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Enhancing Food Safety and Productivity: Technology Use in the Canadian Food Processing Industry

by John R. Baldwin, David Sabourin

Micro-Economic Analysis Division
24-B R.H. Coats Building, Ottawa K1A 0T6

Telephone: 1 613 951-3962   Fax: 1 613 951-5403

This paper represents the views of the authors and does not necessarily reflect the opinions of Statistics Canada.

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Micro-Economic Analysis Division
24-B R.H. Coats Building
Ottawa, K1A 0T6
Statistics Canada

* (613) 951-8588
Email: baldjoh@statcan.ca

** (613) 951-3735
Email: sabodav@statcan.ca

Facsimile Number: (613) 951-5403

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The authors' names are listed alphabetically.

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Aussi disponible en français

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Abstract

This paper examines the factors contributing to the adoption of advanced technologies in the Canadian food-processing sector. The numbers of technologies used by a plant is found to be highly correlated with expected net gains (benefits less costs). The benefits of enhanced food safety and quality, as well as productivity improvements, are closely associated with technology use. Costs that negatively affect technology use include software costs, problems with external financing, lack of cash flow for financing, and internal management problems. Even after accounting for the different benefits and costs associated with technology adoption, the numbers of advanced technologies that are adopted are found to be greater in larger plants, in foreign-controlled plants, in plants that engage in both primary and secondary processing, and in the dairy, fruit and vegetable and 'other' food product industries.

Keywords: advanced technology use, food processing, food safety, regulation, productivity

Executive Summary

Studies have shown that those plants that manage to successfully incorporate advanced technologies into their production process experience larger productivity gains and higher economic growth than plants that do not adopt these technologies (Baldwin, Diverty and Sabourin, 1995; Baldwin and Sabourin, 2001; Barkley, 1995; Stoneman and Kwon, 1996).

This study examines which factors are most closely related to the adoption of advanced technologies in the food-processing sector and which factors impede it.

A number of key questions were posed in this study:

1. *What are the main benefits that plant managers attribute to the adoption of new advanced technologies in food processing?*

The study focuses first on whether technology is primarily aimed at enhancing food safety as opposed to improving productivity. Food processing is an industry heavily reliant on product-market regulation since concerns about food quality and food safety are common in this industry. Recently, productivity growth in the food-processing sector has been lagging behind that of the rest of the manufacturing sector. Therefore, the paper asks whether plants appear to be adopting new technologies for safety or regulatory reasons as opposed to productivity reasons and which of these matters most.

The paper investigates the relationship between the number of advanced technologies that are adopted and the importance of a set of associated benefits—ranging from improvements in productivity (arising from reductions in labour, materials savings, reduced capital requirements, a shorter set-up time or a lower rejection rate), product quality improvement (due to improved nutrition, taste, appearance, shelf-life, or consumer convenience) or regulatory compliance (worker safety, food safety, or environmental protection).

Gains in labour productivity, production of higher quality products, and an enhanced ability to meet regulatory requirements topped the benefits that plant managers indicated came from adopting advanced technology.

The analysis also investigated which of these benefits was more closely associated with greater use of advanced technologies. It found that enhanced productivity was just as important as regulatory compliance in stimulating more intensive technology use. Improving quality and safety are on a par with improving labour productivity in terms of their impact on the use of advanced technologies in the food processing sector.

2. *What are the main obstacles to adoption*?

The paper investigates which factors provided the greatest impediments to technology adoption as seen by plant managers. Impediments are grouped into six categories—costs, financing

problems, management deficiencies, human resource problems, lack of external support and problems relating to government policies.

The costs associated with integration and operation were seen to offer the greatest impediment to advanced technology use. This is followed by impediments that arise from regulation (food safety), financing, skill shortages and management in that order.

An analysis of the relationship between the impediments noted and the number of technologies used found that technology use was less when serious problems were said by plant managers to exist with respect to software development and integration costs, external and internal financing, senior management buy-in, and training.

The results indicate that adoption of advanced technology in food-processing plants would be higher were it not for problems with financing. Often seen as a barrier to the performance of research and development (R&D), problems with inadequate financing also extend to the acquisition of advanced machinery and equipment.

The study also finds that a lack of management support impedes technology adoption. When senior management is seen as not placing enough emphasis or priority on the use of advanced technology within their organization, the number of advanced technologies in operation in a firm is significantly lower.

Training and software costs also act as an impediment to adoption. Implementation of new technologies requires both additional software and skilled workers to operate them. Firms that lack adequate training strategies are at a disadvantage and tend to adopt fewer advanced technologies.

3. *What type of establishment adopts advanced technology*?

While the primary emphasis of the paper is on the relationship between the benefits and impediments that are rated by plant managers and the adoption of advanced technologies by food processing plants, the paper also examines whether there are other characteristics that are related to technology adoption, after controlling for the importance of the benefits and impediments discussed previously. The characteristics that were investigated include size of plant, nationality (foreign- or domestically controlled), nature of operations (primary or secondary processing) and industry of location. Finding a relationship with a particular characteristic (such as plant size), after controlling for benefits and impediments, suggests that the list of benefits and impediments that have been used is not exhaustive or that their intensity is related to the particular plant characteristics (like plant size).

The paper reports that after the impact of benefits and impediments are considered, large plants make the greatest use of advanced technology. This is particularly the case for network communications and processing technologies. The nature of the production process used in a plant also matters. Greater use of advanced process control and packaging technologies is found in plants engaged in some form of secondary processing. Finally, being foreign-owned increases the number of technologies adopted.

1. Introduction

Technological change is a key ingredient to productivity gains and economic growth (Baldwin, Diverty and Sabourin, 1995; Barkley, 1995; Baldwin, Sabourin and Rafiquzzaman, 1996; Stoneman and Kwon, 1996; and Baldwin and Sabourin, 2001). Plants adopting advanced technology, in addition to having higher growth rates and being more productive, are also less likely to fail (Doms, Dunne and Roberts, 1995).

Understanding the process by which technological change takes place is of interest to researchers and policy makers alike. One group of studies (Mairesse and Sassenou, 1991; Geroski et al., 1993; Stoneman and Kwon, 1996) have examined the returns to technological change in an attempt to understand whether these returns are large or small. Other studies have examined the effect of firm and industry characteristics on the adoption of advanced technology (Rose and Joskow, 1990; Dunne, 1994; Gale, 1998; Doms, Dunne and Roberts, 1995; Baldwin and Diverty, 1995). These studies have attempted to identify which characteristics are associated with adoption, because of a concern that plants differ in terms of their ability to absorb new technologies and that these differences will have an effect on both the industrial structure and on overall productivity growth.

This paper falls into the latter group in that it focuses on the use of new technologies in the Canadian food processing industry. The food-processing sector differs from other manufacturing sectors by the degree of product-market regulation. Many of the regulations governing this industry are aimed at ensuring high quality products, free of contamination. Of particular concern to this industry is microbiological safety. Since regulations are sometimes seen to be inimical to the application of new technologies, one of our objectives will be to examine the extent to which regulation is affecting technological choice.

The food industry is also currently undergoing major structural change. It is moving towards biological manufacturing and the adoption of process control technology to coordinate the entire food supply chain. This shift is meant to enhance and control quality and safety throughout the whole production process. In the United States, the industry is also moving away from independent stages in the food production process to food supply chains (Boehlje, 1999).

The same trends can be found outside of North America. For example, process control technology is making inroads in France as evidenced by the success of the *Label Rouge* Poultry System. Based on a Hazard Analysis Critical Control Point (HACCP) system, the *Label Rouge* System is a nationwide quality control management system used to ensure quality and safety across the entire production process (Westgren, 1999). Despite commanding higher prices than industrial chicken products, *Label Rouge* products had captured half of all household purchases by 1988.

While improvements in quality are an important result of the application of new technologies in the food-processing industry, there are many other reasons that advanced technologies are likely to be adopted. Advanced technologies also affect firm performance through their impact on the prices that firms can charge for their products and through their effect on production costs. Production costs can be reduced when technologies improve productivity.

Unfortunately, productivity growth in the Canadian food-processing sector has been lagging the rest of the manufacturing sector. Between 1980 and 1995, labour productivity in food processing grew at an annual rate of 1.1%, while that of the manufacturing sector as a whole grew at 2.6%. This inferior performance then raises the question of the effectiveness of the most recent generation of technologies on productivity growth. It may be the case that these advanced technologies do not have much of an impact on productivity. This will be the second target of our study.

The advantages arising from new technologies depend not only on the impact of new technologies on the safety and quality of food products and on production costs, but also on the costs that are incurred during the adoption process. These costs include the expenditures on new equipment, on training skilled workers, and on reorganizing the production process to incorporate the new machinery and equipment.

Managers who evaluate the advantages of new technologies must weigh the benefits of doing so against adoption costs. This process, however, is less than perfect. It is difficult to estimate the costs and benefits associated with the adoption of new technology (Dean, 1987). And even after firms have made the decision to adopt, they are still faced with the decision as to the optimal time to adopt, which requires imperfectly forecasting the advantages of waiting for the next round of technologies as opposed to adopting equipment today that imbeds the present state of the art (Rosenthal, 1984).

Firms vary dramatically in terms of their capabilities both to make use of new technologies and to assess the advantages of new technologies. As a result, they differ in terms of their use of advanced technology. Advanced technology surveys have typically been used to provide an overview of which benefits and impediments are most important to firms who happen to be the leaders in adoption. In order to determine the importance of these different factors, most advanced technology surveys include a question on the benefits associated with advanced technology adoption and another question on the obstacles or impediments to adoption. The benefits questions include such items as increased productivity, increased profitability and superior product quality. The impediments questions include the high cost of capital, integration costs and skill shortages.

In this paper, we will examine how the numbers of technologies adopted is related to the different impacts and impediments that are listed in a recent technology survey of the Canadian food-processing industry conducted by Statistics Canada. Our analysis focuses on the population of plants that use at least one technology (technology users)[1] and investigates the factors that are related to the number of technologies employed. It also controls for other factors that have been found previously to affect technology adoption—differences in plant size, nationality of control, and industry.

The paper is organized as follows. The survey data that are used for the study are described in Section 2. Bivariate analysis of the relationship between technology adoption and selected plant and industry characteristics—plant size, nationality and industry—are provided in Section 3.

[1] We focus only on different levels of use within the population of technology users because questions on benefits and problems were only posed to this group. Non-users find it difficult to answer such questions.

Section 4 describes the framework that is used for multivariate analysis that examines the joint effect of benefits and impediments to technology adoption and other plant characteristics. Empirical results are contained in Section 5.

2. The Survey

The data for this study come from the 1998 Survey of Advanced Technology in the Canadian Food Processing Industry conducted by Statistics Canada in conjunction with Agriculture and Agri-Food Canada. The list of advanced technologies that are examined in the survey was developed in conjunction with plant managers in the industry. The survey is based on a frame of Canadian food processing establishments obtained from Statistics Canada's Business Register. Establishments were randomly sampled using strata that are based on establishment size, industry and country of control. The overall response rate to the survey was 84%.

The questionnaire for the survey consists of nine sections covering a range of issues pertaining to the technological regime of food processing plants. There is a section dealing with general firm characteristics, followed by sections on the production environment, advanced technology adoption, use of associated business practices, the development process for new technologies, skill development, the competitive environment, and the benefits and problems pertaining to adoption.

Sixty-two advanced technologies covering nine functional technology groups were identified in the survey. The nine functional groups are—processing, process control, quality control, inventory and distribution, management systems and communications, materials preparation and handling, pre-processing, packaging, and design and engineering (Table 1). Details about the individual technologies that make up each functional group are provided in Appendix A. The survey itself is included as Appendix D.

Table 1. Advanced Technologies by Functional Group

Functional Technology	Description
Processing	• Includes thermal preservation; non-thermal preservation; additives and ingredients; and separation, concentration and water removal technologies.
Process control	• Technologies such as programmable logic controllers and computerized process control used to automatically control the production process.
Quality control	• Technologies such as rapid testing techniques and automated laboratory testing used to ensure that quality standards are being met.
Inventory and distribution	• Used to automate the inventory and distribution process; bar coding is a familiar example.
Management systems and communications	• Computer-based network systems that enable information to be transferred between different parts of a firm, between plants and suppliers, and between plants and customers.
Materials preparation and handling	• Technologies used for manipulating and moving raw materials and products.
Pre-processing	• Technologies that contribute to the quality enhancement and quality assessment of raw products.
Packaging	• Technologies used to protect food products from contamination and spoilage.
Design and engineering	• Integral parts of product and process development including recipe formulation, simulation and quality control planning.

3. Advanced Technology Adoption

3.1 Introduction

Baldwin, Sabourin and West (1999) report that the use of advanced technology is high in the food processing industry. Eighty-eight percent of establishments use at least one of the advanced technologies listed in the survey. More importantly, a substantial number of plants are multi-technology users. Slightly more than half of the plants use six or more technologies, while close to a third use more than ten (Table 2).

Use of advanced technology in the food processing industry is not restricted to certain parts of the production process, rather it permeates the whole process (Baldwin, Sabourin and West, 1999). Even so, adoption rates are not uniform across technologies. Processing and network communications technologies lead with adoption rates of 62%. This is followed by process control, then packaging technologies with adoption rates of just over 50% each.

