternately, it could be that the commonly found firm-size effect stems from an aggregation phenomenon. If each firm has an equal probability of training any one of its workers irrespective of firm size, large firms are more likely to train someone in any given period simply because they have more workers.

However, even if there is an aggregation effect, size may be a proxy for other factors associated with growth, one of which is the human resource stance of the firm. For example, work by Knoke and Kalleberg (1994) suggests that there may be an observed size effect because size is a proxy for the human resource stance of the firm. They find that the size effect is substantially diminished when one includes variables representing the internal structure of the firm. Firms that have formalized job classifications and internal labour markets, offering promotion trajectories that link jobs within an organization, are both larger and more likely to train. Consequently, if these indicators are not included in the regression analysis, size captures some of these effects.

Size is measured for both the plant and its owning enterprise. The scale of the plant is measured by the number of its production and non-production workers.[7] In order to purge the size variable of the effect of recent growth, which is captured by a separate variable, plant size is measured as of 1980. A binary variable is created, equalling 0 for small plants (fewer than 100 employees) and 1 for medium-sized or large plants (more than 100 employees).[8]

To separate the effects of enterprise from establishment size, establishment employment is subtracted from enterprise employment, creating an enterprise employment variable. Three binary variables are created to capture variations in the amount of employment in the enterprise that is outside the plant under study. The three variables are: the case where the parent enterprise is the same as the size of the establishment — a stand-alone plant (small) — and residual enterprise sizes of 1 to 999 employees (medium-sized) and 1,000 or more employees (large).

Finally, the fact that Canada's economy is regionally based necessitates the inclusion of a set of binary variables that control for regional differences. The five regions are the Atlantic provinces, Quebec, Ontario, the Prairie provinces and British Columbia.

The observations used in the probit regression are establishment- and shipment-weighted. Weighting by establishment provides a picture that is more representative of the average manufacturing plant in the population as a whole. As there are substantially more smaller firms than larger firms, the average is more representative of smaller firms. Weighting by shipments provides a systematic method of examining the extent to which the results differ in large and small plants. In the discussion that ensues, emphasis will be placed on the establishment-weighted results, with brief mention being made of differences that are generated when large plants are given more importance.

Empirical Results: Incidence of Training

Given the dichotomous nature of the dependent variable, the model is estimated using probit analysis. Table 5 presents the results of the probit regression models for the probability of the plant offering training. The dependent variable is 1 (the plant engages in formal training) or 0 (the plant does not).[9] Since each of the explanatory variables takes a value of either 0 or 1, the coefficient attached to the explanatory variable is the effect on the probability of training when that variable is equal to 1.

The results of the establishment-weighted regression indicate training is an important part of a technology strategy. Technology use itself is one of the most important determinants of whether or not a plant will train its employees. The effects of technology use are measured against an omitted variable defined as "no advanced technology use." The results show that plants using two to five technologies are more likely to train than plants using none. Plants using more than five advanced technologies are the most likely to train their workers. Plants that have difficulty in hiring personnel to work with those technologies are also more likely to train. These results support our earlier finding that technology adoption leads to higher skill requirements.

The decision to train is also an integral part of the strategies of successful establishments; holding all else constant, characteristics associated with success lead to an increased probability of training. Engaging in R&D and, to a lesser degree, operating in an innovative industry, are factors that increase the probability of training. Both are indicators of management's willingness to learn and adapt and, as such, should be positively correlated with training. The effect of growth in manufacturing sales on the probability of training is also unambiguous. Plants that experienced moderate to rapid growth are more likely to offer training than those with only negative or slight growth.

The effects of diversification on training are measured against an omitted variable representing operation in only one industry. The results indicate that more diversified enterprises are more likely to engage in training than single-industry producers, likely pointing to the existence of spillover benefits to training.

The age and ownership of the plant also have an impact on the probability of training. Plants that were in existence before 1970 are more likely to train than younger plants.[10] These plants have well-established structures and have the benefit of experience to develop effective training programs. Foreign-owned plants are also more likely to train, but the coefficient attached to this variable is one of the few that is not significant at even the 10 per cent level in the establishment-weighted results, although it is significant in the shipment-weighted model.

