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CHAPTER 8

FIRM PERFORMANCE IN THE CANADIAN FOOD PROCESSING SECTOR: THE INTERACTION BETWEEN ICT, ADVANCED TECHNOLOGY USE AND HUMAN RESOURCE COMPETENCIES

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Abstract

This chapter investigates the evolution of industrial structure in the Canadian food processing sector and its relationship to technological change. It uses a dataset combining advanced technology use that is derived from a 1998 special survey on advanced technology use in the food sector that is linked to data on firm performance derived from administrative records covering the period 1988-1997.

The chapter first examines the characteristics of firms (size, nationality, emphasis given to training, innovativeness) that adopt advanced technologies and then how the use of these technologies is related to plant performance (growth in productivity and market share). Plants that adopted more advanced technologies enjoyed superior productivity growth. Process control and network communications technologies are particularly important to productivity growth in the food-processing sector. Those plants that increased their relative productivity growth and used more advanced technologies saw their market share increase.

8.1 Introduction

The choice of a successful strategy is key to a firm's growth. One of the strategies that we have found to be related to growth is innovation (Baldwin, 1996, Baldwin and Johnson, 1999*a*). One successful innovation strategy involves the use of advanced technologies.

This chapter examines how an advanced technology strategy in the food-processing sector is related to superior firm performance. It builds on two previous streams of research. The first are the studies that examine the characteristics of firms that are more innovative, either in the sense of introducing new products or new processes, or in terms of introducing new technologies. The second is the research that examines the connection between innovation and firm performance. Our work in both these areas conditions our view of the forces that are operating to influence dynamic change in the business population.

Firms have choices to make with regards to the strategies that they follow. Some try to be more innovative than others. To be successful innovators, firms have to combine a number of competencies (Baldwin and Johnson, 1998, 1999*a*, 1999*b*). They have to develop the capabilities to innovate – either by investing in R&D or in their technological capabilities. But they also have to develop special capabilities on the human-resource side, and in marketing and finance.

Decisions on which strategic competencies are developed are then reflected in a firm's performance. Growth is a stochastic process that involves learning. Production opportunities are not unique and the growth of individual firms occurs in a world where each explores which advanced technologies and other strategies out of a set of many technological possibilities and strategies might be the most suitable to its circumstances. Firms adopt new, advanced technologies as they learn about their possibilities and experiment with the applicability of the new advanced technologies to their specific situations. Experimentation rewards some firms with superior growth and profitability. Market forces cull those firms that have made the wrong choices and reward those who have correctly chosen those policies that work.

This chapter replicates and expands upon earlier work that finds performance is related to technological choice (Baldwin, Diverty and Sabourin, 1995; Baldwin and Sabourin, 2001). In these papers, we find that manufacturing plants that had adopted advanced manufacturing technologies, in particular information and communications technologies (ICTs), experienced faster growth in productivity and in market share than those plants that had not managed to incorporate these advanced technologies into their plants.

These findings, based on Canadian empirical evidence, are confirmed by research that covers the experience of other countries. Stoneman and Kwon (1996), Rischel and Burns (1997), Ten Raa and Wolff (1999), Van Meijl (1995), and McGuckin *et al.* (1998) find a positive relationship between advanced technology use and superior firm performance.

Many other papers focus on a narrow range of ICTs. In our papers, we ask not only how advanced communications systems affect performance but also how a range of other advanced manufacturing technologies does so. The first of these two papers (Baldwin, Diverty and Sabourin, 1995) examines this connection in the 1980s; the second paper (Baldwin and Sabourin, 2001) does so for the 1990s.

Here, we examine a specific sector – the food-processing sector – and extend our earlier work that focused on all manufacturing industries in two ways. First, by focusing on a specific sector, we are able to examine a far more extensive list of technologies. The earlier work that focused on all of manufacturing had to focus on a core set of about 20 technologies that were common across a wide range of industries. Here we use *The Survey of Advanced Technology in the Food Processing Sector* (see Baldwin, Sabourin and West, 1999) to examine a group of more than 60 technologies. Second, we focus on how groups of technologies interact. Imbedded in the list of technologies examined are a number of industry-specific technologies (infra-red heating) plus most of the technologies previously examined. In particular, information and communications technologies (ICT), which were found in the two previous studies to be associated with growth, are included. This enables us to examine not only whether ICT matters, but also which other technologies they complement.

The focus of this chapter is on technology choice and its consequences for performance. While R&D is often stressed as a key activity for innovators, technological capabilities are just as important. Baldwin, Hanel and Sabourin (2000) demonstrate that the probability of becoming an innovator increased by about 20 percentage points if a firm goes from placing little emphasis on technology to a much greater emphasis on technology, while performing R&D has about a 30 percentage point effect. Baldwin and Hanel (2003) stress that a technological focus is a unique way, often quite separate from R&D, by which firms develop innovations.

While our focus is on technology, we recognize that other factors may impact on performance. We therefore also examine the relative importance of other factors – such as whether a firm is conducting R&D, developing a cadre of skilled workers, or has adopted specific advanced business practices.

This chapter first asks what factors are related to technology use. The chapter then studies the effect of technological choices on plant performance – using measures such as growth in market share and growth in relative productivity (the ratio of a plant's labour productivity to the average labour productivity of its industry). It examines the relationship between the use of advanced manufacturing technology – such as programmable controllers, aseptic processing, and local and wide area networks – and these two measures of plant performance. It investigates whether plants using advanced technologies are selected for survival and growth by the search and culling process that is associated with competition.

The economic performance data used in the study come from a longitudinal file developed from the *Annual Survey of Manufactures*, which includes data on employment (production and non-production), labour productivity (value added per worker), wages and salaries, shipments, and value added for Canadian food-processing plants during the period 1988 to 1997. These data allow us to develop an objective measure of actual plant performance (growth in market share and relative productivity), as opposed to subjective measures derived from an evaluation by the survey respondents of their performance relative to competitors. The objective economic performance data were linked to data on advanced technology use at the plant level derived from the *1998 Survey of Advanced Technology in the Canadian Food Processing Industry*. In what follows, we will be using plants as the unit of analysis. The results are weighted so that they represent the population of plants in the food-processing sector.

8.2 Market turnover

Within industries, there is a considerable amount of turnover, as growing firms replace declining firms. Previous studies (Baldwin, 1995; Baldwin, Diverty and Sabourin, 1995; Baldwin and Sabourin, 2001) have described the amount of change taking place over a ten-year period within the manufacturing sector. Growth and decline also takes place in the food-processing sector as some plants wrest market share away from others. During the period 1988-97, some 32% of market share was transferred, on average, from those losing market share to those gaining market share measured at the four-digit industry level.[1] Growing continuers accounted for 20 percentage points of the gain, while entrants accounted for the remaining 12 percentage points. Decline in market share, on the other hand, came from declining continuers (13 percentage points) and exits (19 percentage points).

One of the factors that facilitate the development of competitive advantage is productivity growth. Firms that gain productivity relative to their competitors can put that advantage to work by dropping prices or increasing quality and thereby gain market share. There is also substantial change taking place in relative productivity of different plants in the food-processing sector.