3.2 Differences in Technology Use Across Size and Control

3.2.1 Size Differentials

Previous manufacturing technology studies have found a strong positive relationship between technology use and establishment size (Baldwin and Diverty, 1995; Dunne, 1994; Gale, 1998; Lane, 1991; Majumdar, 1995). Reasons for this include better information and greater financial capabilities that are associated with larger establishment size. Large firms, it is often argued, may enjoy scale economies in the acquisition of information regarding new technologies. In addition, the benefits of applying the new technologies in small or domestic plants may be fewer because their operations may be quite different. To the extent that large plants perform more functions than small plants, we would expect them to find more applications for advanced technologies and to implement a larger number of them.

Nine out of ten plants have adopted at least one of the 61 advanced technologies identified on the survey questionnaire. This varies, however, according to the size of the plant and its nationality. For all technologies considered together, the use of at least one advanced technology increases with plant size and foreign control (Table 2). Large establishments[2] have a slight edge on small plants; as do foreign-controlled over domestic-controlled establishments.

Use of at least one advanced technology ranges from a low of 20% for design and engineering technologies to a high of 62% for processing and communications technologies.[3] Adoption rates also differ by size and nationality across most of the different types of advanced technologies.

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[2] Large plants are those with 250 or more employees; medium plants have 100 to 249 employees; and small plants have between 10 and 99 employees.

[3] Separate reference to inventory and distribution, and automated materials handling technologies will be dropped for the remainder of the paper. With low adoption rates, mostly because they consist of only two or three individual technologies each, they lend little to the analysis. These technologies are included, however, in the overall results.

The largest size differentials are found for process control, packaging and design and engineering technologies, whereas the greatest nationality of control differences are found for process control, communications and pre-processing technologies. Process control and communications technologies are common to both.

Table 2. Use of at Least One Advanced Technology by Size and Nationality of Control

Advanced technology use	*Plant size*			*Nationality of control*		*All*
	Small	*Medium*	*Large*	*Domestic*	*Foreign*	
	(percentage of establishments)					
Overall	86	91	97	87	96	88
Functional technology						
• processing	58	61	88	62	62	62
• process control	47	74	86	52	86	56
• quality control	37	57	72	42	61	44
• communications	54	78	91	59	91	62
• pre-processing	30	47	61	33	63	36
• packaging	43	66	82	49	68	51
• design and engineering	11	30	66	17	43	20

In what follows, we focus on the numbers of advanced technologies used rather than on whether *any* technology is used because questions on the benefits of adoption in the survey are posed only to plants that have adopted at least one advanced technology. All subsequent tabulations will be based on the population of establishments that have adopted at least one advanced technology.

We measure the numbers of technologies in use at two separate levels in this study: first, across all technologies; second, at the level of the functional group, e.g., fabrication or communications. The mean number of technologies adopted overall and by functional technology group are presented in Table 3. On average, technology users adopt nine out of a total of 61 advanced technologies listed on the survey. The number of technologies adopted by large plants is more than double that of small plants. Whereas small plants adopt, on average, seven advanced technologies, large plants adopt 17 technologies. These differences extend across functional groups.

3.2.2 Nationality of Control

Multinational firms play an important role in the global diffusion of advanced technologies. They are seen to possess superior access to advanced technology (Blomstrom and Kokko, 1997). The theory of the multinational firm stresses that expansion across national borders is related to the need to exploit hard-to-transfer skills that are related to marketing or technology (Caves, 1982). The advantages of multinational enterprises are typically related to their size, expertise and financial resources.

Table 3. Mean Number of Technologies Used by Size and Nationality of Control for Advanced Technology Users Only

	Plant size			*Nationality of control*		*All*	*Number of technologies in the group*
	Small	*Medium*	*Large*	*Domestic*	*Foreign*		
Overall	7.1	11.4	16.9	8.6	12.4	9.0	61[4]
Functional group							
• processing	1.5	1.8	3.2	1.8	1.6	1.8	20
• process control	1.1	2.1	2.8	1.4	2.4	1.5	6
• quality control	0.6	1.0	1.2	0.7	1.1	0.8	7
• communications	1.4	2.3	3.1	1.6	2.5	1.8	5
• pre-processing	0.5	0.9	1.6	0.6	1.3	0.7	9
• packaging	0.9	1.6	2.3	1.2	1.7	1.2	6
• design and engineering	0.2	0.5	0.9	0.3	0.6	0.3	4

In the food processing industry, foreign-controlled plants lead domestic-controlled plants in the use of advanced technologies, particularly when it comes to multiple use. One and a half times as many foreign-controlled (78%) as domestic-controlled (51%) plants adopt five or more technologies (Baldwin, Sabourin and West, 1999). On average, foreign-controlled plants adopt slightly more than 12 technologies compared to only eight and a half for domestic plants. These differences extend across functional groups. Differences by nationality of control are largest in the areas of advanced process control, communications, and pre-processing technologies. Foreign- and domestic-controlled plants, on the other hand, have similar adoption rates when it comes to fabrication and processing technologies.

3.3 Differences in Advanced Technology Use Across Industries

Adoption rates vary substantially by industry, partially because the technologies vary in terms of their applicability. With a mean rate of 12 advanced technologies, plants in the dairy industry use the most technologies (Table 4). Next comes fruit and vegetable, meat and "other" with mean adoption rates of ten technologies each. At only six technologies, the bakery industry is last. This pattern of adoption holds across functional technology groups. The biggest difference across industries occurs in fabrication and processing technologies where dairy plants adopt between one and a half to three times the number of advanced technologies than plants located elsewhere in the food processing industry.

[4] Includes inventory and distribution, and automated materials handling technologies.

Table 4. Mean Number of Technologies Used by Industry for Advanced Technology Users Only

Mean Number of Technologies Used	*Industry*						
	Bakery	*Cereal*	*Dairy*	*Fish*	*Fruit and vegetable*	*Meat*	*Other*
	(percentage of establishments)						
Overall	6.0	8.2	12.4	7.9	10.4	9.9	9.6
Functional group							
• processing	1.1	1.0	3.1	2.0	2.3	2.2	1.5
• process control	1.2	1.5	2.1	1.0	2.0	1.4	1.6
• quality control	0.4	0.7	1.3	0.7	0.8	0.8	0.9
• communications	1.4	2.0	1.8	1.5	1.7	1.6	2.1
• pre-processing	0.2	0.8	1.1	0.6	0.8	0.9	0.7
• packaging	0.8	0.7	1.7	1.0	1.4	1.5	1.5
• design and engineering	0.1	0.4	0.4	0.3	0.4	0.3	0.4

3.4 Benefits and Impediment Costs of Advanced Technology Adoption

3.4.1 Introduction

The extent to which establishments adopt advanced technology is expected to be positively related to the benefits a firm receives and negatively related to the costs incurred. Or more precisely, it should be positively related to the net benefits received—the difference between the benefits and the costs of implementation. Benefits such as better product quality, increased profitability, savings due to reduced downtime and reduced manufacturing costs provide the incentives for adoption, while impediments such as acquisition costs, integration costs, operation costs, financing costs and software development costs provide the disincentives.

If benefits and costs are independent of one another, we should expect technology adoption to be positively related to the benefits listed by a firm and negatively related to the impediments that can be considered as a proxy for whether costs are incurred. However, it should be remembered that benefits and costs may not be independent. A firm may report severe impediments, but may face such large benefits that these benefits overcome the impediments. In the following sections, we ask whether the number of technologies adopted is related to particular benefits and impediments listed by advanced technology users.

3.4.2 Benefits

Because of heterogeneity in firms' capabilities, benefits and impediments vary from firm to firm. In order to evaluate the importance of specific benefits resulting from adoption, we use a survey question that asked plant managers to rate the importance of a set of thirteen benefits resulting from advanced technology adoption. These questions can be classified into three broad categories—productivity gains, product improvements, and meeting regulatory requirements.

The answers to the questions were scored on a five-point scale. Scores of one and two indicate the benefit to be of low importance to the firm, while scores of four and five indicate high importance. For our purpose, we chose to use extreme scores to capture the importance of the category. That is, we dichotomise the responses into those where the benefit was deemed to be very important (a score of four or five) and those with scores of 0 to 3. The percentage of establishments that deemed the benefit to be very important is given in Table 5.

Broadly speaking, regulatory compliance benefits are ranked highest, followed by product improvement and then reductions in production costs. Of the regulatory benefits, meeting food safety requirements is found to be important by the largest group of food processors. Seventy-seven percent of plant managers scored it a four or a five in terms of importance. It is ranked almost ten percentage points higher than the second highest-ranked benefits, improved worker safety and better tasting products. This is consistent with the findings of Sanderson and Schweigert (1988) for the U.S. food industry—that improved food safety and quality are prime motivators for technological change.

Product development is just behind safety. In this highly competitive industry, taste and packaging sell. Consumers are drawn to products that taste good and are attractively packaged. Convenience is another important selling point. Food products that are quick and easy to prepare are attractive to consumers.

Reduction of costs is next in importance. Except for labour productivity gains, productivity improvements are consistently ranked lower than product safety or product improvement.

While these data show the difference in the perceived benefits of different categories, by themselves, they do not tell use which of these benefits is most closely related to advanced technology adoption. In order to investigate this issue, we examine whether plants that adopt greater numbers of technologies tend be more likely to report certain benefits.

To do so, we categorize technology-using establishments according to the number of technologies adopted (grouped into 1-5 technologies, 6-10 technologies, and more than 10 technologies) and examine the percentage of firms ascribing high importance attributed to the particular benefit (Table 5). The importance of reported benefits rises with the number of technologies used. High intensity users—those with more than 10 advanced technologies—are more likely to consider a benefit important. This is especially true for those relating to labour productivity improvements.

Table 5. Benefits of Advanced Technology Adoption by Number of Technologies Adopted

Benefits of Adoption	*Number of Technologies Adopted*			
	1-5	*6-10*	*over 10*	*All*
	(percentage of establishments indicating a specific benefit is important)			
Productivity improvement				
• Reduced labour	45	65	74	60
• Reduced materials	33	50	53	44
• Reduced capital	36	47	56	46
• Reduced set-up time	35	53	56	47
• Reduced rejection rate	43	62	68	57
Product improvement				
• Nutrition	46	51	51	49
• Taste or appearance	57	72	75	67
• Shelf-life	56	66	72	64
• Consumer convenience	56	69	68	64
Regulatory compliance				
• Worker safety	58	73	77	69
• Food safety	67	79	88	77
• Environmental protection	59	69	70	65
• Food composition	54	65	62	60

3.4.3 Impediment Costs

In examining the importance of different impediment costs to advanced technology adoption, we make use of a question that asked plant managers to rate the importance of a set of twenty-one impediments to technology adoption using a five-point Likert scale. Scores of one and two correspond to a minor problem in a particular area, while scores of four and five indicate a major impediment to adoption.

The impediments are classified into six categories—lack of financial justification, lack of financial resources, lack of commitment from management, inadequate human resources, lack of external support services, and problems meeting government regulations. These factors encompass two very different types of impediments. The first level consists of the more general, all-inclusive, costs that should affect most plants. This group covers the financial costs of the new technologies, that is, the investment costs of machinery and equipment. Most firms would be expected to report these general costs as an impediment unless the investment decision to adopt new technology was overwhelmingly in favour of the new technology—net benefits were so large that small changes in costs did not affect decisions at the margin.

At the second level, there are more specific costs, like training, technology licensing, costs of technical support, and the costs of persuading management to adopt new technologies. While we expect most establishments to report general costs as an impediment, we expect fewer to do so for the more specific costs.

Table 6 provides the percentage of plants that consider a factor to be an impediment to adoption. Again we adopt the convention of reporting the percentage of firms that scored a factor with a four or five.

Generally, the more general costs pose a greater problem. Over 63% of plants rate the cost of equipment as a major impediment. Operations and integration costs come next with some 40% of plants indicating that this is a problem. Of the specific problems, some 20% of plants find human resource problems, financing, and management to be a problem.

As was done with benefits, we also compare the importance of an impediment across plants that are grouped by number of technologies used. This allows us to investigate whether more intense users of numbers of technologies report more impediments. A caveat is in order here. In previous work (Baldwin and Lin, 2001), it was found that firms adopting more technologies actually reported greater impediments in some areas. Intense adopters of technology were found to face more problems that had to be solved, but apparently were willing to do so because of higher perceived benefits.

The sign of the differences in the importance attached to obstacles faced by users of many, as opposed to fewer, technologies varies across different types of impediments. Low intensity users are more concerned about inadequate financing, lack of cash flow and management priority. Low intensity users encounter greater problems in attaining adequate financing and generally suffer from a lack of adequate cash flow. They also have greater problems convincing management of the importance of advanced technology. But there are few other categories with a significant negative difference between the least intensive technology category and the most intensive technology category.

On the other hand, the most important impediment (cost of equipment) is reported as a greater problem by users of many technologies. Compliance with food safety regulations has the same directional effect. This accords with our earlier findings reported in Baldwin and Lin (2001).