Table 5 Factors that Influence a Plant's Decision to Train

	Coefficient			
	Establishment-Weighted		Shipment-Weighted	
Log-likelihood (Distributed as χ^2)	-1185		-532	
Intercept	0.52	***	0.91	***
Activities:				
Use of Technologies: 1 technology	0.14		0.28	*
2 to 5 Technologies	0.30	***	0.33	***
More than 5 Technologies	1.16	***	0.93	***
Characteristics:				
Hiring - Difficulty in hiring skilled workers	0.70	***	0.21	**
Research and Development - Engages in R&D	0.65	***	0.37	***
Innovation - Operate in an innovative industry	0.16	**	-0.11	
Diversification - Operates in two or more industries	0.37	***	0.13	
Growth in Manufacturing Sales: Moderate to Rapid	0.36	***	0.25	**
Age of the plant - Born in the 1970s	-0.13	*	0.44	***
Ownership - Foreign-owned	0.10		0.27	***
Establishment Size - Mid- to large size	-0.44	***	0.12	
Enterprise Size: Medium	-0.28	***	0.07	
Large	0.16		0.24	
Region of Operation:				
Quebec	0.18		-0.57	**
Ontario	-0.72	***	-0.68	**
Prairie Provinces	-0.47	***	-0.44	
British Columbia	-0.35	**	-0.84	***

*** Significant at the 1 per cent level.

** Significant at the 5 per cent level.

* Significant at the 10 per cent level.

Source: 1980 and 1989 Censuses of Manufactures; 1989 Survey of Manufacturing Technology.

Strong regional effects are also seen in the model. The omitted variable here is the Atlantic region. Once other factors are held constant, plants in each of the other regions except Quebec are less likely to train than plants in Atlantic Canada.

The effects of establishment and enterprise size are both measured relative to the standalone plant. The estimated coefficients indicate a negative relationship between training and indicators of plant and firm size. This result is contrary to the findings of many previous studies (Bartel, 1989), though it should be recognized that other studies have not been able to measure technology with the same detail.[11]

Technology and the Location of Training

A manufacturing firm's strategy does not end with the decision to train. It must decide where the formal training will take place. Here, we make a distinction between formal training that takes place on and off the plant floor and we explore the various factors influencing that decision. The location of training done by a plant is available from the 1989 Survey of Manufacturing Technology, where plants were asked whether they *primarily* performed training within the plant, elsewhere in the firm or through the purchase of training courses in public or private institutes. More than half (63 per cent) of both large and small plants that train do so within the plant, while the rest train elsewhere (Table 6).

The location of the training is important because, as Lynch (1991) has argued, in-plant or on-the-job training is typically firm-specific, whereas off-plant or off-the-job training is typically more general. The latter type of training is subject to more of an externality problem, while the former is not. Generic skills are easily transferred across firms, and once workers receive training they can move to other firms that will readily compensate them for their skills without having had to bear the training costs. Firms that know they will lose some of their investment in general training as a result may be less inclined to make such investments (Mincer, 1989; Simpson, 1984). Although they may still have an incentive to invest, their investments will be less than is optimal for society. As a consequence, this type of program is generally supported by public funds. Vocational training programs are one example of this type of publicly-supported training program.

Training also creates tacit knowledge. This involves skills that enable employees to make things work in the context of a specific organization. Workers with tacit knowledge do not have the same value to other firms and are therefore less likely to be hired for that knowledge alone. Investments by the firm in tacit or firm-specific knowledge are less likely to be lost and thus are more likely to be provided in socially optimal amounts by firms responding to private incentives.

A Model of the Location of Training

Firms will find it necessary to train when the skill requirements of their workers change and when they cannot easily hire appropriately qualified employees. Firms will be less likely to hire appropriately qualified employees when: a) their skill requirements are highly firm- or plant-specific; or b) the skills

Table 6 Location of Training for Plants that Train Workers

	Per cent of Establishments	
	Establishment-Weighted	Shipment-Weighted
Training Provided within the Plant	63	55
Training Purchased Outside the Firm	19	29
Training Provided Elsewhere in the Firm	18	16

Source: Survey of Manufacturing Technology (1989).

they require are very sophisticated and, consequently, rare. Specific skills are those which are unique to the production process of a particular firm. They do not require a high degree of knowledge or competency per se. Sophisticated skills, however, are those which *do* require high levels of knowledge and competency. Sophistication is a characteristic of both generic and plant-specific skills.