A substantial percentage of continuing plants shifted position with regards to relative labour productivity between 1988 and 1997. More than half of the continuing plants that were in the lowest quartile in 1988 shifted up at least one quartile by 1997, while half shifted down out of the top quartile. The movement was even higher for the middle two quartiles, with only a third of plants still remaining in the same quartile in which they had started.

Changes in relative productivity and changes in market share are related. The relative labour productivity of plants that gained market share over the period was lower than that of decliners at the start of the period. Opening-period success with regards to relative productivity is not a good indicator of growth in market share over a subsequent period. But, by the end of the period, those plants gaining market share simultaneously managed to increase their relative productivity. By 1997, their relative productivity was well above that of the declining group. The market rewards those who have managed to improve their labour productivity with an increase in market share.

All of this suggests that there is a close relationship between changes in relative productivity and market-share growth – but that the relationship is one that is best investigated by examining the growth in market share over a period and the differences in characteristics that have emerged by the end of the period. The market rewards correct choices – but the evidence for this emerges only by the end of the period studied.

8.3. Data source for advanced technology use

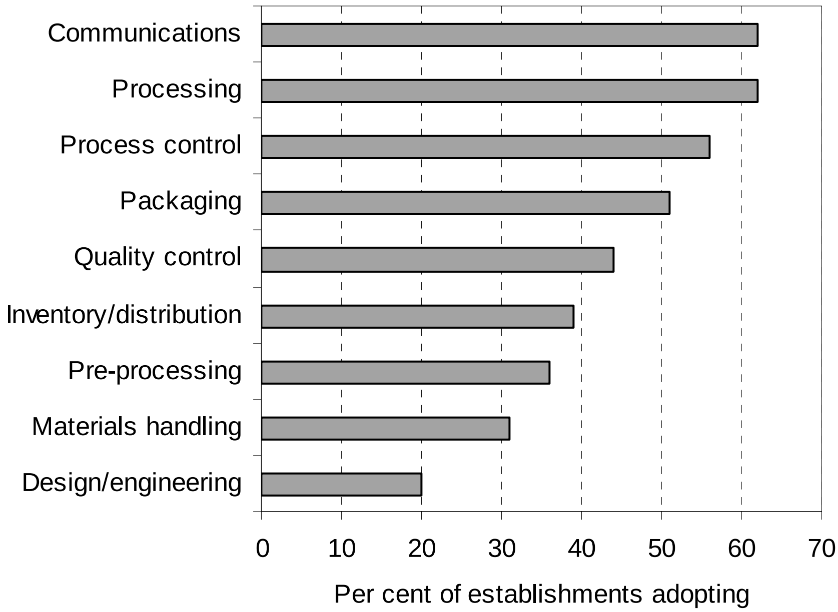
We focus, in this chapter, on the adoption of a list of advanced technologies developed specifically for the Canadian food processing sector – a two-digit SIC manufacturing industry. The survey from which the data on technology used were taken is based on a frame of Canadian food processing establishments drawn from Statistics Canada’s Business Register. The sample was randomly drawn from a population of food processing establishments that was stratified by four-digit SIC industry, size and nationality of ownership. Excluded from the target population were food-processing establishments with fewer than 10 employees. The overall response rate to the survey was 84%.

1. Industry structure is measured at the establishment level (SIC-E).

The survey covered questions about advanced technology used, general firm and establishment characteristics, about skill development, the use of various business practices, as well as questions about the benefits and obstacles to the adoption of advanced technologies (see Baldwin, Sabourin and West, 1999).

Sixty advanced technologies covering nine functional areas are listed on the survey. These sixty technologies are grouped into nine functional areas: processing, process control, quality control, inventory and distribution, information and communications systems, materials preparation and handling, pre-processing, packaging, and design and engineering. Within each of these areas were questions on the use of up to fourteen specific individual technologies. For example, within processing, plant managers were asked whether they used five different types of thermal preservation technologies, four different types of non-thermal preservation technologies, six different types of separation, concentration and water removal technologies, and two different types of additives.

Figure 8.1. **Advanced technology use in Canadian food processing**



In terms of broad functional technology categories, adoption rates were greatest for network communications and processing technologies, with 62% of food-processing plants adopting at least one technology from each of these two areas (Figure 8.1). Communications technologies include local and wide area networks, while processing includes the likes of advanced filter technologies, thermal preservation techniques, and the use of bio-ingredients. Process control and packaging are next, both with adoption rates of more than fifty percent. Programmable logic controllers and computerized process control were the most widely-used process control technologies, while the use of multi-layer materials and laminates were the most popular advanced packaging technologies.

Among ICTs, local area networks top the list at 43%, followed closely by inter-company computer networks at 37%. Being able to communicate and pass information within different parts of an organization and between different organizations is essential for doing business in today's economy. The fact that these two technologies have the highest adoption rates of all confirms the importance of ICTs in the workplace today.

8.4 Model specification

In order to meet their objectives, firms have a wide array of strategies from which they choose. One of those strategies is what we refer to as an advanced technology strategy. But in order to implement this technology strategy, a set of complementary competencies like human-resource strategies needs to be put in place. The successful use of technology will depend on the existence of these complementary competencies, but also on the nature of the industry environment in which the firm finds itself. For example, firms in a more competitive environment may behave differently from firms in a less competitive environment.

Three separate equations are estimated. The first examines technology use. The second equation estimates the correlates of productivity growth. The third investigates the correlates of market-share growth. The regressions that were estimated are:

1. $\text{Tech} = \alpha_0 + \alpha_1\text{*Size88} + \alpha_2\text{*Foreign} + \alpha_3\text{*R\&D} + \alpha_4\text{*Compet} + \alpha_5\text{*Practices} + \alpha_6\text{*Compenv} + \alpha_7\text{*Strategies} + \alpha_8\text{*Innov} + \alpha_9\text{*Industry}$

2. $\text{Prodgrth} = \beta_0 + \beta_1\text{*Tech} + \beta_2\text{*Size88} + \beta_3\text{*Foreign} + \beta_4\text{*}\Delta\text{Capint} + \beta_5\text{*Labprod88} + \beta_6\text{*R\&D} + \beta_7\text{*Compet} + \beta_8\text{*Practices} + \beta_9\text{*Compenv} + \beta_{10}\text{*Strategies} + \beta_{11}\text{*Innov} + \beta_{12}\text{*Industry}$

3. $\text{Shargrth} = \gamma_0 + \gamma_1\text{*Tech} + \gamma_2\text{*Size88} + \gamma_3\text{*Foreign} + \gamma_4\text{*Labprod88} + \gamma_5\text{*}\Delta\text{Labprod} + \gamma_6\text{*Mktshr88} + \gamma_7\text{*R\&D} + \gamma_8\text{*Compet} + \gamma_9\text{*Practices} + \gamma_{10}\text{*Compenv} + \gamma_{11}\text{Strategies} + \gamma_{12}\text{*Innov} + \gamma_{13}\text{*Industry}$

where:

TECH measures the number of advanced technologies used by the establishment.

PRODGRTH measures the growth in relative labour productivity of a plant.

SHARGRTH MEASURES THE GROWTH IN market *SHARE OF A PLANT*.

SIZE88 measures opening-period employment size of the plant.

FOREIGN captures whether or not an establishment is foreign owned.

ΔCAPINT captures changes in the capital intensity of a plant through changes in profitability.