Table 6. Impediments to Advanced Technology Adoption by Number of Technologies Adopted

Impediments to Adoption	*Number of Technologies Adopted*			
	1-5	*6-10*	*Over 10*	*All*
	(percentage of establishments indicating a specific impediment is important)			
Financial justification				
• Small market size	36	38	40	38
• Evaluation uncertainty	31	42	35	35
• Cost of equipment	55	70	65	63
• Software development costs	37	43	32	37
• Integration costs	41	48	41	43
• Operation costs	43	50	42	45
Financial resources				
• Lack of outside financing	29	24	21	25
• Lack of cash flow	30	28	23	27
Management				
• Lack of scientific information	21	23	20	22
• Low priority	27	27	19	24
• Lack of evaluation capabilities	22	21	20	21
Human resources				
• Skills shortage	25	27	22	25
• Training difficulties	24	27	22	24
• Worker resistance	16	22	22	20
External support				
• Lack of technical support	13	17	18	16
• Lack of technological services	14	16	14	15
Government policies				
• Labour	22	30	23	25
• Food composition	16	20	24	20
• Food safety	23	34	29	28
• Plant hygiene	25	34	30	30
• Environment	21	31	29	27

3.5 Net Benefits

In the previous sections, benefits and impediments to adoption were examined separately. Firms, however, consider them jointly when deciding whether or not to adopt. And the score that firms report on some impediments is positively correlated with the score on benefits—thereby indicating that the two are best considered together.

In this section, we examine the net effect of benefits and impediment costs. In order to do so, we construct several measures from the answers to the benefits and impediments questions to proxy the net benefits that a firms derives from advanced technology adoption. In doing so, we aggregate across the benefits questions weighting each category equally by taking an arithmetic average of the responses across each category, do the same for the impediments questions and then subtract the latter from the former to generate a measure of net benefits. This procedure not only weights each benefit equally but weights the overall benefit measure equally with the overall impediment measure.

To derive a measure of overall impediments, we use the impediment questions described in Section 3.4.3, that asked plant managers to rate the importance of a list of 21 factors that impeded the adoption of advanced technologies. These impediments applied to the adoption process of any advanced technology, rather than specific technologies. Using these results, an overall *impediment cost measure* was constructed that was the average score for a plant across the 21 impediments. It ranges from a low of zero (for no impediments for any technology) to a high of 5 (for very high impediments for all technologies).

On the benefits side, two different questions were used to devise two separate measures of gross benefits. For the first, responses to the benefits question described in Section 3.4.2 were used to construct an overall *benefits measure*, similar to that done on the impediments side. Like the overall impediment measure, the overall benefit measure ranges from a low of one to a high of five. Taking the difference between the overall benefits and the overall impediments measure, where both are measured for technology users as a whole, provides us with our first measure of overall net benefits (NETBENE1).

For our second net benefits measure, we use a different question to measure the benefits of advanced technology—a question that asks plant managers to rate, using a five-point scale, the ‘economic impact’ from adopting advanced technology. Answers ranged from a low of one, for ‘insignificant’ impact, to a high of five for ‘major’ impact. Unlike the other benefits question, this question is asked about the benefits derived from individual technology groups, eg., processing and process control. As such, it provides us with a measure of the effect of specific technologies on the performance of the firm. The second net benefits measure (NETBENE2) is then calculated as the difference between the overall economic impact score and the overall impediment cost measure described above. Using this method, a separate net benefits variable was constructed for each functional group.[5]

Both net benefits variables are continuous, and they range from plus five (indicating all benefits and no costs) to minus five (no benefits and all costs). Plants for which net benefits are high are expected to adopt greater numbers of technologies. In order to investigate this, establishments were ranked according to their ‘net’ scores, and were then divided equally into three groups, those with high, medium, and low net benefit scores. High net benefits represent situations where benefits outweigh impediments; medium net benefits are found where benefits and impediments are roughly equal; while low net benefits occur when impediments outweigh benefits.

Table 7 contains the average number of technologies adopted by net benefit category. Even though our measure of net benefits must be regarded as only a rough proxy for the dollar value of benefits actually received, the number of technologies employed is higher for plants reporting higher net benefits. This holds across all advanced technology groups.[6] The effect is largest for processing, process control, and packaging, where high net benefits plants adopt one-and-a-half times as many technologies as low net benefits plants.

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[5] In order to derive the cost measure at the functional technology level, we simply replicated the overall results across the functional groups.

[6] The tabulations for this table are based on users of specific technologies only. For example, users of processing and fabrication were divided into three ‘net benefits’ groups—low, medium and high—and the mean number of advanced processing technologies adopted by each group was then calculated.

Table 7. Mean Number of Technologies for Advanced Technology Users by Net Benefits Category

Functional Technology Use	*Net Benefits*			*Difference*	
	Low	*Medium*	*High*	*Medium-Low*	*High-Low*
	(mean number of technologies)				
NETBENE2					
• processing	2.0	3.1	3.0	1.1***	1.0***
• process control	1.8	2.5	2.9	0.7***	1.1***
• quality control	1.3	1.5	1.7	0.2***	0.4***
• communications	2.1	2.6	2.8	0.5***	0.7***
• pre-processing	1.6	1.8	2.0	0.2	0.4***
• packaging	1.6	2.2	2.6	0.6***	1.0***
• design and engineering	1.2	1.5	1.6	0.3***	0.4***

*** Statistically significant at the 1% level; ** at the 5% level; * at the 10% level.

4. Empirical Model

4.1 Introduction

The bivariate analysis of the preceding sections suggests that use of advanced technology varies by size of plant, nationality of control, type of industry, and net benefits received. Plants, where net benefits are largest, adopt greater numbers of technologies. Similarly, large plants and foreign-controlled plants also tend to be more technologically advanced. But size and nationality of control are related, as foreign-controlled plants tend to be larger, thereby limiting the conclusions that may be drawn from these bivariate tabulations.

In this section, we turn to multivariate analysis to jointly estimate the effect on technology adoption of net benefits, size and nationality of control, in addition to other plant and industry characteristics on the number of technologies employed. Only those plants that have adopted at least one of the 61 advanced technologies listed on the survey are included in the analysis.

4.2 Dependent Variable

The dependent variables used in this paper measure number of technologies employed. All regressions are estimated based on advanced technology users only. The dependent variable for the first regression measures the number of technologies used in all areas. As there are 61 advanced technologies listed on the survey, this is a variable ranging from one to 61. The second set of regressions use number of technologies employed within each functional area. Separate regressions are estimated for each functional group. Only plants using a specific functional technology are included in the regressions for that technology. This set of dependent variables range from zero to n, where n is the total number of individual technologies within a functional group.[7]

[7] See Appendix A for details about the technologies that comprise each of the functional groups.

4.3 Explanatory Variables

Size

Establishment size is measured by the number of production and non-production workers employed by the establishment. Five binary variables have been constructed to capture size effects. They are based on the following five categories—10 to 19 employees (ESTSIZE1), 20 to 49 employees (ESTSIZE2), 50 to 99 employees (ESTSIZE3), 100 to 249 employees (ESTSIZE4), and 250 or more employees (ESTSIZE5).

Nationality of Control

Nationality of control (FOREIGN) is captured by a binary variable that takes a value of one if the establishment is foreign controlled, and a value of zero if the establishment is domestically controlled.

Benefits and Impediments

Three broad categories of benefits from adoption were introduced earlier in the paper—productivity gains, product improvements, and meeting regulatory requirements. Three binary variables were created to capture these benefits. The first is used to capture productivity gains, a second to capture product quality improvements, and a third to capture regulatory compliance benefits.

The first benefits variable (LABREDUC) measures the importance of labour productivity gains resulting from advanced technology adoption. The second benefits variable (PRODUCT) measures the importance of improved taste or appearance and longer shelf life. The third benefits variable (SAFETY) measures the importance of meeting worker and food safety regulations. Each variable takes a value of one if the establishment scores the impact as a four or a five (high importance) on a five-point Likert scale, and a zero otherwise.

Similarly, three binary variables have been created to capture impediments to adoption. They are based on the three types of impediments found earlier to be most important. The first variable (EQPCOST) measures the importance of equipment costs as a possible impediment to adoption. The second variable (OPCOST) measures the importance of integration costs and increased operating costs. The third variable (FINCOST) measures the impact of inadequate financing. Each takes a value of one if the plant rates the impediment as an important concern, and a zero if it does not.

Our hypothesis is that higher benefits should lead to increased use of technologies. *Ceteris paribus*, firms reporting large productivity gains or the production of superior quality products are expected to adopt a larger number of technologies. *Ceteris paribus*, firms for which impediments are less of a problem are expected to adopt more technologies. Of course, any close connection between the reporting of some impediments and benefits will weaken these relationships.

We also experiment with an alternate formulation of benefits and costs that takes into account all the benefits and costs together. In order to do so, we calculate the principal components for the benefit variables and for the impediment variables separately and each of the components are then included as separate variables in the regression.

Principal component analysis groups a set of variables (X_i) into a new group of variables—the principal components (PC_i). Each new variable, the principal component (PC_i), is a weighted average of the original variables, eg., $PC_i = \Sigma w_i * X_I$ where w_i are the weights. The weights are chosen so that the new variables exhaust the variance in the original set of variables and the new variables are orthogonal to one another. The weights on the first principal component are chosen so as to maximize the amount of variance explained; the weights on the second component are chosen to maximize the remaining amount of variance explained and so on until all the variance is exhausted.

Examination of the weights reveals how the new variable relates to the original set of variables. For example, if the weight on productivity is positive and the weight on regulation is zero, then the principal component represents the benefits from productivity and does not depend upon regulatory effects. As another example, a positive weight on productivity and a negative weight on regulation represent the situation where productivity is important to the firm while regulatory compliance is quite unimportant. By examining the relationship between the coefficients on the principal components and the nature of the components, we can ascertain which specific combinations of benefits or impediments are related to technology use. The interpretation of the principal components for the benefits variables and the eigenvectors are provided in Appendix B, Tables B1 and B2 respectively. Likewise, Tables B3 and B4 contain the same information for the impediments variables.

Net Benefits

To overcome the conceptual difficulties in measuring benefits and impediment costs separately, we also include the net benefits measures derived in the previous section. The net benefits variable (NETBENE1) provides a measure of the relative importance of the benefits and costs associated with the adoption of advanced technology that considers 21 different benefits at the level of the firm. A second measure (NETBENE2) focuses on overall economic gain but does so at the functional group level.

Production Type

Plants differ by type of activity. Some establishments are strictly primary processing facilities. Plants dedicated to the initial stage of processing, such as the production of fresh meat, flour, fluid milk, and canned fruit, fall under this category. Others are dedicated to the production of secondary, value-added products. This includes those plants that transform primary products into secondary products. Examples include sausages, frozen dinners and baked goods. Still others do both.

Three binary variables have been created to capture the production type of a plant. The first variable (PRODTYP1) takes a value of one if the establishment is a pure primary processing plant, otherwise it takes a value of zero if it is engaged in some secondary processing activity—either purely secondary or combined primary-secondary processing. The second binary variable (PRODTYP2) takes a value of one if the plant is strictly a secondary processing facility, zero otherwise. The third binary variable (PRODTYP3) captures the combined facilities. It takes a value of one if combined primary and secondary process activities take place, and a value of zero otherwise.

Batch versus Continuous

It is possible that new advanced technologies are more suitable to continuous rather than batch operations. To distinguish continuous from batch operations, we use a binary variable (BATCH) that takes a value of one if the plant is primarily a batch operation, and a value of zero if it is primarily a continuous operation.

Growth

Past growth in a firm and technology usage have been found to be closely connected (Baldwin and Diverty, 1995). Growth tends to generate cash flow, which is a strong determinant of investment in new technology. In order to capture this effect, growth in output (GROWTH), as measured by the growth in total shipments of the plant over the period 1991-1997, has been included in our regression. The shipment data come from a longitudinal file developed from the Annual Survey of Manufactures. This data was linked to the Technology Survey data at the plant level. GROWTH is calculated as the difference between total shipments of the plant in 1997 less total shipments of the plant in 1991 divided by total shipments of the plant in 1991.

Industry

Industry effects were also included. Seven binary variables were constructed for the seven sub-industries that are considered here—bakery (BAKERY), cereal (CEREAL), dairy (DAIRY), fish (FISH), fruit and vegetables (FRUIT), meat (MEAT), and other (OTHER) food products.

Summary Statistics

Summary statistics for the dependent and explanatory variables for technology-using establishments are provided in Table 8. The means provided in the table are weighted population estimates for plants that have adopted at least one of the 61 advanced technologies listed on the survey. The mean values for the binary variables represent the proportion of establishments in the population exhibiting a particular characteristic. For example, for the binary foreign control variable, 12% of technology-using plants are foreign controlled. For the continuous variables, which include the number of technologies used and the net benefits variables, the mean values capture the traditional arithmetic average. For example, Canadian food processing plants had adopted, on average, 8.9 advanced technologies by 1998.

4.4 Methodology

The form of the regression that was estimated is:

$$\text{TECHNO} = \alpha_0 + \alpha_1{*}\text{ESTSIZE} + \alpha_2{*}\text{FOREIGN} + \alpha_3{*}\text{NETBENE} + \alpha_4{*}\text{PRODTYPE} + \alpha_5{*}\text{BATCH} + \alpha_6{*}\text{GROWTH} + \alpha_7{*}\text{INDUSTRY}$$

where TECHNO measures the number of technologies used, first at the overall level, and second at the functional technology level. Definitions of the explanatory variables are provided in the preceding section.