An example of a specific skill is the knowledge associated with the utilization of an automated guided-vehicle (AGV) system on a plant floor. Training in this case enables employees to make the AGV work in the particular confines of the plant. On the other hand, sophisticated non-specific skills are required for the artificial intelligence/expert system — an integration and control technology — that controls AGVs and other computer-based technologies in the plant. These types of technologies rely on highly complex and sophisticated logical statements that are generic to most applications. In order to accommodate the introduction of new technologies that are controlled by this integration technology, users must be able to understand how the logic of the technology works, regardless of the specific application. Finally, an example of a sophisticated plant-specific skill is provided by materials requirement planning technologies. These technologies require specific knowledge of the plant's inputs as well as some general knowledge of how to adapt the system as processes, prices and products change.

A firm can typically impart plant-specific or generic skills by training either on or off the plant floor. It is postulated here that if a firm's skill requirements are primarily *plant-specific, regardless of the degree of sophistication,* it will be more likely to train on the plant floor; if its skill requirements are primarily *for sophisticated skills that are relatively non-plant-specific,* it will be more likely to train off the plant floor. There will be a degree of plant specificity to all desired training and a degree of sophistication in order for training to be required; however, it is the dominance of specificity versus non-specificity that is critical to determining where training is performed.

Plant-Specific Knowledge

Two factors influence the specificity, and thus the location, of the desired training. The first is the specificity of the work activity itself — that is, the extent to which the *work involves tacit knowledge*. In the example cited above, the use of the AGV technology constituted an activity specific to the plant floor.

The second factor that determines the specificity of the desired training is the degree of *tacit knowledge within the firm*. Clearly, all firms have some degree of tacit knowledge, but the degree of that "tacitness" is determined by the extent to which that knowledge is easily transferable across firms and by the extent to which a large base of knowledge already exists within the firm. Leading firms are those which have found a successful method that others cannot emulate. By definition, they possess special knowledge. Followers are those which adopt a strategy of employing existing or generic knowledge. Therefore, leading-edge firms should be expected to do more training that develops plant-specific skills.

Sophisticated Non-specific Knowledge

The more sophisticated the technology, the more likely the firm will have to look outside for expertise in utilizing and exploiting that technology. While firms could bring in external specialists to train on their shop floor, several factors are likely to favour external training for sophisticated tasks.

First, it is usually the case that the more sophisticated is the desired training, the greater is the specialization of function and the smaller is the range of workers within any establishment to which the training will apply. Therefore, the costs of bringing a specialist or of having a training specialist on staff can only be spread over a small number of workers. Furthermore, the more sophisticated the required training, the more likely it is to require specialized facilities in terms of training space and equipment. Consequently, it will be more cost-effective to send those employees who require training on sophisticated technologies to locations outside the plant for that training. In outside training, these costs are spread across many workers, often from different firms, who also share the training facilities.

Second, the more sophisticated are the technologies in use, the greater are the benefits that the firm can derive from sending its employees for external training. External training courses offer an opportunity for employees to

develop contacts with specialists in their field. Informal communication networks, even across competitors, have been found to be a critical source of information. "Individual employees provide information to colleagues from other firms with the expectation of receiving valuable information in return, either immediately, or in the future" (Schrader, 1990). The more sophisticated the technologies, the more firms can expect to gain by developing networks with others utilizing the same technologies.

Determinants of the Location of Training

The dependent variable is the location of training. It is equal to 1 if training is performed off the plant floor, and to 0 otherwise. Once again, given the dichotomous nature of the dependent variable, the model is estimated using probit analysis.