ΔLABPROD measures changes in relative labour productivity over time.

LABPROD88 measures opening-period labour productivity levels.

MKTSHR88 measures opening-period market share.

R&D captures whether or not an establishment is an R&D performer.

COMPET measures the number of competitors a firm faces.

PRACTICES measures the use of advanced business and engineering practices.

COMPENV measures the intensity of competition within an industry.

STRATEGIES measures the competencies of a firm.

INNOV measures the innovative characteristics of a firm.

INDUSTRY captures industry effects.

For equation 1, the technological capabilities of the firm are hypothesized to be related to certain intrinsic characteristics of the firm such as foreign ownership, to the activities in which the firm is engaged such as innovation, and to the competitive environment in which it is placed.

In equation 2, we estimate the effects of different plant characteristics on relative productivity growth. We focus first on whether plants with higher relative productivity growth are those using advanced technologies. But we are careful to avoid being biased towards technological determinism. Other characteristics of a firm may also influence productivity growth. In particular, some of the same characteristics that influenced technological choice may have an additional impact on productivity growth. For example, foreign ownership may not only be related to whether more advanced manufacturing technologies are used, but it may have an independent effect if multinationals are more efficient in other domains than just technology acquisition.

We relate performance over a period (1988-97) to advanced technology use at the end of the period (1998). Technology use at the end of a period is just the sum of technology use at the beginning of the period plus changes in technology use over the period. As such, we are postulating that performance over any period is posited to be a function of both advanced technology use at the beginning of the period and changes during the period.

In equation 3, we ask whether those plants with growth in relative labour productivity also have a higher growth in market share. As firms improve their relative productivity, this superior performance can be reflected in either price reductions or quality improvements. In either case, market share should improve. In addition to the impact of productivity growth on market-share growth, we hypothesize that other plant, firm and environmental characteristics may affect market-share growth.

It may be the case that productivity growth and advanced technology use are endogenous variables, that is, they are each correlated with the error term. The degree to which this is true will depend on the lag structure inherent in the effect of technology use on performance. If the effects of technology use on firm performance are felt with a relatively long lag, then performance during a period will be mostly a function of technology use at the beginning of the period, and less a function of additions of technology during the period. As such, end period technology use will be little affected by productivity growth over the preceding period.

We examine the issue of possible endogeneity using the Hausman (1978) test, and reject the existence of simultaneity between productivity growth and technology use. As a result we employ ordinary least-squares regression techniques for the growth in productivity equation.

In equation 3, we see productivity growth driving market-share growth. While there may be a feedback effect from market-share growth to productivity growth (for example, that runs from market-share growth to increased profitability to increases in the purchases of technology), we believe that lags in this process make simultaneity unlikely. We examined the existence of this possibility by running two-stage least squares regressions for both equations two and three. When market share was included in the productivity growth equation, it was found to be insignificant[2] and corrections for endogenous productivity growth in equation three had no significant effect on the parameter estimates produced by ordinary least squares. We therefore report the results of the latter technique here.

Finally, it should be noted that both equations two and three are in their first-difference form because we are naturally interested in the growth of performance over time. By taking first differences, we coincidentally remove the problem of fixed effects that may exist in the productivity or market share equations expressed in levels, if these effects should happen to remain unchanged over time. But to the extent that they do change, we may still have a specification problem in both equations. However, our inclusion of a large number of characteristics and activities of the firm in both equations 2 and 3 partially serves the function of correcting for the remaining problem of changing fixed effects. The coefficients on these variables will be zero if the fixed effects related to these variables are unchanging.

8.5 Technology use

8.5.1 Variables

8.5.1.1 Technology use

Technology use in this study is measured first as the number of advanced technologies that had been adopted. But this method does not allow us to effectively measure how different technologies are being used in combination, one with another.

Principal component analysis was also used to examine how different combinations or dimensions of technology use is related to firm performance. Interpretation of the resulting principal components is provided in Table A8.1 of Annex A of this chapter.[3] For example, the first principal component jointly captures the use of advanced process control, information and communications and packaging technologies. The second principal component captures the combined use of advanced processing technologies of all types. But at the same time it represents plants in which advanced packaging machinery, robots and the use of CAD output for procurement are not important.

The first principal component, which explains 14% of the variance in the original set of variables representing each of the 60 technologies, captures the use of advanced process control, information and communications, and packaging technologies.

8.5.1.2 Plant and firm characteristics

Plant size is included to capture several factors. First, large plants are likely to have more functions within them and therefore a higher probability of needing more advanced technologies. Second, large plants tend to invest more per dollar of sales in new equipment and capital are therefore more likely to spend part of their investment on advanced technologies. Third, larger plants are also

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2. We note that we do not rule out the possibility of simultaneity. But the data used herein do not allow us to discern its impact. Part of the reason for the insignificance of market-share growth in the relative productivity growth equation using the two-stage approach is the low explanatory power of the equation that predicts market-share growth. Market-share growth is a stochastic process and is difficult to predict in the best of circumstances. Our choice then of the methodology adopted here is as much a result of our priors on the nature of the lag process as a result of definitive statistical tests on endogeneity.

3. For more detail, see Baldwin, Sabourin and Smith (2002).

more likely to have the superior financial and informational capabilities needed to ingest new advanced technologies. Employment data are used to measure size.

Nationality of control of an establishment is included since multinational firms are seen to play an important role in the global diffusion of advanced technologies (Caves, 1982). The advantages of multinational enterprises are typically related to their size, expertise and financial resources. Nationality of control 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.

Size is often used as a proxy for scale effects. But it is also a proxy for differences in the internal capabilities of firms. The largest firms at any point in time contain a large group that are more competent and that have recently grown. Competencies of firms are rarely included in economic studies of the innovation process,[4] despite the fact that firms build up sets of competencies that are important for their overall growth and success. Baldwin and Johnson (1998) concluded in their study of small and medium sized businesses that the more successful innovative firms placed more emphasis on marketing, finance, production and human-resource competencies than less-innovative firms. Technologically advanced firms are among the most innovative and, therefore, might be expected to build up these types of competencies in order to incorporate new technologies into the production process.

Whether a firm will be able to adopt new advanced technology should depend on whether a firm has developed a number of specialized competencies – relating to organisational structure, culture, and the capabilities of employees. To construct a set of measures that capture a variety of competencies that we have shown elsewhere to be related to whether a firm is capable of innovation (Baldwin and Johnson, 1998), we use a question on the food-processing survey that asks respondents to rate the importance of a set of factors, ranging from management to marketing to human-resource strategies. Firms rank the importance they gave to various marketing, technology, production, management and human-resource strategies on a five-point Likert scale, ranging from 1 (low importance) to 5 (high importance).

Three competency variables are constructed that are based on the firms' responses to this set of questions. Responses to three questions are used to construct a *market strategy* variable. The questions measure the importance to the firm of introducing new products in present markets, introducing current products in new markets, and introducing new products in new markets. Similarly, a *technology strategy* variable is constructed using the responses to three other questions – the importance of using technology developed by others, of developing new technology, and of improving existing technology. Finally, *management and human-resource strategies* were combined into a single category. Six questions were used to construct this variable. They measure the importance to the firm of continuously improving quality, of introducing innovative organizational structure, of using information technology, of continuously training staff, of introducing innovative compensation packages, and of recruiting skilled workers.