Parameter estimates for the ordinary least squares regressions,[8] using numbers of technologies as the dependent variable are provided in Tables 9, 11 and 12. Regression results for the use of any type of advanced technology are provided in Tables 9 and 11, while individual regressions for each of the nine functional technology groups are provided in Table 12. All regressions are estimated against an excluded plant that is small, engaged strictly in primary processing, does continuous processing, is Canadian controlled, and is in the bakery industry.

[8] As the dependent variable in these regressions consists of count data, it may be more appropriate to use a negative binomial regression rather than ordinary least squares. Both methods were tried and give essentially the same results. Least squares regression results are reported here in the main body of the paper, while the negative binomial results are presented in Appendix C.

Table 8. Summary Statistics for Dependent and Independent Variables

Variable	***Description***	***Mean***	***Standard Deviation***
1. Dependent Variable			
Number of Technologies Used	Advanced Technology Use		
TECHNO	- mean number of technologies adopted	8.93	0.24
2. Plant Characteristics			
Establishment Size	Employment Size		
ESTSIZE1	- 10 to 19 employees	0.22	0.02
ESTSIZE2	- 20 to 49 employees	0.27	0.02
ESTSIZE3	- 50 to 99 employees	0.20	0.02
ESTSIZE4	- 100 to 249 employees	0.19	0.01
ESTSIZE5	- 250 or more employees	0.12	0.01
Nationality of Control	Country of Control		
FOREIGN	- Foreign owned	0.12	0.01
Production Type	Production Type		
PRODTYP1	- primary processing	0.36	0.02
PRODTYP2	- secondary processing	0.23	0.02
PRODTYP3	- both primary and secondary	0.40	0.02
Type of Operation	Type of Operation		
BATCH	- batch (not continuous) operations	0.47	0.02
Past Growth	Growth in Output		
GROWTH	- growth in total shipments	8.4	7.2
3. *Industry Characteristics*			
BAKERY	Bakery industry	0.15	0.01
CEREAL	Cereal industry	0.15	0.01
DAIRY	Dairy industry	0.11	0.01
FISH	Fish products industry	0.14	0.01
FRUIT	Fruit and vegetables industry	0.08	0.01
MEAT	Meat industry	0.18	0.02
OTHER	'Other' food products industry	0.20	0.02
4. *Benefits and Problems*			
Specific Benefits	Benefits of technology adoption		
LABREDUC	- labour productivity gains	0.60	0.02
PRODUCT	- product improvements	0.76	0.02
SAFETY	- regulatory safety compliance	0.81	0.02
Specific Impediments	Impediments to technology adoption		
EQPCOST	- cost of equipment	0.63	0.02
OPCOST	- operating costs	0.56	0.02
FINCOST	- financing costs	0.32	0.02
Net Benefits	Net benefits (benefits less impediments)		
NETBENE1	- benefits measure based on specific benefits from technology use overall	0.79	0.04
NETBENE2	- benefits measure based on economic gains at the functional technology level	-0.23	0.07

5. Empirical Results

5.1 Overall

Regression results for number of technologies used are presented in Table 9. Several specifications were tried in order to examine the robustness of the results to different specifications of the benefits and impediments variables. First, benefits and impediments were included separately (column 2), followed by the net benefits variable based on specific benefits (column 3), then the net benefits variable based on economic impact (column 4). Growth was added in the final specification (column 5). Similar results were obtained with all specifications with a few exceptions.

Production type is positive and generally significant. Establishments engaged in both primary and secondary processing activities adopt greater numbers of advanced technologies. Without specific benefits and impediments variables included in the regression, secondary-processing plants are found to adopt more technologies than primary processing plants. With their inclusion, this result is no longer significant.

With the inclusion of past growth in the model, production type loses its significance. Past growth is related to production type. Combined primary-secondary processing plants are growing faster than pure primary or pure secondary units.

Employment size is positively related to the number of technologies used across all models. The size coefficients are positive and statistically significant indicating that number of technologies increases with plant size. This is consistent with the findings of others (Gale, 1998; Baldwin and Diverty, 1995; Rose and Joskow, 1990) that larger plants use greater numbers of technologies.

The multinational or foreign-control variable is also positive and significant for all model specifications. Foreign-owned establishments adopt greater numbers of technologies, even after controlling for differences in size, industry and type of operation. The significance level on the foreign-control coefficient is, however, lower for the regression using economic impact in the formulation of the net benefits variable (NETBENE2). Economic impact, therefore, captures some of the underlying difference between foreign and domestic-owned establishments not captured by the specific benefits results. Foreign-owned establishments appear to receive greater economic gains from the adoption of advanced technology than do their domestic counterparts.

Establishments that are primarily batch operations adopt fewer technologies than those that are more continuous-run operations, a result that is only statistically significant with the inclusion of the benefits and impediments variables (column 2, Table 9).

Past growth is significant. Establishments with high output growth during the nineties have adopted a greater number of technologies. Armed with increased cash flow, these establishments are in a better position to invest in new technologies.

Table 9. Determinants of Numbers of Technologies Used—Ordinary Least Squares Regression

Variables	*OLS Regression*				
	Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*
INTERCEPT	1.865***	0.560	1.656***	3.101***	2.810***
Establishment Size					
ESTSIZE2	1.746***	1.525***	1.643***	1.482***	1.589***
ESTSIZE3	4.335***	3.570***	4.064***	3.983***	3.637***
ESTSIZE4	6.471***	5.762***	6.168***	5.650***	5.821***
ESTSIZE5	11.278***	10.317***	10.832***	10.307***	10.304***
Nationality of control					
FOREIGN	1.484**	1.412**	1.357**	1.121*	1.425*
Production Type					
PRODTYP2	1.000*	0.700	0.765	0.849*	0.987
PRODTYP3	1.273***	1.106**	1.065**	0.988**	0.741
Type of Operation					
BATCH	-0.674	-0.788*	-0.693	-0.392	-0.130
Benefits					
LABREDUC	---	1.202***	---	---	---
PRODUCT	---	0.937**	---	---	---
SAFETY	---	1.165**	---	---	---
Impediments					
EQPCOST	---	1.082**	---	---	---
OPCOST	---	-1.031**	---	---	---
FINCOST	---	-1.001**	---	---	---
Net Benefits					
NETBENE1	---	---	0.772***	---	---
NETBENE2	---	---	---	0.966***	0.849***
Past Growth					
GROWTH	---	---	---	---	0.002***
Industry Characteristics					
CEREAL	3.532***	3.254***	3.297***	2.624***	2.930***
DAIRY	5.590***	5.038***	5.536***	4.992***	4.991***
FISH	-0.084	0.016	-0.059	-0.547	-0.146
FRUIT	3.666***	3.261***	3.445***	3.127***	3.034***
MEAT	3.139***	2.994***	3.264***	2.585***	2.873***
OTHER	3.128***	2.916***	3.045***	2.445***	2.737***
Summary Statistics					
N	760	760	760	760	523
F (vars,d.f.)	F (14, 745) = 33.0	F (20, 739) = 26.3	F (15, 744) = 32.1	F (15, 744) = 41.2	F (16, 506) = 38.1
R-square	0.36	0.39	0.38	0.42	0.39

*** Significantly different from zero at the 1% level; ** significantly different from zero at the 5% level ; * significantly different from zero at the 10 % level.

The industry to which an establishment belongs is important. All of the coefficients on the industry variables are positive and, with the exception of fish, highly statistically significant. Establishments in the dairy industry tend to adopt the most technologies, followed by the cereal and fruit and vegetables industries. Plants in the fish products and bakery industries adopt fewer technologies.

The coefficients on the benefits variables are all positive and highly significant. As hypothesized, the greater the benefits the greater the number of technologies adopted. Interestingly, we find a slightly different picture using multivariate analysis than we did for our bivariate results in Section 3.4.2. Whereas our bivariate results indicated that regulatory compliance benefits outrank productivity improvement, multivariate analysis suggests that each is of roughly equal importance. This is confirmed by the elasticities of adoption with respect to the benefits arising from the effect of technology use on labour productivity and on safety. Using the parameter estimates provided in Table 9, elasticities of 0.15 were found for each.[9] The benefits from gains in productivity and meeting regulatory concerns with regards to product quality and safety are, therefore, of equal importance when it comes to technology adoption.

The parameter estimates for the impediments variables are also highly significant. Two are negative (operating costs and lack of external financing and lack of cash flow) indicating that higher impediments are associated with the use of fewer technologies. These results for the operating costs and financial costs variables confirm our hypothesis. Plants lacking adequate cash flow or outside financing or expecting high operating costs are less likely to adopt many technologies.

In contrast to the impediments variables like software cost whose scores are negatively associated with technology adoption, equipment cost scores are positively related to technology adoption. Plants for which high acquisition costs are seen to be a problem are also those that adopt greater numbers of technologies. This occurs because the more intensive users of advanced technologies report both greater benefits and greater costs. This accords with the learning-by-doing explanation reported by Baldwin and Lin (2001). Technology users derive greater benefits but also come across more problems that have to be resolved. It should be noted that consideration of the benefits and impediments variables together via the inclusion of a net benefits variable, rather than benefits and impediments separately, indicates that the positive effects of benefits overwhelm the positive effects of equipment costs. The net benefits variable has a positive effect on technology use.

The results of the regression that uses the principal components of the benefits and the impediments variables are summarized in Tables 10 and 11. Table 10 contains a summary of the principal components that are statistically significant in Table 11. Table 11 contains two sets of results. The first column reports the parameters of an OLS model. The second reports the results of a two stage least squares (TSLS) model where the benefits and impediments are treated with instrumental variables that are designed to purge these variables of both errors in measurement and endogeneity.[10] The instrument for each of the benefits and impediments principal components is its rank. A priori, the benefits and impediments variables are likely to contain an element of endogeneity since more intense users of advanced technologies are more likely to report larger benefits and to report greater costs—at least from higher equipment costs. Moreover, each of the benefits and costs variables is only a proxy for the monetary values that flow from technology use.

[9] The elasticity is calculated as Y_1-Y_0/Y_0 where Y_1 the number of technologies when the particular benefit is reported as being important and Y_0 the value when the benefit is not seen to be important.
[10] A Durbin-Wu-Hausman test finds that the error term of the regression was related to a number of these benefits and impediments.

In the OLS regression, benefits are positively related to technology use—though there are only two components that have a significant coefficient. The first (BENE1) gives positive weights to most benefits. But the second (BENE2) gives positive weights to gains in productivity and negative weights to regulatory compliance. There is therefore a component of benefits that is associated with the firm indicating that there were positive productivity gains and little in the way of regulatory compliance that leads to or is associated with the more intense use of new technologies.

Table 10. Summary of Statistically Significant Benefits and Impediments Principal Components

Regression Includes	*Statistically Significant*	*Interpretation*
• Principal Component **Benefits** minus **Impediments**	• BENE1	• technology use positively linked to overall benefits
	• BENE2	• technology use positively linked to productivity gains, not to product improvements or regulatory compliance
	• IMPED2	• software development and integration costs impede technology use, while regulatory compliance does not
	• IMPED4	• external and internal financial constraints and lack of management 'buy-in' impede use
	• IMPED13	• high equipment costs translates into greater numbers of technologies being adopted
	• IMPED15	• low management strategic priority impedes adoption but lack of information gathering capabilities does not
	• IMPED20	• inadequate cash flow, not lack of outside financing, impedes technology adoption
• Two Stage Least Squares Principal Component **Benefits** minus **Impediments**	• BENE1	• technology use positively linked to overall benefits
	• BENE2	• technology use positively linked to productivity gains, not to product improvements or regulatory compliance
	• BENE12	• technology use positively linked to improved taste and appearance of food products, not to prolonged shelf-life
	• BENE13	• technology use positively linked to food safety, not to worker safety
	• IMPED2	• software development and integration costs impede technology use, while regulatory compliance does not
	• IMPED4	• external and internal financial constraints and lack of management 'buy-in' impede use
	• IMPED15	• low management strategic priority impedes adoption but lack of information gathering capabilities does not
	• IMPED18	• training problems, not skill shortages, impedes technology adoption

On the impediments side, there are at least four different principal components that are significantly related to less technology use. The second impediment component (IMPED2) causes lower use when software and integration costs are higher and where government regulations, in general, are less important. The next significant impediment component (IMPED4) leads to less technology use when financial constraints are important (where either external sources or internal cash flow is a problem) and where various management problems arise (either technology is given low priority, there is a lack of scientific information in the firm, or the technology assessment process is imperfect). This confirms earlier findings drawn from a bankruptcy survey (Baldwin et al., 1997) that financial problems are often associated with internal capabilities. The next significant component that impedes technology adoption (IMPED15) also heavily weights the lack of management priority. The final component that impedes technology use (IMPED20) once more involves the lack of financing—but this time involves only internal cash flow constraints. Finally, as in the previous section, we find that high equipment costs (represented by IMPED13) are associated with more, not less, technology use.

Turning to the results of the TSLS regression, we see that two additional benefit variables become significant. The first (BENE12) reveals that advanced technology use is associated with firms reporting that it improves food quality via improved taste. The second (BENE13) is also related to quality—but this time to food safety. In the TSLS regression, software and integration costs as well as the financial constraints variables remain significant; but the equipment cost component (IMPED13), which we have argued is most likely to have feedback effects, is no longer significant. In addition, the component that is linked to inadequate internal cash flow alone (IMPED20) also loses its significance. But training costs (IMPED18) now enter as a significant deterrent to the use of advanced technologies.