Technologies

In order to allow for differences in sophistication across technologies, two sets of technology adoption variables are used to measure the incidence and pattern of use. Incidence is measured by the number of advanced technologies that are used. Once the degree of tacit knowledge within the firm is accounted for, plants using more technologies are hypothesized to do more training off the plant floor because of their sophistication. Sophistication here primarily derives from the need to integrate and control different functions as more and more technologies are utilized. In a second probit regression, the effect of the pattern of technology use is measured by including six separate variables representing technology use for each of the six functional groups. These variables equal 1 if at least one technology is used from a particular functional group, and 0 otherwise. The sign of the coefficients attached to each indicates whether the use of technologies in each of these groups is associated primarily with plant-specific skills or with sophisticated non-specific skills.

Establishment Characteristics

Since dynamic, leading-edge firms are hypothesized to require plant-specific training, several different attributes are included to measure whether the firm is an industry knowledge leader. One of the prime factors in success is an innovation- and technology-driven strategy (Baldwin *et al.*, 1994). Plants that report a research and development unit within the organization are more likely to develop entirely new products and processes; plants that report they modify, instead of just adopting, the technologies of others have leading-edge capabilities. Both of these categories are included as explanatory variables in the probit regression.

There are other characteristics likely to be correlated with leading-edge, knowledge-intensive firms. Firms that operate successfully in multiple-product markets succeed not just because they offer one superior product but because they have developed a set of superior competencies that afford success in these markets. Firms that are older, *ceteris paribus*, have survived by building and maintaining skills that exceed those of their competitors. Foreign-owned firms, which have succeeded not just in their own domestic markets but have crossed geographical, political and cultural borders to succeed in a foreign country, embody special knowledge. Growing firms are those which have managed to succeed in an economy where knowledge is increasingly important and which, therefore, might be expected to emphasize internal skills. Accordingly, the measures of diversification, age, foreign ownership and growth that were included in the training equation are also used in the training-location regression.

Finally, the size of the plant and that of the owning firm are also included as explanatory variables. Size represents two factors, each with opposing effects on the location of training. On the one hand, size represents competence and age. To the extent that competence depends on knowledge that is not easily replicated, size will be positively correlated with in-plant training. On other hand, size may represent sophistication. Larger plants tend to use more sophisticated technologies than smaller ones. As a result, larger plants will have a tendency to do more training elsewhere than on the plant floor. Whether the sign of the coefficient is positive or negative will depend upon which of the two effects dominates.

It should be recognized that this multiplicity of effects is true for all of the regressors. For

example, plants with research and development are both sophisticated and engaged in activities that require plant-specific knowledge. And it is no doubt true that almost all plants will invest in both generic and plant-specific skills. However, the dependent variable is derived from the question that asked plant managers where most of the training was done. Therefore, the sign of the regressor in the probit regression indicates whether the predominant form of training involves plant-specific or more generic and sophisticated types of knowledge.

Empirical Results

Table 7 presents establishment- and shipment-weighted results of the regression model for the probability of training off the plant floor. The coefficients associated with the explanatory variables have the same interpretation as in the model of training reported above; however, now the dependent variable is 1 if a plant trains mainly off the plant floor, and 0 if it trains mainly on the plant floor. A plant that trains mainly off the plant floor may do so elsewhere in the firm or through purchased training courses. As this model uses only the data on plants that engage in training, the coefficients on the variables confer exactly equal and opposite effects on the probability of training on the plant floor. Thus a positive sign on a coefficient indicates the effect on the probability of training *off* the plant floor when that variable is equal to 1, while a negative coefficient is the effect on the probability of training *on* the plant floor when that variable is equal to 1. In all cases, the omitted variables remain the same as in the model of training presented above.

When the number of technologies is used as the regressor (Table 7, column 1), the coefficients are positive and significant. When a plant uses more technologies, it is more likely to train off the plant floor. Sophistication is equated with the number of technologies utilized by the plant. The use of technologies *by itself* stimulates firms to offer training in order to impart sophisticated, generic skills.

The coefficients attached to the technology use by functional category (Table 7, column 2) reveal which categories require more sophisticated generic skills and which are more closely associated with firm-specific skills. Automated materials-handling systems, design and engineering, and manufacturing information systems technologies are all highly specific to the plant and are all related to in-house training.