The scores given to these strategy variables by a firm are taken here to represent underlying competencies in the firm. We use principal factor analysis to represent these underlying competencies. Two factors were constructed and used for each of the three competency variables (see Annex B of this chapter).

4. For an exception, see Baldwin and Hanel (2003).

Also driving the need for advanced technologies are certain activities in which a firm may be engaged. For example, firms employ a variety of business and engineering practices that require advanced technologies if they are to be effective. Some, such as hazard analysis critical points (HACCP) and food safety enhancement programs (FSEP), are aimed at enhancing the quality of the products produced by the firm. Others are used to manage the materials handled by the firm. Materials requirement planning and just-in-time inventory are two examples of this type of practice. A third set includes techniques geared to increasing the speed, efficiency and effectiveness of product and process development. Examples include rapid prototyping and concurrent engineering. Each of these activities requires or is facilitated by the use of advanced technologies.

Previous studies (Gordon and Wiseman, 1995; Baldwin and Sabourin, 2000) find that the adoption of such practices, particularly those devoted to product and process development, provide firms with a comparative advantage and an increased likelihood of being innovative.

Three binary variables are constructed to capture the effects of using advanced practices. The first binary variable captures whether a plant uses practices aimed at quality enhancement; the second, whether it uses practices targeted for materials management; the third whether it uses practices aimed at product and process development.

Each of the three binary variables takes a value of one if a firm uses any of the practices listed within the group, and a value of zero otherwise.

Eight practices are listed on the survey questionnaire relating to quality enhancement – continuous quality improvement, benchmarking, acceptance sampling, certification of suppliers, good manufacturing practices, hazard analysis critical control points, food safety enhancement program and plant quality certification.

Seven practices pertain to materials management – materials requirement planning, manufacturing resource planning, process changeover time reduction, just-in-time inventory control, electronic work order management, electronic data interchange and distribution resource planning.

Nine practices are listed for product and process development – rapid prototyping, quality function deployment, cross-functional design teams, concurrent engineering, computer-aided design, continuous improvement, process benchmarking, process simulation and process value-added analysis.

Finally, the innovative stance of a firm is hypothesized to affect technology adoption. Innovative firms are more likely to use advanced technologies because the latter are often associated with the introduction of either new products or new processes (Baldwin and Sabourin, 2001). The innovative stance of the firm is measured in two ways in this study – first, with a variable that captures the extent to which innovations are being produced; second, with a variable that captures whether R&D is being performed.

Innovation characteristics are captured using a taxonomy that classifies firms into one of five mutually exclusive types – process specialized innovators, product specialized innovators, combined innovators, comprehensive innovators and non-innovators. Process specialized innovators are innovators that specialize in process innovations. Product specialized innovators are innovators that primarily produce product innovations. Combined innovators are establishments that introduce some combination of process innovation and product innovation, either with or without associated process innovation. And comprehensive innovators are innovators that introduce innovations of all types. Five binary variables were constructed to capture the innovator type.

To capture related aspects of an innovation program, a binary variable is also included indicating if a plant reported that its parent firm performs R&D. Contrary to the innovation variables that capture whether there any outputs from the innovation process, this variables captures inputs to the innovation process. A firm may not have any innovative outputs despite having devoted resources to R&D. For this reason, both the innovation and R&D variables are used here.

8.5.1.3 Industrial environment

Technology use might be related to the competitive environment faced by a firm. Firms involved in fiercely competitive markets could have more pressures placed upon them to adopt technologies.

Competition is measured in two ways in this study. First, it is measured by numbers of competitors. Plants are assigned to one of three competition groups according to the number of competitors they face – five or fewer, six to 20, or more than 20 competitors. Three binary variables are used to capture these competitive categories.

An alternative approach is also pursued. Plant managers are asked in the food processing survey to evaluate the importance to their industry of a set of factors that together determine the competitive environment faced by their plant – whether competition from imports is important; whether new competitors pose a constant threat; whether production technology changes rapidly; whether consumer demand is hard to predict; whether competitors are unpredictable; whether products quickly become obsolete; whether competitors can easily substitute among suppliers; and whether customers or suppliers can easily become competitors.

Scores on these categories are summed across all eight statements. High aggregate scores suggest a highly competitive environment, while low aggregate scores suggest just the opposite.

Finally, binary variables are included to control for industry effects. Seven sub-industries of food processing were used – bakery, cereal, dairy, fruit and vegetables, fish, meat, and other food products.

8.5.2 Empirical results for technology use

The results of the OLS regression that measures technology use by numbers of technologies adopted are presented in Table 8.1. All regressions are weighted and are estimated against an excluded plant that is Canadian-owned, does not perform R&D, and is in the bakery industry.

The number of technologies that are used is a positive function of both size and of nationality. As has been found repeatedly (Baldwin, Diverty and Sabourin, 1995; Baldwin and Sabourin, 1995; and Baldwin, Sabourin and West, 1999), larger plants use more advanced technologies than small plants.

Table 8.1. **Regressions for technology use (establishment weighted)**

	Model 1	Model 2	Model 3
Intercept	-3.80***	-4.21***	-1.72*
Plant size			
Employment Size-1988	0.017***	0.016***	0.014***
Nationality of control			
Foreign	1.81***	1.54**	1.22*

(continued on next page)

Table 8.1. **Regressions for technology use (establishment weighted)** *(continued)*

	Model 1	Model 2	Model 3
Innovation			
Process specialised	.	1.92**	1.32
Product specialised	.	0.96	0.77
Combined	.	2.67***	2.29***
Comprehensive	.	3.83***	3.38***
R&D			
Ongoing R&D performer	1.09**	0.45	0.11
Competition			
6-20 competitors	1.06**	0.71	0.49
Over 20 competitors	1.12**	0.96*	0.73
Business practices			
Product quality	1.94***	1.42*	0.37
Management	2.54***	2.52***	2.15***
Product/process development	3.24***	2.78***	2.54***
Firm strategies			
Technology			
– Factor 1	.	.	0.78***
– Factor 2	.	.	0.16
Marketing			
– Factor 1	.	.	-0.10
– Factor 2	.	.	-0.18
Management/human resources			
– Factor 1	.	.	0.45*
– Factor 2	.	.	-0.38**
Industry			
Cereal	1.53**	1.92***	1.71***
Dairy	4.43***	4.31***	4.10***
Fish	1.45*	1.46*	1.22
Fruit & vegetables	2.12***	2.34***	2.44***
Meat	3.17***	3.19***	3.11***
Other	2.30***	1.98***	1.83***
Summary statistics			
N	538	538	538
F(degrees of freedom)	F(14,523) = 26.90	F(18,519) = 23.27	F(24,513) = 19.07
R^2	0.38	0.43	0.46

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

We also confirm the finding that foreign plants are more likely to use more advanced technologies, even after for controlling for their larger plant size (Baldwin, Rama and Sabourin, 1999).

Firms that are more innovative are more likely to use advanced technologies, which confirms the findings of the *1993 Survey of Innovation and Advanced Technology* that many firms that introduce innovations adopt new advanced manufacturing technologies at the same time (Baldwin and Hanel, 2003). Performing R&D is positively related to technology use, though this variable becomes insignificant once the innovation variables are included. The categories of innovation that are positively related to the use of advanced technologies all involve some aspect of process innovation.