5.2 Specific Technologies

As was reported previously, the adoption of advanced technology is directly linked to the net benefits plant managers associate with it.[11] Using the second specification for net benefits (NETBEN2), which is based on economic impacts as a measure of benefits, we find the coefficients to be positively and significantly related to the numbers of technologies used. This confirms our hypothesis that plants expecting higher rates of return (higher benefits) and lower impediments (lower costs) on their technology investments are more likely to adopt greater numbers of technologies.

The size coefficients are positive and statistically significant for all but quality control and design and engineering technologies. Where significant, it increases monotonically with size. The size-technology relationship is particularly strong for network communications, process control, pre-processing, and packaging technologies. Much weaker relationships are found for processing. For design and engineering the coefficients are negative, although rarely significant.

In contrast to its effect on technology use in general, the foreign-control variable is rarely significant in the multivariate analysis at the level of the individual technologies. Even with the exclusion of the net benefits variable, similar results are found. The parameter estimates are positive and significant only for quality control technology, whereas they are negative and significant for processing, and design and engineering. Foreign-owned plants are the leaders when it comes to adopting such quality control technologies as rapid testing techniques and automated laboratory testing. Canadian owned plants, on the other hand, adopt greater numbers of advanced processing, and design and engineering technologies. No significant difference is found for the other five functional groups.

[11] Growth was not included in this set of regressions as it was rarely significant and its inclusion greatly reduced the number of usable observations in some functional groups.

Table 11. Determinants of Numbers of Technologies Adopted Using Benefits and Impediments Principal Components

VARIABLE	COEFFICIENT	
	Principal Component	***2SLS Principal Component***
INTERCEPT	2.85***	2.84***
Establishment Size		
ESTSIZE2	1.39***	1.48***
ESTSIZE3	3.49***	3.61***
ESTSIZE4	5.72***	5.75***
ESTSIZE5	10.49***	10.39***
Ownership		
FOREIGN	1.18*	1.17*
Production Type		
PRODTYP2	0.67	0.73
PRODTYP3	0.99**	1.08**
Type of Operation		
BATCH	-0.70*	-0.74*
Benefits		
BENE1	0.47***	0.46***
BENE2	0.38***	0.29*
BENE3	-0.02	-0.07
BENE4	-0.06	-0.02
BENE5	-0.01	0.06
BENE6	-0.20	-0.17
BENE7	-0.06	0.24
BENE8	-0.44	-0.46
BENE9	0.15	0.01
BENE10	0.32	0.34
BENE11	-0.49	-0.31
BENE12	-0.33	-0.78*
BENE13	-0.48	-0.90**
Impediments		
IMPED1	-0.07	-0.13
IMPED2	-0.39***	-0.42***
IMPED3	-0.08	-0.08
IMPED4	0.40**	0.49***
IMPED5	0.01	0.10
IMPED6	0.00	-0.02
IMPED7	0.18	0.18
IMPED8	0.23	0.15
IMPED9	0.08	0.05
IMPED10	0.22	-0.12
IMPED11	-0.22	-0.27
IMPED12	0.12	0.01
IMPED13	0.58**	0.43
IMPED14	0.32	0.29
IMPED15	0.90***	0.86**
IMPED16	0.31	0.46
IMPED17	0.19	-0.01
IMPED18	0.45	0.82**
IMPED19	0.16	0.12
IMPED20	0.62*	0.33
IMPED21	0.57	0.45
Industry Characteristics		
CEREAL	3.07***	2.95***
DAIRY	5.32***	5.19***
FISH	0.24	0.25
FRUIT	3.29***	3.27***
MEAT	3.13***	3.07***
OTHER	2.83***	2.82***
Summary Statistics		
N	760	760
R-square	0.43	0.43

*** significantly different from zero at the 1% level; ** significantly different from zero at the 5% level ; * significantly different from zero at the 10 % level.

This difference between the effect of foreign control on overall technology use and on technology use at the functional group level indicates that foreign-controlled plants are more able to integrate technologies. They are more comprehensive users of technologies across a broad spectrum of functional areas.

Production type is generally positive. Yet the coefficient is significant only for process control, and packaging technologies. It is weakly significant for design and engineering. Establishments engaged in some type of secondary processing activity have an advantage when it comes to adopting advanced process control, and packaging technologies.

Whether or not a plant is a batch operation has little effect on the number of technologies used. Equally divided between positive and negative values, this coefficient is only significant for quality control. Since it is negative, this means that continuous operation plants have the edge when it comes to quality control technologies.

The industry to which a plant belongs has an influence on the number of technologies used. Industry effects are most important for processing, packaging, network communications, and design and engineering technologies. In general, plants in the fruit and vegetable, dairy and 'other' food products industries are more likely to use more technologies. Dairy, meat and fruit and vegetable plants are the leaders for processing and packaging technologies. Fruit and vegetable plants also lead for network communications technologies. 'Other' food product plants use more technologies in the areas of communications, packaging, and design and engineering technologies.

Table 12. Determinants of Functional Technology Adoption Ordinary Least Squares Regression

VARIABLE	*PROCESSING*	*PROCESS CONTROL*	*QUALITY CONTROL*	*COMMUNICATIONS*	*PRE-PROCESSING*	*PACKAGING*	*DESIGN*
INTERCEPT	2.052***	1.218***	1.340***	1.518***	1.191***	1.305***	1.552***
Establishment Size							
ESTSIZE2	-0.146	0.352**	0.003	0.386**	0.016	-0.055	-0.401
ESTSIZE3	0.190	0.633***	0.112	0.628***	0.426**	0.336*	-0.517**
ESTSIZE4	0.241	0.971***	0.124	0.814***	0.469***	0.423**	-0.147
ESTSIZE5	0.967**	1.439***	0.127	1.387***	1.027***	0.830***	-0.158
Nationality of Control							
FOREIGN	-0.377	0.090	0.193*	-0.064	0.176	-0.009	-0.296***
Production Type							
PRODTYP2	-0.175	0.399***	0.113	0.115	-0.112	0.389***	-0.253
PRODTYP3	0.009	0.464***	0.128	0.083	-0.025	0.211*	-0.274*
Type of Operation							
BATCH	-0.247	0.150	-0.174**	-0.090	-0.032	0.070	0.086
Net Benefits							
NETBENE	0.183***	0.190***	0.080***	0.113***	0.052*	0.164***	0.129***
Industry Characteristics							
CEREAL	0.162	0.174	0.069	0.575***	0.490*	0.238	0.428**
DAIRY	1.664***	0.331	0.174	0.256	0.202	0.610***	0.396**
FISH	0.282	-0.389	-0.317**	0.195	-0.010	-0.069	0.260
FRUIT	1.006***	0.432*	0.117	0.365**	0.227	0.377*	0.244
MEAT	0.617***	-0.158	-0.116	0.196	0.381	0.408**	0.111
OTHER	0.377	-0.055	0.033	0.546***	0.120	0.333**	0.412**
Summary Statistics							
N	532	526	343	565	339	466	213
R-square	0.14	0.25	0.12	0.17	0.17	0.19	0.21

*** significantly different from zero at the 1% level; ** significantly different from zero at the 5% level ; * significantly different from zero at the 10 % level.

6. Conclusion

In this paper, we have examined how the numbers of technologies used by food processing plants are related to different benefits and impediments. Several specific questions were addressed. The first was the extent to which regulation was driving the adoption of advanced technologies in the food-processing sector. Sanderson and Schweigert (1988) suggest that technologies in the food-processing sector have been primarily aimed at enhancing food safety.

Our second objective was to investigate the extent to which productivity gains were only of secondary importance. Because of lagging productivity in the food-processing sector, we examined whether there was evidence that firms acted positively in response to the benefits of productivity growth.

Our third objective was to understand which impediments were most closely related to technology adoption. Are there some areas, which are amenable to policy intervention, that are particularly important? It is argued that spending on R&D is constrained by imperfect capital markets—that lenders have difficulty in assessing risk in the high technology area and that a lack of collateral provides problems to industries that are making these investments. This may also be the case for the acquisition of advanced technologies, which requires investments in more than just machinery. It also requires extensive investments in training, technological licences, and in software development. While machinery provides collateral, the peripheral investments required are often large (Baldwin and Johnson, 1999) and provide little in the way of security.

Our multivariate analysis reveals that benefits are positively and significantly related to the number of technologies used, whereas the impediments, for the most part, are negatively and significantly related to adoption. Establishments expecting labour productivity gains, superior product quality and improved ability to meet regulatory requirements adopt greater numbers of technologies. In addition, establishments for which technology acquisition costs and financing costs are a concern adopt less technology. Concerns about high equipment costs, however, were found to be positively and significantly related to the number of technologies used. This latter result accords with a world in which it is the high intensity users that are most likely to encounter the costs associated with the purchase of the new equipment (see also Baldwin and Lin, 2001).

Our principal component analysis confirmed the result that productivity gains, product improvement and regulatory compliance are all positively associated with more technology use. As such, firms that indicated they were both gaining productivity and improving their ability to meet regulatory standards adopted more technologies. But the analysis also demonstrated that a separate productivity dimension, not associated with regulatory compliance, increased technology use. In other words, productivity gains *along with* regulatory compliance influence technology use. But the directional effects are not always the same. The two operate jointly in some situations while they oppose one another in others.

The principal component analysis also confirmed that financing problems impede technology adoption. Financing problems are often an issue for R&D, because of the difficulties of financing the soft assets produced by R&D that do not offer good collateral. This paper has shown that financing problems are not restricted to just the R&D-part of the innovation process. They also cause difficulties in acquiring advanced technologies. This result extends earlier findings that science-based firms are more likely to use equity to finance both investments in R&D and technology as well as machinery and equipment (Baldwin and Johnson, 1999). The present study has found that a lack of cash flow also affects the acquisition of advanced machinery and equipment, especially when it involves new advanced technologies.

But equally important, we have also shown that the financial difficulties are sometimes associated with internal management deficiencies. Senior management is sometimes seen by plant managers as not placing sufficient priority on new technologies, or not developing adequate monitoring systems to evaluate new technologies. This deficiency, by itself, is significantly related to less technology use, but when combined with external and internal financial problems, it is also associated with lower technology usage. Finally, we confirm the results derived from the 1993 Survey of Innovation and Technology that software costs are a serious impediment to technology use (Baldwin, Sabourin and Rafiquzzaman, 1996). The new advanced technologies are often computer-based. And to implement them requires software and workers who have been trained in software skills.

Finally, there is evidence to suggest that training costs, but not skill shortages, are an impediment to technology adoption. This accords with the view that skills shortages invariably exist in a world that is adopting technology, but they only become a problem in those firms that are unable to adopt a training strategy to overcome them.

We have also considered the importance of both benefits and impediments together. Businesses consider the ‘net’ benefits to adoption when deciding whether to adopt an advanced technology. While impediments and benefits are listed as separate questions on technology surveys, they are not considered independently by firms when it comes to making technology investment decisions. While there are problems in separating the two, there are equal problems in combining them in a meaningful net benefits measure. Therefore this paper has done both—in order to test the robustness of our results.

We found that our ‘net’ benefit measure was strongly related to the number of technologies adopted. Plants make their adoption decision by weighing benefits against impediments. Whether measured at the overall benefit level or at the functional group level, the result is the same. Net benefits are positively and significantly related to technological use.

In an earlier study, Baldwin and Diverty (1995) examined the technology adoption process by focusing on the relationship between technology use and specific plant and industry characteristics, ignoring the effect of benefits and impediments—because a measure of benefits and impediments was not available. Significant differences in technology use were found across plant sizes, with small plants making use of less technologies. It also found that foreign-controlled plants implemented more technologies. This paper focuses directly on the extent to which advanced technology adoption is related to different factors that affect the benefits to be derived from using advanced technologies and the impediments that stand in the way of adoption of new technologies. It asks whether plant size and nationality are still related to technology use once the effect of benefits and impediments have been taken into account.

We find size effects are little affected by the inclusion of the benefits variable. Thus, the benefits variable captures effects other than simply size. For all but quality control and design and engineering technologies, technology use is positively and significantly related to size. The largest establishments use the greatest number of technologies, particularly network communications, process control, pre-processing, and processing technologies. The inclusion of the benefits variable diminishes the foreign-control effect; but it does not make it disappear. The foreign-control coefficient is still significant at the overall technology level.

Multivariate analysis also reveals that the production characteristics of a plant are related to the number of technologies used. Plants engaged in some type of secondary processing, either alone or in conjunction with primary processing, are more likely to use more process control, and packaging technologies. Except for quality control technologies, whether an operation is continuous or batch does not matter. Continuous operation plants are significantly more likely to adopt greater numbers of advanced quality control technologies than are batch operations.

Appendix A: Detailed List of Advanced Technologies

Table A1 provides a detailed list of the 61 technologies—belonging to nine functional groups—listed on the 1998 Survey of Advanced Technology in the Canadian Food Processing Industry.