Conversely, inspection and communication technologies are more general, off-the-shelf type products. Communication technologies are relatively generic and are not specific to any part of the production process. Thus users of communication technologies would be more likely to purchase training. This is supported by a significant positive coefficient on the communication category and also by evidence provided by the marketplace — namely, the growth and proliferation of firms whose main purpose is to develop training programs for communication technology.

Fabrication and assembly as well as integration and control technologies are sophisticated technologies that also have positive coefficients. Training here is accomplished mainly off the plant floor, perhaps by the supplier who has specialized facilities for training on the new equipment. Given the sophistication of these technologies, the plant is unlikely to have significant in-house training expertise in those areas. The cost associated with bringing a specialist into the plant to train a small number of workers and the potential benefits of networking with others utilizing the technologies lead to more off-site training.

Variables other than those dealing with the use of technologies are also significantly related to the location of training. Plants experiencing difficulty in hiring skilled workers are more likely to train on the plant floor. This is consistent with the argument that the demand for workers with plant-specific skill sets cannot be met through external hiring. Alternatively, it is likely that if more general skills are available through purchased training programs outside the firm, prospective employees would have obtained this training prior to seeking employment with the firm.

The results also confirm that training on the plant floor, which is associated with the development of firm-specific skills, is related to whether a firm is at the leading edge of the industry. Plants that have access to their firm's research and development, that are mature,

Table 7 Factors Influencing Training Off the Plant Floor

	Establishment-Weighted		Establishment-Weighted		Shipment-Weighted	
Log-likelihood (Distributed as χ^2)	-1491		-1503		-2162	
Intercept	-0.76	***	-0.71	***	-0.36	**
Number of Technologies: 1 Technology	0.61	***				
2 to 5 Technologies	0.40	***				
More than 5 Technologies	0.21	**				
Type of Technologies: Fabrication and Assembly			0.13	*	-0.16	***
Automated Materials-Handling Systems			-0.33	***	-0.29	***
Design and Engineering			-0.16	**	-0.13	**
Inspection and Communication			0.32	***	0.46	***
Manufacturing Information Systems			-0.01		0.04	
Integration and Control			0.22	**	0.01	
Hiring: Some Difficulty in Hiring Skilled Workers	-0.13	**	-0.12	*	-0.24	***
R&D: Firm Engages in Research and Development	-0.24	***	-0.18	***	-0.39	***
Innovation: Firm Operates in an Innovative Industry	0.29	***	0.28	***	0.24	***
Modification of Technologies: Modifications Undertaken to Improve Output	-0.13	**	-0.11	*	-0.13	***
Establishment Size: Medium to Large	0.30	***	0.21	***	0.18	*
Enterprise Size: Medium	0.29	***	0.29	***	0.36	***
Large	0.26	*	0.25	*	0.35	***
Diversification: Operates in Two or More Industries	-0.24	**	-0.23	**	0.00	
Growth in Manufacturing Sales: Moderate to Rapid	0.05		0.10		-0.06	
Age of Plant: Born in the 1970s	-0.25	***	-0.22	***	-0.05	
Ownership: Foreign-owned	-0.06		-0.12		-0.14	***
Region of Operation:						
Quebec	1.40	***	1.40	***	0.76	***
Ontario	-0.22	*	-0.20	*	-0.05	

	Establishment-Weighted		Establishment-Weighted		Shipment-Weighted	
Prairie Provinces	-0.53	***	-0.51	***	-0.24	*
British Columbia	-0.23	*	-0.19		0.09	

*** Significant at the 1 per cent level.
** Significant at the 5 per cent level.
* Significant at the 10 per cent level.
Source: 1980 and 1989 Censuses of Manufactures; 1989 Survey of Manufacturing Technology.

that modify their advanced technologies to improve output and that belong to diversified parents are more likely to train on the plant floor.

The size and scale variables show the importance of sophistication and economies of scale and task specialization in the location of training. Again, the omitted variable for plant size is fewer than 100 employees; for enterprise size, it is the stand-alone plant. Small plants are more likely to train on the plant floor. If the plant is large, training is more likely to take place elsewhere in the firm or outside the firm through purchased training courses.