Two of the groups of business practices are positively and significantly related to advanced technology use, after controlling for firm competencies. Certain activities – managing materials and product/process development – drive the adoption of advanced technologies. Product quality practices are positively correlated to technology use but their significance is greatly reduced when innovation is included. Innovation and quality improvement are closely related.

Most of the underlying characteristics are found to be insignificant once the other controls are included. Not surprisingly, adopting a technological bent (developing new technologies and improving existing technologies) matters. But so does the second factor under the management and human-resource group. The results show that using innovative compensation packages, information technology and innovative organizational structures is associated with the use of advanced technologies.

8.6. Productivity growth

8.6.1 Description of variables

Productivity growth is hypothesized to be a function of the technological profile of the industry. We capture advanced technology use in two ways. In the first case, we employ a measure of intensity of use – the number of technologies an establishment has adopted. As there are 60 advanced technologies listed on the survey, this is a variable ranging from zero to 60.

In the second case, we employ a measure of the different combinations of technologies being used. To measure different combinations of advanced technology use, we employ principal component analysis, which was discussed in Section 4.

Productivity growth is also likely to be a function of changes in capital intensity. Since advanced technology use probably increases with increases in the capital intensity of a plant, our measure of technology use may simply capture capital intensity. We would also like to know whether advanced technology use still matters after capital intensity has been taken into account. For then it is not so much the amount of capital employed, as the type of capital (advanced or otherwise) that matters. To correct for capital intensity, the increase in a plant's relative profitability (its profit/sales ratio) is included.

Productivity growth is also postulated to depend on productivity in the initial period in order to allow for regression-to-the-mean. Previous studies (Baldwin, 1995; Baldwin and Sabourin, 2001) have reported that plants tend to regress to the mean over the period.

Finally, we include the same set of firm characteristics – nationality, competencies, innovation intensity, and competitive environment – that were used in the technology equation. Our use of this variable allows us to test whether productivity growth depends not just on technology but also on a wider range of firm characteristics.

Nationality is included since previous work has found that labour productivity growth in foreign-controlled plants has been higher than in the domestic sector in the 1980s and 1990s (Baldwin and Dhaliwal, 2001).

Competencies are included to test whether the underlying characteristics of firms that are related to technology use also affect the amount of productivity growth that is generated. The inclusion of these variables not only provides us with insight into the types of competencies that are associated with productivity growth, but it also helps to reduce the fixed-effects econometric problem. The econometrics literature has spent considerable effort worrying that equations such as the ones we are trying to estimate will yield biased estimates of the parameters attached to the independent variables if there are omitted fixed effects at the plant level that are correlated with the included variables. Previous studies have found advanced technology adoption is correlated with R&D activity, innovation, and the use of advanced business and engineering practices. Because of this, a regression that includes advanced technology use, but not any of the firm characteristic and activity variables, risks attributing any effect due to intrinsic competencies and activities to the adoption of advanced technology. The correlation between technology use and productivity growth may simply reflect the fact that superior firms, in addition to making more use of advanced technologies, do a host of other things that influence growth as well (see McGuckin *et al.*, 1998). The inclusion of several measures of firm characteristics and activities hopefully serves to alleviate this problem.

Previous studies (Lichtenberg and Siegel, 1991; Hall and Mairesse, 1995; Dilling-Hansen *et al.*, 1999) indicate that R&D has a positive effect on productivity. In this study, we are also interested in knowing whether R&D activity and innovation affect productivity performance after the technology mix has been taken into account.

Productivity growth might also be related to the competitive environment faced by a firm. Firms involved in fiercely competitive markets might be expected to have more gains in productivity than those firms in a much less competitive environment. For this reason, our measures of competitive environment are included.

8.6.2 Empirical results for growth in labour productivity

The results for productivity growth are presented in Table 8.2. Interpretations of the principal component results for the technology variables are provided in Table 8.3.

Growth in relative labour productivity is positively and significantly related to the number of advanced technologies used (results not reported here) and to six of the technology principal components. Establishments that emphasize the joint use of advanced information and communications systems, process control, and packaging technologies are more likely to enjoy productivity growth, according to the coefficients attached to the first principal component (Tech1). ICT systems then are critical to processing control technologies.

Plants, for which the use of advanced pre-processing and process control technologies together are important, and where advanced packaging and thermal preservation together are not (Tech4), are also more likely to undergo growth in productivity. Process control technology includes the likes of programmable logic controllers, computerized process control and sensor-based inspection equipment. Pre-processing technologies are technologies used for raw product quality enhancement and raw product quality assessment, including bran removal, micro separation and electronic grading. In an industry concerned with product regulations governing food quality and safety, the use of advanced technologies dedicated to minimizing spoilage and wastage can lead to gains in productivity.

The coefficient attached to the seventh principal component (Tech7) is also highly significant. This component is negatively related to productivity growth, which means that plants that emphasize advanced separation processing techniques, sophisticated testing techniques and the use of advanced packaging methods, while de-emphasizing information and communications systems, thermal preservation heating and design and engineering, are more likely to be associated with productivity growth.

Three other of the top fifteen principal components (Tech5, Tech6 and Tech15) are significant at the 10% level. All three are negatively related to productivity growth. In the case of Tech6, this means that plants favouring information and communications technologies and rapid testing techniques, and not statistical process control, machine vision, product handling and high-pressure sterilization, are more likely to achieve growth in productivity.

In summary, information and communication technologies have been positively linked to productivity growth through a number of different components. ICT is important, but in combination with other technologies. Adoption of technologies like local and wide area networks, and inter-company computer networks are positively associated with higher productivity growth throughout the 1990s. Transfer of information both within an organization and between organizations is closely associated with growth in productivity, lending support to the view that the adoption of ICTs is important to productivity growth.

There is a large, significant effect of the growth in capital intensity on the growth in relative labour productivity that is consistent with the literature.

The coefficient on the starting-period relative productivity variable is negative and highly significant. There is regression-to-the-mean in relative productivity. Plants that started the period with a high relative labour productivity saw their relative labour productivity decline. Equivalently, those plants that were below average in terms of relative labour productivity at the start of the period saw their productivity increase relative to their compatriots.