Table A1. List of Individual Advanced Technologies by Functional Group

Functional Technology Group	*Advanced Technology*
1. Processing	
1.1 Thermal preservation	• aseptic processing
	• retortable flexible packages
	• infrared heating
	• ohmic heating
	• microwave heating
1.2 Non-thermal preservation	• chemical antimicrobials
	• ultrasonic techniques
	• high pressure sterilization
	• deep chilling
1.3 Separation, concentration, water removal	• membrane process
	• filter technologies
	• centrifugation
	• ion exchange
	• vacuum microwave drying
	• water activity control
1.4 Additives or ingredients	• bio-ingredients
	• microbial cells
1.5 Other	• electrotechnologies
	• microencapsulation
	• irradiation
2. Process control	• automated sensor-based equipment
	• automated statistical process control
	• machine vision
	• bar-coding
	• programmable logic controllers
	• computerized process control
3. Quality control	
3.1 Process testing	• chromatography
	• monoclonal antibodies
	• DNA probes
	• rapid testing techniques
3.2 Laboratory testing	• automated laboratory testing
3.3 Simulation	• mathematical modeling of quality or safety
4. Inventory and distribution	• bar-coding
	• automated product handling
5. Management or inventory systems or communication	• local area network
	• wide area network
	• inter-company computer networks
	• internet for marketing or promotional purpose
	• internet for procurement, research, hiring, etc.

Table A1. List of Individual Advanced Technologies by Functional Group (continued)

6. Materials preparation and handling	• integrated electronically controlled machinery • individidual electronically controlled non-integrated machinery • electronic detection of machinery failure
7. Pre-processing activities	
7.1 Raw product quality enhancement	• animal stress reduction • bran removal before milling wheat • micro-component separation
7.2 Raw product quality assessment	• electronic or ultrasonic grading • collagen, colour or PSE probe • near infrared analysis • colour assessment or sorting • electromechanical defect sorting • rapid testing techniques
8. Packaging	
8.1 Equipment	• non-integrated electronically controlled packaging machinery • integrated electronically controlled packaging machinery
8.2 Preservation	• modified atmosphere
8.3 Advanced materials	• laminates • active packaging • multi-layer materials
9. Design and engineering technologies	• computer aided design and engineering (CAD/CAE) • CAD output used for control manufacturing machines (CAD/CAM) • computer aided simulation and prototypes • digital representation of CAD output used in procurement activities

Appendix B: Principal Component Analysis for Benefits and Problems Variables: 1998 Survey of Advanced Technology in the Canadian Food Processing Industry

Benefits

Table B1. Principal Components for Benefits to Adoption

Principal component	*Eigenvalue*	*Cumulative proportion of variance explained*	*Description of principal component*
PRIN1	4.66	0.36	General benefits with equal emphasis on productivity gains, product improvement, and regulatory gains
PRIN2	1.87	0.50	Emphasis on productivity gains; downplays product improvements and regulatory gains
PRIN3	1.35	0.61	Emphasis on product improvements; downplays regulatory gains
PRIN4	0.80	0.67	Heavy on shelf-life and to lesser extent food safety; downplays nutrition and set-up time
PRIN5	0.66	0.72	Heavy on nutrition and to a lesser extent material reduction; downplays set-up time reduction, rejection rate reduction and consumer flexibility
PRIN6	0.65	0.77	Stresses capital reduction and to a lesser extent shelf-life
PRIN7	0.55	0.81	Strong emphasis on labour reduction; strong de-emphasis on material reduction
PRIN8	0.51	0.85	Heavy on food composition; downplays worker safety
PRIN9	0.48	0.89	Consumer flexibility, food composition, and labour reduction important; shelf-life not important
PRIN10	0.40	0.92	Strong emphasis on set-up time reduction; strong de-emphasis on rejection rate
PRIN11	0.39	0.95	Stresses environmental protection and consumer flexibility
PRIN12	0.35	0.97	Stresses shelf-life; strongly downplays taste
PRIN13	0.34	1.00	Emphasizes worker safety; downplays food safety

Table B2. Eigenvectors for Benefits to Adoption

Benefits	***Specific Benefit***	***PRIN1***	***PRIN2***	***PRIN3***	***PRIN4***	***PRIN5***	***PRIN6***	***PRIN7***	***PRIN8***	***PRIN9***	***PRIN10***	***PRIN11***	***PRIN12***	***PRIN13***
Productivity gains	Labour reduction	0.19	0.43	-0.03	0.48	0.31	-0.14	0.50	0.09	0.37	0.13	0.12	0.07	-0.09
	Material reduction	0.24	0.40	-0.02	0.10	0.30	-0.13	-0.76	0.25	-0.05	0.12	-0.05	-0.05	-0.06
	Capital reduction	0.25	0.34	0.02	-0.22	0.10	0.77	0.02	-0.22	0.14	-0.29	-0.06	-0.14	0.07
	Set-up time reduction	0.28	0.34	-0.05	-0.32	-0.46	-0.08	0.16	-0.09	-0.11	0.63	-0.10	-0.17	-0.04
	Rejection rate reduction	0.30	0.34	0.04	-0.09	-0.31	-0.33	0.09	0.04	-0.33	-0.60	0.23	0.21	0.08
Product improvement	Nutrition	0.27	-0.15	0.30	-0.52	0.49	-0.10	0.16	0.01	-0.05	0.12	-0.01	0.44	-0.22
	Taste	0.31	-0.19	0.39	0.02	0.16	-0.26	0.12	-0.01	-0.04	-0.17	-0.30	-0.68	0.13
	Shelf-life	0.27	-0.16	0.37	0.45	-0.13	0.35	0.02	0.18	-0.42	0.21	-0.12	0.30	0.26
	Consumer flexibility	0.28	-0.21	0.38	0.15	-0.31	-0.01	-0.26	-0.31	0.45	0.03	0.41	0.03	-0.28
Regulatory gains	Worker safety	0.31	-0.16	-0.37	0.07	0.09	-0.20	-0.13	-0.58	0.11	0.02	-0.26	0.24	0.46
	Food safety	0.31	-0.18	-0.38	0.22	-0.08	0.07	0.07	0.02	-0.13	-0.15	-0.36	0.02	-0.70
	Environmental protection	0.29	-0.26	-0.38	-0.01	0.23	0.11	0.05	0.03	-0.31	0.13	0.66	-0.29	0.07
	Food composition	0.30	-0.26	-0.21	-0.20	-0.22	0.04	0.00	0.64	0.46	-0.07	-0.07	0.07	0.26

Impediments

Table B3. Principal Components for Impediments to Adoption

Principal component	*Eigenvalue*	*Cumulative proportion of variance explained*	*Description of principal component*
PRIN1	5.31	0.25	General impediments with equal emphasis across all categories
PRIN2	2.31	0.36	Downplays regulatory impediments, while emphasizing software development and integration costs
PRIN3	2.00	0.46	Downplays human resources and support services problems, while emphasizing financial costs
PRIN4	1.40	0.52	Downplays financial resources constraints and management problems, while emphasizing financial justification costs and support services problems
PRIN5	1.18	0.58	Emphasizes financial resources constraints and support services costs, and to a lesser extent inadequate market size
PRIN6	1.11	0.63	Emphasizes market size and evaluation uncertainties, while de-emphasizing financial resources
PRIN7	0.98	0.68	Emphasizes market size, worker resistance and benefits evaluation problems
PRIN8	0.75	0.72	Emphasizes labour and food composition regulatory problems; de-emphasises evaluation problems
PRIN9	0.68	0.75	Stresses operating costs and evaluation problems while de-emphasizing market size problems
PRIN10	0.66	0.78	Human resources mixed bag—stresses worker resistance while downplaying skill shortages
PRIN11	0.60	0.81	Strong on food composition regulations and operating costs; weak on labour policy regulations
PRIN12	0.58	0.84	Strong on small market size and worker resistance; weak on evaluation problems and food composition regulations
PRIN13	0.55	0.86	Stresses equipment costs very strongly
PRIN14	0.48	0.89	Stresses evaluation abilities, operation costs and support problems; downplays information gathering capabilities
PRIN15	0.45	0.91	Stresses information gathering capabilities while downplaying strategic priority
PRIN16	0.42	0.93	Stresses integration costs; downplays software development costs
PRIN17	0.38	0.94	Stresses environmental impact costs, while downplaying food safety and plant hygiene costs
PRIN18	0.35	0.96	Stresses skills shortages; downplays training problems
PRIN19	0.34	0.98	Support services mixed bag—stresses lack of technological services, while downplaying lack of technical support
PRIN20	0.29	0.99	Stresses outside financing problems; downplays cash flow problems
PRIN21	0.20	1.00	Stresses plant hygiene regulatory problems; downplays food safety regulatory problems

Table B4. Eigenvectors for Impediments to Adoption

Specific Impediment	***PRIN1***	***PRIN2***	***PRIN3***	***PRIN4***	***PRIN5***	***PRIN6***	***PRIN7***	***PRIN8***	***PRIN9***	***PRIN10***	***PRIN11***	***PRIN12***	***PRIN13***
Market size	0.15	0.16	0.04	0.11	0.28	0.51	0.43	0.09	-0.35	-0.18	0.04	0.46	-0.09
Uncertainty of benefits	0.19	0.16	0.14	0.09	0.18	0.32	0.40	-0.32	0.39	0.18	-0.20	-0.50	-0.07
Equipment costs	0.21	0.20	0.23	0.27	-0.16	-0.01	-0.02	0.14	-0.14	0.06	-0.18	-0.04	0.81
Software costs	0.23	0.22	0.19	0.22	-0.16	0.02	-0.29	-0.12	-0.29	0.28	-0.19	0.00	-0.37
Integration costs	0.22	0.27	0.21	0.24	-0.18	-0.08	-0.26	-0.01	-0.06	-0.03	0.09	0.03	-0.27
Operating costs	0.22	0.16	0.26	0.23	-0.01	-0.03	-0.05	0.13	0.55	-0.28	0.41	0.15	-0.06
Lack of outside financing	0.19	0.16	0.26	-0.39	0.32	-0.35	0.00	-0.02	-0.01	-0.02	-0.02	-0.06	0.00
Lack of cash flow	0.19	0.16	0.25	-0.37	0.36	-0.30	0.06	0.03	-0.16	0.01	0.01	0.06	0.01
Lack of scientific information	0.24	0.14	-0.26	-0.25	-0.11	0.20	-0.22	0.09	0.21	-0.14	-0.02	0.09	0.00
Low priority	0.20	0.18	-0.17	-0.36	-0.11	0.30	-0.14	-0.02	-0.01	0.39	0.19	0.17	0.13
Lack of capabilities to evaluate	0.25	0.12	-0.23	-0.30	-0.17	0.15	-0.12	0.02	0.14	-0.11	-0.25	-0.07	0.01
Skill shortages	0.26	0.04	-0.27	0.05	-0.18	-0.17	0.20	-0.26	-0.19	-0.44	0.14	-0.10	0.02
Training difficulties	0.27	0.04	-0.27	0.03	-0.20	-0.24	0.24	-0.21	-0.23	-0.08	0.08	-0.15	-0.05
Worker resistance	0.19	-0.04	-0.20	0.11	-0.15	-0.38	0.43	0.14	0.25	0.51	0.00	0.37	-0.04
Lack of technical support	0.16	-0.06	-0.32	0.30	0.46	-0.03	-0.26	-0.11	-0.05	0.21	-0.09	-0.02	-0.05
Lack of technical services	0.17	-0.01	-0.35	0.24	0.46	-0.07	-0.23	0.09	0.08	-0.08	0.11	-0.04	0.17
Labour regulations	0.25	-0.21	-0.01	0.02	-0.03	-0.03	0.09	0.65	-0.01	-0.17	-0.47	-0.15	-0.20
Food composition regulations	0.23	-0.28	0.07	-0.05	-0.03	0.16	0.04	0.35	-0.22	0.21	0.56	-0.43	-0.04
Safety regulations	0.24	-0.43	0.16	-0.03	-0.01	0.06	-0.05	-0.21	-0.03	0.06	0.08	0.07	0.09
Hygiene regulations	0.24	-0.41	0.17	-0.03	-0.03	0.04	-0.08	-0.29	0.00	-0.07	-0.12	0.14	0.11
Environment regulations	0.23	-0.39	0.14	-0.01	-0.01	0.05	-0.08	-0.11	0.14	-0.06	-0.12	0.24	-0.08

Table B4. Eigenvectors for Impediments to Adoption (continued)

Specific Impediment	***PRIN14***	***PRIN15***	***PRIN16***	***PRIN17***	***PRIN18***	***PRIN19***	***PRIN20***	***PRIN21***
Market size	0.07	0.10	0.09	-0.03	0.01	0.05	0.11	0.00
Uncertainty of benefits	-0.16	-0.04	0.03	0.01	0.00	-0.01	-0.06	-0.01
Equipment costs	0.01	0.08	-0.01	0.12	0.01	-0.08	0.03	-0.01
Software costs	-0.03	0.18	-0.48	-0.04	-0.03	0.29	0.06	0.00
Integration costs	-0.18	-0.15	0.70	-0.04	0.09	-0.12	-0.12	-0.02
Operating costs	0.32	-0.10	-0.29	-0.07	-0.09	-0.05	0.03	0.03
Lack of outside financing	0.02	0.02	0.07	-0.01	0.31	0.08	0.62	0.02
Lack of cash flow	-0.04	0.05	-0.10	0.05	-0.27	-0.12	-0.62	-0.03
Lack of scientific information	-0.45	0.48	-0.08	-0.11	-0.10	-0.36	0.12	-0.02
Low priority	-0.04	-0.62	-0.12	0.00	0.07	-0.03	0.00	0.05
Lack of capabilities to evaluate	0.58	0.22	0.24	0.08	0.04	0.35	-0.16	-0.05
Skill shortages	-0.15	-0.09	-0.22	0.07	0.54	0.03	-0.23	-0.04
Training difficulties	0.15	-0.13	0.05	0.04	-0.63	-0.15	0.30	0.03
Worker resistance	-0.05	0.19	0.08	-0.06	0.14	0.09	-0.07	0.02
Lack of technical support	0.35	0.03	-0.03	0.09	0.20	-0.50	-0.01	0.02
Lack of technical services	-0.29	-0.09	0.08	-0.08	-0.20	0.56	0.00	0.01
Labour regulations	-0.05	-0.34	-0.10	-0.15	0.02	-0.10	0.01	-0.04
Food composition regulations	0.05	0.26	0.05	0.12	0.08	0.03	-0.02	0.16
Safety regulations	0.04	0.01	0.03	-0.35	-0.02	0.00	0.02	-0.73
Hygiene regulations	0.02	0.00	0.06	-0.40	0.00	0.01	-0.07	0.66
Environment regulations	-0.16	-0.06	0.01	0.78	-0.07	0.05	0.06	-0.01

