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Innovation, Survival and Performance of Canadian Manufacturing Plants

by John R. Baldwin and Wulong Gu

Micro-economic Analysis Division
18-F, R.H. Coats Building, Ottawa, K1A 0T6

Telephone: 1 800 263-1136

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How to obtain more information :
National inquiries line: 1 800 263-1136
E-Mail inquiries: infostats@statcan.ca

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The authors' names are listed alphabetically.

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Abstract

This paper examines the determinants of innovation and the role of innovation in productivity growth, shifts in market share and survival in the Canadian manufacturing sector. The paper presents a model that examines the effect of innovation on plant performance and plant survival. It uses a unique data set that allows us to develop a detailed time profile of plant performance both before and after the introduction of an innovation. We find strong evidence that labour productivity growth is faster and survival rates higher after the introduction of a process innovation. Process innovation is also linked to gain in market shares through its effect on productivity growth. In contrast, product innovation appears to have little impact on plant performance and a negative impact on plant survival. We find that R&D, technology competencies and past innovation are linked to higher rates of innovation. Previous innovation experience is linked to innovation but previous growth is not.

JEL classification: L1; L6; O3

Keywords: Innovation, productivity growth, market share, survival.

Executive Summary

Innovation and technological progress are viewed as the main drivers of productivity growth. This study examines whether this is the case for individual producers in the manufacturing sector.

Analysis of innovation focuses here on three main questions. In the first instance, it asks what factors lead some firms to succeed in introducing an innovation and others to fail. For example, is R&D the only crucial input to the innovation process, or are other complementary competencies critical to the process?

In the second instance, the analysis focuses on understanding the underlying patterns in the firm population that may permit us to discern changes that are occurring therein. Here the paper asks whether there is a segment of the economy where innovation is more intense.

The third theme investigates the impact of innovation. It asks how innovation contributes to the success of firms. By understanding how innovation affects individual producers, we further our understanding of how innovation affects the overall economy.

To answer these questions, the paper focuses on the innovation activities of individual firms and establishments using the 1993 Innovation Survey. Second, this paper links the innovation survey with measures of firm performance derived from the Census (Annual Survey of Manufactures) that permit an examination of the link between innovation and plant performance.
The paper poses a number of questions. These are:

1) What factors are linked to innovation outcomes of Canadian manufacturing firms?

The paper shows that R&D investment, competencies and past innovation activities are the three main factors affecting innovation outcomes of Canadian manufacturing firms. R&D investment is an important determinant of innovation. Being a performer of continuous R&D is closely related to innovation of most types—though it is more important for the most novel than the least novel innovations. The location of R&D activity is less important, that is, having a separate R&D department is not as critical as the presence of continuous R&D.

The second factor affecting innovation outcomes is technology competencies of firms. The paper finds that firms placing more emphasis on technology strategies are more innovative. While the firms' commitment to R&D is important for innovation, the technological competencies that are accumulated over time are as important. In contrast, this paper finds no evidence that the emphasis on marketing, production and human resources is related to innovation.

The third factor affecting innovation outcomes is past innovation activities. The use of patents and trade secrets, which is associated with past innovation, is a strong predictor of being an innovator. The firms that have obtained patents or used trade secrets to protect their intellectual property in the past have innovation rates that are 23 percentage points higher than those with no intellectual property rights. The difference is 23 percentage points for process innovations, 18 percentage points for product innovations, 2 percentage points for world-first innovations, and 15 percentage points for non-world-first innovations.

2) Are there particular sectors where innovation is more intense? Are large firms more innovative than small firms? Are foreign-controlled firms more innovative than small firms?

Firm size is found to be more closely related to process innovation than product innovation. The paper finds that large firms have higher rates of process innovations than small firms. But there is no difference in product innovation rates between them. Our results show that large firms have process innovation rates that are 14 percentage points higher than small firms.

It is also the case that foreign-controlled firms have innovation rates that are about 10 percentage points higher than their domestic counterparts. The higher innovation rates of foreign-controlled plants are a result of their larger size, higher export participation rates, technology competencies, and past innovation activities. After controlling for these firm characteristics, the nationality of a firm is not significantly related to innovation.

3) Is innovation linked to plant survival and plant performance?

Product innovation and process innovation have different effects on plant survival. Process innovation is associated with higher plant survival rates while product innovation is related to lower survival rates. The firms that introduced process innovations during the period 1989-1991 have survival rates that are 6 percentage points higher than those that did not. In contrast, the average survival rate of plants with product innovation is lower than those without product innovation. This suggests that these different types of innovators are at different phases of the product life cycle. Product innovation dominates the early stages of the life cycle when turnover is high: process innovation occurs later when market shakeouts have already occurred and competition no longer depends as much on providing unique product characteristics but rather emphasizes price advantages because products have become more homogeneous.