Table 8.2. **OLS principal components regressions for productivity growth (1988-97)**

(Establishment-weighted)

	Model 1	Model 2	Model 3	Model 4
Advanced technology use				
Tech1	0.034**	0.029*	0.039**	0.033*
Tech2	-0.009	-0.008	-0.008	-0.006
Tech3	-0.072	-0.071	-0.074	-0.073
Tech4	0.082**	0.082**	0.081**	0.081**
Tech5	-0.053*	-0.054	-0.057*	-0.058*
Tech6	-0.046*	-0.043	-0.056**	-0.053*
Tech7	-0.074***	-0.073***	-0.070***	-0.069***
Tech8	-0.025	-0.024	-0.028	-0.026
Tech9	-0.019	-0.016	-0.024	-0.020
Tech10	0.009	0.011	0.006	0.008

(continued on next page)

Table 8.2. **OLS principal components regressions for productivity growth (1988-97)** *(continued)*

(Establishment-weighted)

	Model 1	Model 2	Model 3	Model 4
Advanced technology use (cont'd)				
Tech11	-0.006	-0.006	-0.005	-0.005
Tech12	0.013	0.015	0.006	0.008
Tech13	-0.007	-0.006	-0.005	-0.004
Tech14	-0.018	-0.015	-0.019	-0.016
Tech15	-0.074*	-0.071*	-0.076*	-0.072*
Plant size				
Employment size (1988)	0.0004	0.0004	0.0005	0.0005
Nationality of control				
Foreign	-0.025	-0.020	-0.028	-0.025
Capital intensity				
Profitability change (1988-97)	0.019***	0.019***	0.019***	0.019***
Initial labour productivity				
Relative productivity (1988)	-0.483***	-0.486***	-0.476***	-0.478***
R&D				
Ongoing R&D performer	-0.142*	-0.168*	-0.129	-0.153*
Competition				
6-20 competitors	-0.024	-0.038	0.004	-0.013
Over 20 competitors	-0.021	-0.030	0.001	-0.008
Business practices				
Product quality	0.147	0.137	0.122	0.110
Management	0.051	0.049	0.077	0.079
Product/process development	-0.001	-0.012	-0.010	-0.018
Competitive environment				
Industry environment	0.00008	-0.00009	-0.00006	0.0001
Innovation				
Process specialised	---	0.126	---	0.136
Product specialised	---	0.103	---	0.088
Combined	---	0.083	---	0.095
Comprehensive	---	0.141	---	0.150

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Table 8.2. **OLS principal components regressions for productivity growth (1988-97)** *(continued)*

(Establishment-weighted)

	Model 1	Model 2	Model 3	Model 4
Firm strategies				
Technology				
– Factor 1	---	---	0.007	0.007
– Factor 2	---	---	-0.032	-0.024
Marketing				
– Factor 1	---	---	-0.006	-0.007
– Factor 2	---	---	-0.019	-0.020
Management/human resources				
– Factor 1	---	---	-0.033	-0.038
– Factor 2	---	---	0.075*	0.077*
Industry				
Cereal	0.048	0.066	0.068	0.087
Dairy	0.229	0.240	0.261	0.270
Fish	0.104	0.118	0.120	0.132
Fruit & vegetables	0.040	0.051	0.073	0.084
Meat	0.285	0.298	0.299	0.310
Other	0.092	0.089	0.107	0.102
N	524	524	524	524
F(degrees of freedom)	F(32,491) = 4.09	F(36,487) = 3.66	F(38,485) = 3.66	F(42,481) = 3.31
R^2	0.20	0.20	0.20	0.21

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

Outside of R&D and certain firm competencies, few of the firm characteristics variables are significant. Size of establishment and whether a plant has introduced innovations are positively, although not significantly, related to productivity growth. The coefficient attached to country of control is negative, but also not significant. And whether an establishment adopts advanced engineering and business practices is also not significant.

Neither innovation nor R&D activity is associated with higher productivity growth. Indeed, R&D activity has a negative and weakly significant impact on productivity growth.

Of the firm competencies, only management and human resources have a significant effect. The second factor for this competency is positively, and significantly, related to productivity growth. The second factor loads positively on three characteristics and negatively on three other characteristics (Annex B of this chapter). The three factors that are positively loaded are continuously improving quality, continuously training staff and recruiting skilled workers. The negative loadings are for introducing innovative organizational structure, using information technology and introducing innovative compensation packages. This factor describing a firm's tendency to concentrate on creating and maintaining a skilled workforce, through both training and recruitment, and to improve the quality of the products offered by the firm. Food processing plants that exhibited this competency were less likely to have adopted advanced technologies but were more likely to have enjoyed productivity growth if they had done so during the nineties. We interpret this to mean that these practices served as substitutes for an advanced technology strategy in the food-processing sector.

The competitive environment, measured in two ways in this study, is not significantly related to the productivity growth of establishments in the food processing industry, at least not throughout the 1990s. Neither the number of competitors that a firm faces, nor the intensity of competition within an industry as measured by an extensive set of environmental characteristics has a statistically significant effect.

Table 8.3. **Interpretation of statistically significant technology principal components for productivity growth regression**

Principal component	Sign of coefficient	Emphasises	Downplays
Tech1	Positive	Process control; information and communications; packaging; rapid testing; CAD/CAE	---------------------------
Tech4	Positive	Pre-processing (separation, testing, grading); process control; DNA probes	Bar coding; modified atmosphere and laminates (packaging); aseptic processing and flexible packages (thermal preservation); monoclonal antibodies (quality control)
Tech5	Negative	Quality control (excl. simulation modelling); bio-ingredients for processing; rapid testing; digital CAD; pre-processing	Inventory and distribution; machine vision; use of the internet
Tech6	Negative	High pressure sterilisation; product handling; statistical process control; machine vision; robots; digital CAD	Information and communications; collagen probe (pre-processing); rapid testing
Tech7	Negative	Information and communications; thermal preservation heating; simulation modeling (quality control); design and engineering (excluding CAD/CAE)	Separation techniques; sensor-based testing; rapid testing; modified atmosphere, laminates, and multi-layer materials (packaging)
Tech15	Negative	Thermal preservation; pre-processing separation and grading; and automated laboratory testing	Chemical antimicrobials; DNA probes; bio-ingredients; chromotography; and defect sorting

8.7 Market-share growth

8.7.1 Description of variables

The third model that we estimate examines the correlates of growth in market share. Growth in market share is postulated to depend on factors that give a firm an advantage over its competitors.

Growth in market share is posited to be a function of both the advantages in labour productivity experienced at the beginning of the period and its growth over the period. Initial period relative productivity is represented by the relative productivity advantage of a plant at the beginning of the period, while growth in relative productivity captures changes in this advantage that take place during the period.

In our formulation, growth in relative labour productivity is a proxy for a host of factors that are related to technical efficiency, changes in capital intensity, and other competencies in a firm – from management capabilities to human-resource strategies such as training.

But we also explicitly include certain measures of a firm's competencies. Measures relating to the importance attributed by firms to their market strategy, their technological development strategy, their management, and their human-resource strategy are included in the market-share equation. This allows us test whether these competencies affect market-share growth independent of their indirect effect on productivity growth through technology use.

Although we already included advanced technology use in the labour productivity equation, we also include it in the market-share equation to test whether there is an effect of advanced technology on market-share growth that is separate from its effect on the growth in relative labour productivity. Advanced technology use not only allows relative cost gains that are reflected in lower prices, but it also improves the flexibility in the production process and the quality of products produced (Baldwin, Sabourin and Rafiquzzaman, 1996; Baldwin, Sabourin, and West, 1999). As such, it might be expected to have an effect on growth in market share independent of its effect on measured labour productivity.

The other variables that were included in the market-share equation are essentially the same as those used in the relative productivity growth model, with the addition of opening-period market share to allow for regression-to-the-mean.

8.7.2 Empirical results for growth in market share

The results for market-share growth are presented in Table 8.4. Interpretations of the principal component results for the technology variables are provided in Table 8.5.

Growth in labour productivity over the period is a positive, and highly significant, factor contributing to market-share growth. Labour productivity at the start of the period, on the other hand, does not significantly contribute to the growth in market share.