APPENDIX C: Negative Binomial Regression Results

Table C1. Determinants of Number of Technologies Used—Negative Binomial Regression (Establishment Weighted)

Variables	**Negative Binomial Regression**				
INTERCEPT	1.160***	0.898***	1.130***	1.313***	1.333***
Establishment size					
ESTSIZE2	0.278***	0.259***	0.262***	0.240***	0.252***
ESTSIZE3	0.591***	0.504***	0.556***	0.542***	0.494***
ESTSIZE4	0.826***	0.745***	0.788***	0.712***	0.718***
ESTSIZE5	1.122***	1.011***	1.068***	0.992***	0.980***
Nationality of control					
FOREIGN	0.165***	0.164***	0.154**	0.123**	0.159**
Production type					
PRODTYP2	0.136**	0.090	0.107	0.111*	0.101
PRODTYP3	0.140***	0.115**	0.117**	0.103**	0.064
Type of operation					
BATCH	-0.072	-0.082*	-0.075	-0.040	-0.016
Benefits					
LABREDUC	---	0.152***	---	---	---
PRODUCT	---	0.143***	---	---	---
SAFETY	---	0.169**	---	---	---
Impediments					
EQPCOST	---	0.150***	---	---	---
OPCOST	---	-0.101*	---	---	---
FINCOST	---	-0.105*	---	---	---
Net benefits					
NETBENE1	---	---	0.096***	---	---
NETBENE2	---	---	---	0.134***	0.119***
Past growth					
GROWTH	---	---	---	---	0.0002***
Industry characteristics					
CEREAL	0.506***	0.495***	0.488***	0.389***	0.385***
DAIRY	0.642***	0.584***	0.629***	0.565***	0.552***
FISH	0.138	0.162	0.132	0.060	0.091
FRUIT	0.543***	0.499***	0.511***	0.454***	0.401***
MEAT	0.473***	0.461***	0.486***	0.394***	0.396***
OTHER	0.441***	0.425***	0.429***	0.345***	0.358***
Summary statistics					
N	760	760	760	760	523
LL	-5356	-5297	-5332	-5243	-3548

*** significantly different from zero at the 1% level; ** significantly different from zero at the 5% level ;
* significantly different from zero at the 10 % level.

Table C2. Determinants of Functional Technology Adoption—Negative Binomial Regression (Establishment Weighted)

Variable	***PROCESSING***	***PROCESS CONTROL***	***QUALITY CONTROL***	***COMMUNICATIONS***	***PRE-PROCESSING***	***PACKAGING***	***DESIGN***
INTERCEPT	0.687***	0.277**	0.282**	.468***	0.237	0.314***	0.399***
Plant characteristics							
Establishment size							
ESTSIZE2	-0.067	0.195**	-0.001	0.177**	-0.002	-0.028	-0.263
ESTSIZE3	0.074	0.329***	0.074	0.283***	0.255**	0.167*	-0.384***
ESTSIZE4	0.084	0.474***	0.083	0.354***	0.282***	0.209**	-0.084
ESTSIZE5	0.293**	0.626***	0.080	0.545***	0.541***	0.360***	-0.097
Nationality of control							
FOREIGN	-0.124	0.020	0.118*	-0.027	0.089	-0.004	-0.210***
Production type							
PRODTYP2	-0.076	0.181***	0.072	0.051	-0.073	0.189***	-0.163
PRODTYP3	0.013	0.201***	0.084	0.034	0.009	0.106*	-0.182**
Type of operation							
BATCH	-0.092	0.064	-0.115**	-0.034	-0.016	0.038	0.042
Net benefits							
NETBENE	0.076***	0.082***	0.056***	0.048***	0.030	0.083***	0.092***
Industry characteristics							
CEREAL	0.073	0.097	0.053	0.250***	0.273	0.137	0.321***
DAIRY	0.581***	0.138	0.116	0.110	0.102	0.296***	0.274**
FISH	0.153	-0.143	-0.229**	0.099	-0.024	-0.015	0.201
FRUIT	0.420***	0.179*	0.085	0.157**	0.115	0.198**	0.191*
MEAT	0.286***	-0.049	-0.072	0.091	0.200	0.213**	0.083
OTHER	0.186*	-0.011	0.029	0.225***	0.059	0.174*	0.294***
Summary statistics							
N	532	526	343	565	339	466	213
LL	-2343	-1800	-911	-2064	-1000	-1595	-479

*** significantly different from zero at the 1% level; ** significantly different from zero at the 5% level ; * significantly different from zero at the 10 % level.

APPENDIX D: Survey Questionnaire

This appendix provides a copy of the actual questionnaire used in the survey.

SECTION A: General Questions

A1. Please indicate the countries in which your firm has any of the following operations.

Countries	Production Unit	R&D Unit
Canada		
U.S.A.		
Other foreign		

A2. Please indicate the geographic region of the head office of your controlling firm, or in the absence of a controlling firm, the head office of your own firm.

Region	
Canada	
U.S.A.	
Other foreign	

A3. Please indicate which of the following markets are served by the products produced in your plant.

Markets	
Regional Canadian markets	
National Canadian markets	
U.S. markets	
Other foreign markets	

A4. Does your plant substantially add to its workforce to meet seasonal peaks?

Yes	
No	

A5. Please indicate the maximum number of employees in your plant (including seasonal workers and contract workers) during the last year.

Number of employees	
Less than 20	
20 to 49	
50 to 99	
100 to 249	
250 or more	

A6. Is your plant inspected

Federally ?	
Provincially ?	
Locally ?	

A7. With respect to the products produced in your plant, please rate the importance of the following factors in your business strategy.

Factors	Importance					
	low			high		N/A
	1	2	3	4	5	
Markets & Products						
a) Maintaining current products in present markets						
b) Introducing new products in present markets						
c) Introducing current products in new markets						
d) Introducing new products in new markets						
Technology						
e) Using technology developed by others						
f) Improving existing technology/processes						
g) Creating new technologies/processes						
h) Accessing R&D facilities						
Production						
i) Using new materials						
j) Using existing materials more efficiently						
k) Increasing line speed						
l) Cutting labour costs						
m) Implementing computer controlled processes						
n) Using high quality suppliers						
o) Reducing energy costs						
p) Reducing waste disposal costs						
Management Practices						
q) Continuously improving quality						
r) Entering into strategic alliances/joint ventures						
s) Introducing innovative organizational structure (e.g. cross functional teams)						
t) Using information technology						
Human Resources Strategy						
u) Continuously training staff						
v) Introducing innovative compensation packages						
w) Recruiting skilled employees						

A8. Please indicate how many firms (whether or not based in Canada) offer products directly competing with yours in Canada.

	None		1 to 5		6 to 20		Over 20

If NONE, skip to B1.

A9. With respect to the products produced in your plant, please score your plant's competitive position relative to your main competitors selling in the Canadian market for each of the factors listed below.

Factor	Score (%)					
	1	2	3	4	5	DK
Products and Services						
a) Quality of products (goods/services)						
b) Customer services						
c) Range of products (goods/services)						
d) Flexibility in responding to customer's needs						
e) Frequency of introduction of new products (goods/services)						
Production Process						
f) Use of advanced manufacturing processes						
g) Cost of production						
h) Production management						
Innovation						
i) Investment in research and development						
j) Speed of adoption of new products and technologies						
Human Resources						
k) Investment in training						
l) Skill levels of employees						

Note: 1: very behind; 2: behind; 3: about the same; 4: ahead; 5: very ahead; DK = don't know.

SECTION B: Production

B1. What percentage of the shipments of your plant is accounted for by high volume products?

B2. Please indicate whether your plant is engaged in:

	(percentage of establishments)
Primary processing	
Secondary/value-added/further processing	
Both	

B3. Please provide the approximate number of major new product and process innovations you introduced in your plant in the last three years. Fill in numbers of innovations.

	Number of innovation
Product innovations Requiring process innovation	
Product innovations Not requiring process innovation	
Process innovations Not associated with product innovation	

B4. Please indicate, irrespective of whether you have a research and development (R&D) program, whether new products produced in your plant are introduced by:

	Yes	**No**
a) Purchasing the right to produce products		
b) Adapting, improving or modifying existing products		
c) Developing new products		

B5. Please indicate whether your firm is involved in any of the following R&D activities.

R&D Activity	**In Cda**	**Out Cda**	**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			

B6. Please indicate the objectives of your R&D program during the last five years. [Question is tabulated only for those establishments indicating in question B5 that they are involved in some R&D activity.]

Objectives	**Yes**	**No**
Creation of Original Equipment or Process Technologies		
a) In your firm		
b) With related (sister) firms		
c) With unrelated firms		
d) With public R&D institutions/universities		
Substantial Adaptation of Technology		
e) In your firm		
f) With related (sister) firms		
g) With unrelated firms		
h) With public R&D institutions/universities		
Minor Adaptation of Technology		
i) In your firm		
j) With related (sister) firms		
k) With unrelated firms		
l) With public R&D institutions/universities		
Creation of Original Products		
m) In your firm		
n) With related (sister) firms		
o) With unrelated firms		
p) With public R&D institutions/universities		
Adaptation of Existing Products		
q) In your firm		
r) With related (sister) firms		
s) With unrelated firms		
t) With public R&D institutions/universities		

SECTION C: Business Practices

Product Quality

C1. Are the following practices or techniques, aimed at enhancing quality, regularly used in your plant?

Practices/Techniques	Yes	No	N/A
a) Continuous quality improvement (CQI)			
b) Benchmarking			
c) Acceptance sampling			
d) Certification of suppliers			
e) Good manufacturing practices (GMP)			
f) Hazard analysis critical control points (HACCP)			
g) Food safety enhancement program (FSEP)			
h) Plant quality certification (e.g. ISO9000, American Institute of Baking)			
i) Other *(please specify)*			

Materials and Distribution Management

C2. Are the following practices, aimed at materials management, used by your plant or your firm in conjunction with your plant operations?

Practices	Yes	No	N/A
a) Materials requirement planning (MRP)			
b) Manufacturing resource planning (MRP II)			
c) Process changeover time reduction			
d) Just-in-time inventory control			
e) Electronic work order management			
f) Electronic data interchange (EDI)			
g) Distribution resource planning (DRP)			
h) Other *(please specify)*			

Product and Process Development

C3. Are the following product or process development techniques used by your plant or your firm in conjunction with your plant operations?

Techniques	Yes	No	N/A
a) Rapid prototyping			
b) Quality function deployment			
c) Cross-functional design teams			
d) Concurrent engineering			
e) Computer-aided design			
f) Continuous improvement			
g) Process benchmarking			
h) Process simulation			
i) Process value-added analysis			
j) Other *(please specify)*			

SECTION D: Operations and Technologies

D1. Please indicate whether the operations in your plant are primarily

	Continuous		Batch
	Fully automated		Semi-automated
	Flexible manufacturing system		Conventional manufacturing system

D2. For this question, please indicate the advanced technologies (owned or leased) that are currently being used for the benefit of your operation.