When the shipment-weighted probit results in column 3 are compared to the establishment-weighted results in column 2, the story is much the same, with the following exceptions. The coefficient attached to fabrication and assembly becomes negative, thereby indicating that larger plants tend to have more specific skills attached to this technology than smaller plants. The coefficient attached to R&D increases, indicating that larger plants with R&D tend to have even more plant-specific skills than smaller R&D performers. Plant age is no longer negative and significant, which suggests that the newer large plants are more likely to require more generic skills. Finally, the coefficient attached to foreign ownership becomes significant.

Technology and Training Costs

The impact of technology adoption on the intensity of training was investigated in the 1993 Survey of Advanced Technology by asking manufacturing plants what impact the adoption of technology had on their education and training costs. The responses are available by type of advanced technology use — fabrication and assembly, materials handling, design and engineering, and inspection and communication.

The responses, both shipment- and establishment-weighted, confirm the conclusions drawn from the multivariate analysis (Table 8). Technology has a significant impact on the investment in human capital that manufacturing plants are making. Between two thirds and three quarters of technology-using plants (shipment-weighted) reported that the adoption of that technology increased their education and training costs in each of the different functional areas. One third of plants that reported an increase in costs associated with technology use stated that technology use increased their training costs *significantly*.

As was the case with the incidence of skill change, the shipment-weighted estimates of training costs are greater than the establishment-weighted estimates. It is the largest plants that generally are the most sophisticated technology users and that incur the greatest increases in training costs as a result of technology adoption.

Conclusion

Technological progress has arguably been one of the most dramatic features of recent changes in the work and leisure environment. Robots and laser technologies are becoming commonplace in surgical rooms. Virtual-reality environments and three-dimensional audiovisual shows are but a few examples of the impacts of the technological revolution on the recreational environment. Entire manufacturing plants are controlled by computers for product design, inventory planning, storage retrieval and production, quality testing,

Table 8 Impact of Technologically Advanced Equipment and Software on Education and Training Costs

	Fabrication and Assembly		Automated Materials-Handling Systems		Design and Engineering		Inspection and Communication	
	Per Cent							
	S	E	S	E	S	E	S	E
Increased Significantly	23	15	15	4	20	20	20	10
Increased Moderately	40	15	24	5	35	16	29	12
Increased Marginally	14	10	16	5	24	13	19	11
No Change	12	8	32	11	12	9	12	9
Decreased	1	3	0	0	0	2	0	0

S=shipment-weighted, E=establishment-weighted.

Source: Survey of Advanced Technology (1993).

and receiving and processing customer orders, among other uses.

These technological changes have meant radical changes in the nature of work. Other research (Baldwin *et al.*, 1996) has demonstrated that technology adoption is associated with higher wages, which are an indication of more skilled workers. Not only do plants that adopt advanced technologies pay higher wages, they also have had a higher rate of wage growth in the 1980s.

The analysis here confirms that technology adoption creates a need for higher skills. First, it has been demonstrated that plant managers generally find that skill requirements have increased as a result of the adoption of advanced technologies. Second, plants with advanced technologies are more likely to have formal training programs, even when other factors are taken into account. Third, the increased skill requirements resulting from technology adoption have led to increased training costs. These three pieces of evidence, along with the previous study on wage differentials between plants with and without advanced technologies (Baldwin *et al.*, 1996), strongly suggests that the implementation of advanced technologies in the Canadian manufacturing industry has had an important skill-enhancing effect. The implication is that technology use in manufacturing plants is associated with higher quality jobs — jobs in which workers are continually challenged with more sophisticated tasks, and where they are supported by the firm, through training, in successfully completing these new tasks.

It is important to note that there are many dimensions to the term "skill," and the data available for this analysis do not illustrate the effects of technology adoption on specific dimensions of skill. These results find only a relationship between technology adoption and aggregate skills.