Even after taking into account the effects of relative productivity growth on market share, there is an additional impact of advanced technology use on the growth in market share. In the market-share growth regression, the first principal component is once again significant. An emphasis on advanced information and communications systems, process control and packaging technologies is positively related to market-share growth.

Plants that manage to incorporate advanced information and communication systems, process control technologies, and even advanced packaging technologies tended to grow in terms of their relative productivity during the past decade. In turn, growth in productivity from adopting these technologies leads to growth in market share. The fact that this principal component is significant even after controlling for growth in productivity indicates that there exists an additional effect, over and above that received from productivity growth.

The sign of the coefficient on the second principal component indicates that establishments that adopt both advanced preservation and advanced packaging technologies, and tend not to adopt advanced processing technologies, are more likely to achieve growth in market share. Similarly, the sign on the fifteenth component indicates that the adoption of advanced thermal technologies, advanced non-thermal preservation technologies and advanced separation and water removal technologies, but not advanced quality control technologies, is associated with increasing market share.

Table 8.4. **OLS principal components regressions for market-share growth (1988-97)**

(Establishment-weighted)

	Model 1	Model 2	Model 3	Model 4
Intercept	0.002	0.002	0.003	0.002
Advanced technology use				
Tech1	0.0003*	0.0004*	0.0003*	0.0003*
Tech2	-0.0004**	-0.0005**	-0.0004**	-0.0005**
Tech3	-0.0002	-0.0002	-0.0002	-0.0002
Tech4	0.0007*	0.0007*	0.0007*	0.0007*
Tech5	0.00005	0.0001	0.00006	0.0001
Tech6	0.00001	-0.00004	0.00004	-0.00001
Tech7	0.00006	0.00004	0.00007	0.00005
Tech8	0.0003	0.0003	0.0003	0.0003
Tech9	-0.0002	-0.0002	-0.0002	-0.0002
Tech10	0.0005	0.0005	0.0005	0.0005
Tech11	-0.0007	-0.0007	-0.0007	-0.0007
Tech12	0.0005	0.0005	0.0005	0.0005
Tech13	0.0005	0.0005	0.0005*	0.0005
Tech14	-0.0002	-0.0002	-0.0002	-0.0002
Tech15	0.0008**	0.0008**	0.0008**	0.0008**
Plant size				
Employment size-1988	0.00001	0.00001	0.00001	0.00001
Nationality of control				
Foreign	0.002	0.002	0.002	0.002
Initial market share				
Market share (1988)	-0.00004	-0.0005	0.0002	-0.0002
Initial labour productivity				
Relative productivity (1988)	-0.0006	-0.0006	-0.0007	-0.0006
Labour productivity growth				
Relative productivity growth	0.0014***	0.0014***	0.0014***	0.0014***
R&D				
Ongoing R&D performer	-0.0007	-0.0006	-0.0008	-0.0007
Competition				
6-20 competitors	0.0007	0.0009	0.0006	0.0008
Over 20 competitors	-0.0002	-0.0001	-0.0003	-0.0002

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Table 8.4. **OLS principal components regressions for market-share growth (1988-97)** *(continued)*

(Establishment-weighted)

	Model 1	Model 2	Model 3	Model 4
Business practices				
Product quality	-0.0002	-0.0002	-0.0002	-0.0002
Management	-0.0006	-0.0004	-0.0006	-0.0004
Product/process development	0.0002	0.0003	0.0003	0.0003
Competitive environment				
Industry environment	-0.00001	0.000002	0.000009	0.000003
Innovation				
Process specialised	---	-0.0005	---	-0.0004
Product specialised	---	-0.0010	---	-0.0010
Combined	---	0.0003	---	0.0003
Comprehensive	---	-0.0008	---	-0.0008
Firm strategies				
Technology				
– Factor 1	---	---	0.0002	0.0002
– Factor 2	---	---	0.0001	0.0001
Marketing				
– Factor 1	---	---	0.0001	0.0001
– Factor 2	---	---	-0.0001	-0.0001
Management/human resources				
– Factor 1	---	---	-0.0001	-0.0002
– Factor 2	---	---	-0.0001	-0.0001
Industry				
Cereal	-0.001	-0.001	-0.001	-0.001
Dairy	-0.0002	-0.0003	-0.0001	-0.0002
Fish	0.0001	-0.0001	0.00004	-0.0001
Fruit & vegetables	0.0006	0.0007	0.0006	0.0007
Meat	0.0008	0.0008	0.0009	0.0009
Other	-0.0010	-0.0009	-0.0009	-0.0009
Summary statistics				
N	537	537	537	537
F(degrees of freedom)	F(33,503) = 1.43	F(37,499) = 1.28	F(39,497) = 1.32	F(43,493) = 1.20
R^2	0.11	0.11	0.11	0.11

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

It is noteworthy that none of the additional strategic competency, business practices, innovation, or competitive environment variables has a significant direct impact on market share. They have a direct impact on technology use and technology use, in turn, affects productivity and productivity affects market-share growth. But they have no separate impact on the latter.

The coefficients for both size and foreign ownership are positive, but neither is significant. R&D and growth in market share are negatively related; but, like the coefficients on size and ownership, this result is not statistically significant.

Table 8.5. **Interpretations of statistically significant technology principal components**

Market-share regressions

Principal component	Sign of coefficient	Emphasises	Downplays
Tech1	Positive	Process control; information and communications; packaging; rapid testing; CAD/CAE	--------------------------
Tech2	Negative	Processing technology, of all types	Robots; packaging machinery; statistical process control; CAD output
Tech 4	Positive	Pre-processing (separation, testing, grading); process control; DNA probes	Bar coding; modified atmosphere and laminates (packaging); aseptic processing and flexible packages (thermal preservation); monoclonal antibodies (quality control)
Tech15	Positive	Thermal preservation; pre-processing separation and grading; and automated laboratory testing	Chemical antimicrobials; DNA probes; bio-ingredients; chromotography; and defect sorting

8.8 Conclusion

This study builds on our previous work that finds firm performance is related to the innovative stance of a firm.

There are many factors behind the growth of firms – from overall management capabilities, to marketing, human resources, and operational capabilities. A substantial part of a firm's capital consists of these internal competencies. These capabilities extend beyond just R&D performance to encompass those activities that enable a firm to ingest new information about new technologies and to act quickly and effectively on it. All of these capabilities underlie a firm's innovative capacity.

The importance given to innovative activity as a factor behind success is confirmed by our Canadian studies that have consistently found that the innovative capabilities of firms are related to their success (see Baldwin and Gellatly, 2004). Earlier studies investigated the difference in the competencies found in growing and declining firms to see whether a key difference between the two lies in the nature of their innovation regime. These studies use three different surveys as sources and find similar results in each case.

Baldwin (1996) and Baldwin and Johnson (1998) find that while firms need to do many things better in order to succeed, innovation is the one factor that appears to discriminate best between the more-successful and less-successful firms. Baldwin, Chandler *et al.* (1994) study growing small and medium sized firms in the 1980s and find that the key characteristic that distinguished the more-successful from the less-successful was the degree of innovation taking place in a firm. Measuring success as a vector of characteristics such as market-share growth and relative productivity growth, they report that the more-successful firms tend to place more emphasis on R&D capability and R&D spending. They are also more likely to give more importance to developing new technology.