1. Do you use any advanced technologies for Processing?

1.1 Thermal Preservation	**Yes**	**No**	**N/A**
a) Aseptic processing/packaging			
b) Retortable flexible packages			
c) Infra red heating			
d) Ohmic heating			
e) Microwave or other high frequency heating			
f) Other *(please specify)*			
1.2 Non-Thermal Preservation			
a) Chemical antimicrobials			
b) Ultrasonic techniques			
c) High pressure sterilization			
d) Deep chilling			
e) Other *(please specify)*			
1.3 Separation, Concentration, Water Removal			
a) Membrane process			
b) Filter technologies			
c) Centifugation (e.g. ultracentrifuge)			
d) Ion exchange			
e) Vacuum microwave drying			
f) Water activity control			
g) Other *(please specify)*			
1.4 Additives/Ingredients			
a) Bio-ingredients			
b) Microbial cells			
c) Other *(please specify)*			
1.5 Other			
a) Electrotechnologies (e.g. electrodialysis, electroreduction)			
b) Microencapsulation			
c) Other *(please specify)*			

2. Do you use advanced technology for Process Control?

2. Process Control	Yes	No	N/A
a) Automated sensor-based equipment used for inspection/testing of materials/products			
b) Automated statistical process control			
c) Machine vision			
d) Bar coding for control of product flow in the plant			
e) Programmable logic controllers (PLC)			
f) Computerized process control			
g) Other *(please specify)*			

3. Do you use advanced technology for Quality Control?

3.1 Process Testing	Yes	No	N/A
a) Chromatography			
b) Monocional antibodies			
c) DNA probes			
d) Rapid testing techniques			
e) Other *(please specify)*			
3.2 Laboratory Testing			
a) Automated			
b) Other *(please specify)*			
3.3 Simulation			
a) Mathematical modeling of quality/safety			
b) Other *(please specify)*			

4. Do you use advanced technology for Inventory and Distribution?

4. Inventory and Distribution	Yes	No	N/A
a) Bar coding			
b) Automated product handling			
c) Other *(please specify)*			

5. Do you use advanced technology for Management/Information Systems/ Communications?

5. Communications	Yes	No	N/A
a) Local Area Network (LAN)			
b) Wide Area Network (WAN)			
c) Inter-company computer networks			
d) Internet (for marketing or promotional purposes)			
e) Internet (for procurement requirements, point-of-sale data, research, hiring, etc.			
f) Other *(please specify)*			

6. Do you use advanced technology for Materials Preparation and Handling?

6. Materials Preparation and Handling	Yes	No	N/A
a) Integrated electronically controlled machinery (e.g. AGVs)			
b) Individual, electronically controlled non-integrated machinery (e.g. robots)			
c) Electronic detection of machinery failure			
d) Other *(please specify)*			

7. Do you use advanced technology in Pre-processing activities?

7.1 Raw Product Quality Enhancement	**Yes**	**No**	**N/A**
a) Animal stress reduction (e.g. gas stunning)			
b) Bran removal before milling wheat			
c) Micro component separation			
d) Other *(please specify)*			
7.2 Raw Product Quality Assessment			
a) Electronic or ultrasonic grading			
b) Collagen, colour or P.S.E. probe			
c) Near infra red (NIR) analysis			
d) Colour assessment/sorting			
e) Electromechanical defect sorting			
f) Rapid testing techniques (e.g. residues, microbial)			
g) Other *(please specify)*			

8. Do you use advanced technology for Packaging?

8.1 Equipment	**Yes**	**No**	**N/A**
a) Non-integrated electronically controlled packaging machinery			
b) Integrated electronically controlled packaging machinery			
8.2 Preservation			
a) Modified atmosphere			
8.3 Advanced Materials			
a) Laminates			
b) Active Packaging			
c) Multi-layer			
8.4 Other			
a) Other *(please specify)*			

9. Do you use advanced Design and Engineering Technologies?

9. Design and Engineering	**Yes**	**No**	**N/A**
a) Computer Aided Design (CAD) and/or computer aided engineering (CAE)			
b) CAD output used to control manufacturing machines (CAD/CAM)			
c) Computer aided simulation and prototypes			
d) Digital representation of CAD output used in procurement activities			
e) Other *(please specify)*			

D3. Of the major technologies listed above, please rate the significance (in terms of economic impact) of the advanced technologies introduced into your plant in the last five years by functional area. [Question is tabulated only for those establishments using the technology being considered.]

Functional Areas	**1**	**2**	**3**	**4**	**5**	**N/A**
a) Processing						
b) Process control						
c) Quality control						
d) Inventory and distribution						
e) Information systems/communications						
f) Materials handling						
g) Pre-processing						
h) Packaging						
i) Design and engineering						

Note: 1: very minor; 2: minor; 3: medium; 4: major; 5: very major.

D4. Please indicate your plans to replace existing technologies with advanced technologies at this location over the next three years.

a) No plans	
b) Under consideration	
c) Minor upgrade (less than 25%)	
d) Major upgrade (25% to 74%)	
e) Total replacement (75% or more)	

D5. Please indicate whether the introduction of process technologies is done by:

Methods	**In Canada**	**Outside Canada**	**Neither**
a) Purchasing ready-to-use equipment, documents, blue prints, or designs *from sources*			
b) Acquiring and modifying existing technologies *from sources*			
c) Adapting technology acquired from unrelated firms *located*			
d) Developing new processes by units of your own firm *located*			
e) Developing new processes in conjunction with other firms *located*			

SECTION E: Skill Development

E1. Please indicate the educational attainment of the majority of your plant's employees (including seasonal workers and contract workers).

Group	Elementary or High School	College or Technical School	University	N/A
a) Production				
b) Supervisory				
c) Professionals				
d) Support staff				
e) Management				

E2. Do you provide training (in-house or outside) for your plant employees in the following areas when you implement advanced technology?

Type of Skills	Yes	No
a) Basic language/literacy skills		
b) Basic numeracy skills		
c) Computer literacy		
d) Problem solving skills		
e) Technical skills		
f) Leadership skills		
g) Quality skills		
h) Safety skills		
i) Interpersonal communication skills		
j) Other *(please specify)*		

SECTION F: Development of New Technologies

Sources of Ideas for New Technologies

F1. Please indicate which of the following sources play an important role in providing ideas for the adoption of new technologies (more than one may apply).

Sources	In Canada	Outside Canada	Neither
Internal Sources			
a) Head office			
b) Sister plants			
c) Research			
d) Development			
e) Design			
f) Production engineering			
g) Production staff			
h) Technology watch group			
i) Sales/Marketing			
j) Other			
External Sources			
k) Industrial research firms			
l) Consultants and service firms			
m) Publications			
n) Trade fairs, conferences			
o) Suppliers			
p) Customers			
q) Other producers in your industry			
r) Industry associations			
s) Universities			
t) Fed/prov research organizations			
u) Other			

F2. What importance does your firm give to the systematic collection or monitoring of information on the following?

Information on	1	2	3	4	5	N/A
a) New products						
b) New technologies						
c) New scientific developments						
d) Supply of skilled personnel						

Development of New Processes and new Technologies

F3. Please indicate which of the following are used by your firm to develop new technologies.

Sources	In Canada	Outside Canada	Neither
a) Own firm research unit			
b) Own firm develop. group			
c) Own firm production group			
d) Other firms' R&D/prod units			
e) Head office or related firms			
f) Suppliers			
g) Consultants			
h) Customers			
i) Government/universities			
j) Other producers in your industry			
k) Other *(please specify)*			

Acquiring Outside Technologies

F4. Please indicate which of the following sources are used by your firm to acquire new technologies.

Sources	In Canada	Outside Canada	Neither
a) Suppliers			
b) Customers			
c) Other producers in your industry			
d) Head office or related firms			
e) Government/universities			
f) Other *(please specify)*			

F5. Please indicate the method used to acquire technologies by source.

Method	Related Firm	Other Firm	Neither
a) Transfer agreements (e.g. licenses, patents, etc.)			
b) Transfer of skilled personnel			
c) Leasing or purchasing equipment			
d) Joint venture/alliances			
e) Mergers/acquisitions			
f) Reverse engineering			
g) Other *(please specify)*			

Implementation of New Technologies

F6. Please indicate which of the following personnel are used to incorporate new technologies into your plant.

Method	Own Firm	Other Firms	Neither
Professionals			
a) Science professionals			
b) Engineering professionals			
c) Computing professionals			
d) Other *(please specify)*			
Technicians			
e) Science technicians			
f) Engineering science technicians			
g) Computer assistants			
h) Computer equipment operators			
i) Electronic equipment operators			
j) Plant and machine operators			
k) Other *(please specify)*			

SECTION G: Competitive Environment

G1. For the industry in which your firm operates, how strongly do you agree or disagree with each of the following statements?

Statements	**1**	**2**	**3**	**4**	**5**	**N/A**
a) Imports offer substantial competition						
b) Consumer demand is easy to predict						
c) Competitors' actions are easy to predict						
d) The arrival of new competitors is a constant threat						
e) Products quickly become obsolete						
f) Production technology changes rapidly						
g) Competitors can easily substitute among suppliers						
h) Customers and/or suppliers can become competitors						

Note: 1: very low; 2: low; 3: medium; 4: high; 5: very high.

G2. For the industry in which your firm operates, please rate the intensity of competition in the following areas.

Intensity of Competition in	**1**	**2**	**3**	**4**	**5**	**Does not apply**
a) Customization of products						
b) Price						
c) Flexibility in responding to customers' needs						
d) Quality of products						
e) Customer service						
f) Offering a wide range of related products						
g) Frequently introducing new/ improved products						

Note: 1: very low; 2: low; 3: medium; 4: high; 5: very high.

G3. For the industry in which your firm operates, please rate the degree of importance that firms attach to the following areas.

Degree of Importance Attached to	**1**	**2**	**3**	**4**	**5**	**N/A**
a) Skilled personnel						
b) Use of advanced technologies						
c) Research and development						
d) Product innovation						

Note: 1: very low; 2: low; 3: medium; 4: high; 5: very high.

G4. How would you compare your production technology with that of your most significant competitors?

Competitors	**1**	**2**	**3**	**4**	**5**	**N/A**
a) Other producers in Canada						
b) Producers in the U.S.						
c) Producers in Europe						
d) Other foreign producers						

Note: 1: much less advanced; 2: less advanced; 3: same; 4: more advanced; 5: much more advanced.

G5. In which of the following functional technology areas do you feel your plant suffers significant technological disadvantages?

Functional Areas	Yes	No	N/A
a) Processing			
b) Process control			
c) Quality control			
d) Inventory and distribution			
e) Information systems/communications			
f) Materials handling			
g) Pre-processing			
h) Packaging			
i) Design and engineering			

G6. Are you a multi-plant firm?

Yes	
No	

G7. How would you compare your production technology with that of other plants also owned by your parent company in Canada or outside of Canada? [Question is tabulated only for multi-plant firms as identified by question G6.]

Related Plants	1	2	3	4	5	N/A
a) In Canada						
b) Outisde Canada						

Note: 1: much less advanced; 2: less advanced; 3: same; 4: more advanced; 5: much more advanced.

SECTION H: Results of Adoption

H1. Please indicate the importance of the following effects as the result of adopting advanced technology.

Results	1	2	3	4	5	N/A
Improvement in Productivity Due to						
a) Reduced labour requirements per unit of output						
b) Reduced material consumption per unit of output						
c) Reduced capital (plant and equipment) requirements per unit of output						
d) Reduced set-up time						
e) Reduced rejection rate						
Product Improvement						
f) Nutrition						
g) Taste/texture/appearance						
h) Shelf-life						
i) Consumer flexibility/convenience						
Changes in Plant Organization						
j) Firm rationalization of product lines among plants						
k) Decreased plant size						
l) Increased plant size						
m)More product lines						
n) Increased production flexibility						
o) Higher skill set required						
Improvement in Meeting or Exceeding Regulatory Requirements						
p) Worker health and safety						
q) Food safety						
r) Environmental protection						
s) Food composition						
Other						
t) Other *(please specify)*						

Note: 1: very low; 2: low; 3: medium; 4: high; 5: very high.

H2. Please indicate whether the introduction of advanced technologies in your plant has increased, decreased or had no effect on the following input requirements.

Inputs	increased	decreased	no effect
Raw Materials			
a) Need for uniform and consistent quality			
b) Need for timeliness or delivery			
c) Need for specific attributes (composition, size, etc.)			
d) Ability to substitute less expensive for more expensive raw materials			
e) Need to substitute imported for domestic raw materials			
Labour			
f) Ability to substitute less skilled personnel			
g) Need to substitute more skilled for less skilled personnel			

SECTION I: Impediments to Adoption

I1. Please indicate the importance of the following financial considerations and decisions as impediments to technology acquisition.

Impediments	1	2	3	4	5	N/A
Lack of Financial Justification Due to						
a) Small market size						
b) Degree of uncertainty associated with evaluation of benefits						
c) Cost of buying, leasing or developing new technology/equipment						
d) Costs to develop software						
e) Cost of integrating new technology with current technology						
f) Additional operating cost						
Lack of Financial Resources						
g) Lack of outside financing						
h) Lack of cash flow						
Other						
i) Other *(please specify)*						

Note: 1: very low; 2: low; 3: medium; 4: high; 5: very high.

I2. Please indicate the importance of the following factors as impediments to technology acquisition.

Impediments	1	2	3	4	5	N/A
Management						
a) Lack of procedures to acquire scientific and technological information						
b) Low strategic priority						
c) Lack of capabilities to evaluate new technology						
Human Resources						
d) Shortage of skills						
e) Training difficulties						
f) Worker resistance						
External Support Services						
g) Lack of technical support						
h) Lack of technological services (e.g. technical and scientific consulting)						
Government Policies/ Standards/ Regulations						
i) Labour						
j) Food composition						
k) Food safety						
l) Plant hygiene						
m) Environment						
Other						
n) Other *(please specify)*						

Note: 1: very low; 2: low; 3: medium; 4: high; 5: very high.

SECTION J : Role of Government

J1. Please rate the importance to you of the government programs/services that have directly benefited your plant in the last three years.

Programs/Services	1	2	3	4	5	N/A
a) Government training programs						
b) Government market information services						
c) Government export incentives/services						
d) Government information and technical assistance programs (e.g. IRAP)						
e) Government R&D grants						
f) Government investment grants						
g) Government strategic technologies programs						
h) Government research facilities						
i) Tax incentives for machinery and equipment						
j) Intellectual property protection						
k) Government procurement (purchase of goods/services)						
l) R&D tax credit						
m) Government hiring program for recent science graduates						
n) Other *(please specify)*						

Note: 1: very low; 2: low; 3: medium; 4: high; 5: very high.

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