Characteristics that are associated with past success and are indicative of superior abilities to adapt and learn are also associated with training. Consequently, the firms that are most likely to train are those which perform R&D; which are innovative, diversified, mature, foreign-owned; and, most directly of all, which have achieved strong growth. It is therefore significant that many of the same variables — the possession of R&D facilities, diversification, ownership and hiring difficulties — are all associated with both more training and a greater likelihood of training on the plant floor. The skills being developed by the training that is provided by plants either are highly plant-specific or leading-edge.

Several policy implications arise from this analysis. Technology-using firms tend to demand greater skills, do more training and invest more in human capital. Accordingly, they tend to offer better jobs and pay higher wages. This confirms the complementarity of technology and human resource policies suggested by Baldwin and Johnson (1995a). That study, using data from the 1992 Growing Small and Medium-Size Firm Survey, links innovation to a broad range of human resource strategies being pursued by the firm. Specifically, firms that are innovative are more likely to recognize the importance of labour skills, to focus on developing innovative employee compensation plans, to stress quality and total quality management and to implement training programs. This implies that policies recognizing the complementarity between innovation and training will be more successful than those which try to target innovation or training separately.

The second important point is that advanced technology use stimulates firms to engage in both plant-specific and generic training to develop sophisticated skills. While leading-edge firms tend to focus on plant-specific training, the need for sophisticated generic skills leads in many instances to generic training despite the externality problem created in the latter instance. The desire for sophisticated generic skills in large plants that use many technologies is sufficient to overcome the likelihood that they risk the loss of these investments if their employees leave for other firms.

Notes

1. See Organisation for Economic Co-operation and Development (1991:136) for a discussion of the differences between a firm's incentive to invest in firm-specific as opposed to general training.

2. Skill impacts are often seen differently at different levels within the plant. It has been suggested to the authors that in some cases, plant managers and other senior management may not be in a position to adequately judge the micro-skill effects of technology adoption. However, plant managers' opinions on the effects of technology adoption are corroborated here by data on the costs of training: the adoption of advanced technology has also led to a general increase in the costs of training. This suggests that more training was being offered or that the training being offered was more sophisticated, in either case resulting in an overall increase in skill levels.

3. See Mincer (1989) and Bartel and Lichtenberg (1987) for studies of the link between technological change and human capital requirements.

4. While informal training may also be an important means for meeting skill requirements in firms, Baldwin and Johnson (1995a) found that the relationship between formal training and various aspects of technological innovation was very similar to that between informal training and these same innovative characteristics.

5. It is true, however, that more innovative plants generally employ a higher percentage of professional and technical/production workers (which typically receive more training) and a lower percentage of other workers relative to non-innovative plants. In turn, a greater proportion of all employees are trained (Baldwin and Johnson, 1995a). This is confirmed in this article, where the results of the regression analysis indicate that the innovativeness of a firm or of the industry in which the firm operates increases the probability of that firm offering training.

6. The output growth variable was created using the Census of Manufacturers data. On the basis of changes in shipments over the period 1980 to 1989, plants were ranked into three equal-sized groups — negative or slight growth, moderate growth and rapid growth. The moderate- and rapid-growth groups were combined for the purposes of this analysis, as tests indicated that there was no significant difference between the coefficients on these two groups in the probit regression results.

7. The size of the parent enterprise is defined as the total employment of all plants in manufacturing owned by the enterprise that controls the plant.

8. Initially, there were three plant employment binary variables included in the model: 1-99 employees, 100-999 employees and 1000 or more employees. As the coefficients for the medium-sized and large plants were not statistically different, these categories were collapsed.

9. The probit typically estimates the probability of the dependent variable being 0. Consequently, for ease of interpretation, the signs on the coefficients have been reversed.

10. Entrants in the survey were born mainly in the 1970s and were therefore relatively mature. Younger entrants might have fared differently.

11. To explore this issue, training is regressed on enterprise size, technology use and interaction terms involving technology use and size. When these interaction effects are factored in, training has a positive relationship with both the number of technologies in use and the size of the enterprise. The interaction effects are negative, indicating that the marginal effects of size are less for technology-using plants. These plants tend to do more training, and perhaps as a consequence, the effects of size on training are less in technology-using plants.

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