Johnson, Baldwin and Hinchley (1997) report that in new firms that entered in the mid 1980s and survived into their teen years in the 1990s, growth in output was closely related to innovation. Faster growing entrants are twice as likely to report an innovation, and more likely to invest in R&D and technology than slower growing firms. However, faster growing firms are also more likely to place higher emphasis on training, recruiting skilled employees and providing incentive compensation programs (Baldwin, 2000).

These findings regarding the importance that firms give to innovative strategies and activities are confirmed by two other studies that use data at the plant level on the use of advanced technologies. Advanced technology use is a form of innovation. These studies report that plants using advanced technology both grow faster and increase their productivity relative to plants not using advanced technologies (Baldwin, Diverty and Sabourin, 1995; Baldwin and Sabourin, 2001).

In summary, all these studies have found that firms that manage to grow more quickly simultaneously *develop* certain innovative competencies that distinguish them from firms that grow less quickly. Differences in technological competencies have the same effect. That innovative and technological competencies are linked is not surprising. Some 53% of respondents to the *1993 Survey of Innovation and Advanced Technologies* who had indicated that they introduced the advanced technologies did so in conjunction with the introduction of a product or process innovation.

This chapter is the third in Canada to confirm the relationship between firm performance and advanced technology use. The previous studies reported that it was information and communications technologies (ICTs) that were most closely associated with superior performance. This study finds the same. It provides strong evidence that the use of ICTs is associated with superior performance. Greater use of advanced information and communication technologies is associated with higher labour productivity growth during the nineties.

Our previous study (Baldwin, Diverty and Sabourin, 1995) also showed that firms that combined ICTs with other advanced technologies fared the best. This chapter corroborates these findings. The results show that beyond ICTs, the adoption of advanced process control and packaging technologies is also associated with higher productivity growth. For certain industries, the adoption of advanced pre-processing technologies also increases firm performance.

Furthermore, the results emphasize that combinations of technologies that involve more than just ICTs are important. For example, adoption of advanced process control technology, by itself, has little effect on the productivity growth of a firm, but when combined with ICTs and advanced packaging technologies, the effect is significant. Similar effects are evident when firm performance is measured by market-share growth instead of productivity growth. ICTs are important, but as facilitators of the effectiveness of other advanced technologies.

What is more significant is that these results still hold even when other activities and underlying characteristics of the firm are taken into account. We know that many factors determine whether a firm succeeds or fails. The food-processing survey has allowed us to measure not only technology use in a detailed way, but also to look at various other characteristics and competencies of a firm. We find that the association between technology use and productivity growth is robust to the inclusion or exclusion of the other activities and characteristics of the firm.

Other characteristics like the innovation stance of the firm, its business practices, and human-resource strategies influence the extent to which a firm adopts new advanced technologies. But their direct impact on productivity growth or market-share growth is less than the indirect impact through their influence on technology use.

Does that mean that the other characteristics of the firm do not matter when it comes to firm growth? The answer is no. The capital intensity of a firm is positively and significantly related to productivity growth. Regression to the mean for the productivity growth equation is highly significant. A management team with a focus on improving the quality of its products by adopting an aggressive human-resource strategy – by continuously improving the skill of its workforce through training and recruitment – is also associated with higher productivity growth.

Despite the importance of strategies outside the technology arena, the central theme that emerges from this analysis is that a high-technology orientation is at the core of a strategy set that is closely associated with success.

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ANNEX A

PRINCIPAL COMPONENTS OF TECHNOLOGY USE

Table A8.1. **Interpretation of principal components and their importance by industry**

Principal component	**Interpretation**	**Variance explained (%)**
Tech1	*Emphasises* process control, information and communications and packaging technologies.	13.6
Tech2	*Emphasises* advanced processing technology, of all types. *Downplays* robots, packaging machinery, statistical process control and CAD output.	5.8
Tech3	*Emphasises* pre-processing (except for near infrared analysis), non-thermal preservation, bar coding, and microwave drying and water activity control. *Downplays* separation and concentration processing, chromotography and near infrared analysis.	4.1
Tech4	*Emphasises* pre-processing, process control, and DNA probes. *Downplays* thermal preservation and advanced materials packaging, bar coding and monoclonal antibodies	3.7
Tech5	*Emphasises* quality control, bio-ingredients, rapid testing, digital CAD, and pre-processing. *Downplays* inventory and distribution, internet use & machine vision.	3.3
Tech6	*Emphasises* product handling, high-pressure sterilization, statistical process control, robots, machine vision, and digital CAD. *Downplays* information and communications, and rapid testing.	3.0
Tech7	*Emphasises* information and communications, thermal preservation heating, simulation modeling, and design and engineering. *Downplays* separation techniques, sensor-based and rapid testing and advanced materials packaging.	2.8
Tech8	*Emphasises* infrared and ohmic heating, microwave drying, and DNA probes. *Downplays* design and engineering, ultrasonic techniques and chemical antimicrobials, and electronically controlled machinery.	2.7
Tech9	*Emphasises* flexible packages, DNA probes, simulation modeling, bran removal and micro component separation, and active and multi-layer materials packaging. *Downplays* ultrasonic techniques, colour assessment, defect sorting and animal stress reduction.	2.5
Tech10	*Emphasises* microwave drying, laboratory testing, simulation modeling, high-pressure sterilisation, and internet use. *Downplays* aseptic processing, animal stress reduction and infra red heating.	2.3
Tech11	*Emphasises* animal stress reduction, deep chilling, monoclonal antibodies, and microwave drying. *Downplays* microencapsulation, defect sorting, and packaging.	2.2
Tech12	*Emphasises* design and engineering and ion exchange. *Downplays* microbial cells, microencapsulation, and robots.	2.2
Tech13	*Emphasises* microencapsulation, laboratory testing, and bar coding. *Downplays* thermal preservation, PLCs, and rapid testing.	2.0
Tech14	*Emphasises* ion exchange, chromotography, packaging machinery and animal stress reduction. *Downplays* CAD/CAM, inventory and distribution, defect sorting and LANs.	2.0
Tech15	*Emphasises* thermal preservation, pre-processing separation and grading, and automated laboratory testing. *Downplays* chemical antimicrobials, bio-ingredients, chromotography, DNA probes and defect sorting.	1.9

ANNEX B

FACTOR ANALYSIS FOR FIRM COMPETENCY VARIABLES

Table B8.1. **Factor loadings for firm competency factors**

Variable	**Factor pattern**	
	Factor 1	**Factor 2**
Markets		
– Introducing new products in present markets	0.832	-0.471
– Introducing current products in new markets	0.780	0.602
– Introducing new products in new markets	0.906	-0.086
Technology		
– Using technology developed by others	0.758	0.622
– Developing new technology	0.865	-0.095
– Improving existing technology	0.803	-0.485
Management/human resources		
– Continuously improving quality	0.695	0.589
– Introducing innovative organisational structure	0.781	-0.387
– Using information technology	0.801	-0.278
– Continuously training staff	0.785	0.346
– Introducing innovative compensation packages	0.767	-0.254
– Recruiting skilled workers	0.778	0.051

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