More innovative producers have higher productivity growth. Process innovation is more important than product innovation for labour productivity growth. The paper finds that process innovators had an annual labour productivity growth that was 3.6 percentage points higher than non-process innovators. In contrast, product innovation has a positive but statistically insignificant effect on labour productivity growth. This is consistent with the view that new products tend to be disruptive to established production processes and productivity growth is unlikely to show significant improvement as a result.

The result that process innovation matters for productivity growth confirms findings from other research studies (Baldwin and Sabourin, 2001; Baldwin, Sabourin and Smith, 2004) that technology use is related to faster productivity growth. These technologies include robots, advanced manufacturing cells, automated process control and many similar state-of-the-art technologies, all of which are integral to new processes. Many of these advanced technologies were introduced in conjunction with process innovations. Together, the results in this paper and those in the work on technology use, stress the importance of process innovation for productivity growth.

The paper finds that innovation is related to market-share growth through its positive effect on productivity growth. The plants that introduce process innovation have faster productivity growth that in turn leads to gains in market share.

4) What do these findings tell us about the innovation process?

In this study, we have found that large firms are more likely to be process innovators, and that process innovation is more likely to be associated with productivity growth. Does this imply that large innovators are more beneficial in some sense? Does it imply that process innovation is more valuable than product innovation?

We do not believe that our findings on the difference in the impact of process as opposed to product innovation warrants strong conclusions about the effectiveness of process innovation and concomitantly the ineffectiveness of product innovation in Canada. Rather, the research that has been reported here needs to be set in context in order that we can see how innovation fits into a larger pattern of firm growth and decline.

Firms, products and industries pass through life cycles. Their focus varies over the life cycle and so too does their success. Early in the life cycle, entry and exit are high. Firms tend to focus on developing new products. Finding the characteristics of the product set that consumers will eventually accept is risky. Only later after the shakeout occurs do firms become larger—as they focus more on reducing production costs and competing more on price in a market where products are distinguished less on the basis of unique product characteristics and more on price.

In the early stages of the life cycle, we would not expect innovation to be closely related to productivity gain. Indeed, in the early stages of a firm, productivity gains may not be very important—as firms have their hands full with just meeting rapidly growing demand when product lines suddenly generate interest. At this stage, production often has the characteristic of a craft production system. Indeed in Baldwin and Dhaliwal (2001), we report that firms that are growing their labour force are often not growing their productivity—that it is in the larger plants that are declining in employment size where productivity gains are largest. It is not surprising, therefore, that in this paper, we have found process innovation affects productivity growth while product innovation is less likely to do so. Most of the plants in the sample belong to larger firms and are therefore more likely to be engaging in the type of innovation (process) that leads to productivity improvements. And those firms that are engaging in product innovation are more likely to be in the early stage of their life cycles where productivity growth is not high.

It is also important to interpret some of our other results in a larger context. Our work, like that of others, finds that firm size is related to productivity growth. Here, as elsewhere (Baldwin and Hanel, 2003, ch. 7), we caution readers not to conclude from this that small firms are not innovative. Small firms are at a different stage in their life cycle from large firms. Large producers are about to face inexorable decline. To stave off this fate, large firms enter into some activities more intensively. They are more likely to merge for instance. They enter industries relatively more frequently via merger than via greenfield entry (Baldwin, 1995). The results of this paper also show that they are more likely to indicate that they have introduced an innovation. But this is most likely for process innovation. Large firms are more likely to be at that stage of the life cycle where process innovation is important for both survival and maintenance. The effect of innovation on survival is also higher for the larger plants. While most exits come from smaller plants, failing to innovate will lead to closure of even the larger plants. Finally, it should be noted that innovation for large plants tends to offset the inexorable dynamics of decline. Larger plants have higher productivity and plants with higher productivity tend to decline in productivity. Process innovation can reduce the amount of this decline.

The same process is at work with regard to changes in market share. Here too, large plants are likely to lose market share because of the forces of competition. And here too, innovations serve, via productivity improvements, to reduce the tendency to lose market share. But this tendency is more pressing for large firms than small firms. Thus, process innovation is found to be more effective than product innovation in the population that is being examined in this paper—probably because they are the larger plants in the population.

1. *Introduction*

Productivity growth is the main determinant of a rising standard of living. Traditionally, the economics profession has examined the causes of productivity growth by focusing on the aggregate economy and by concentrating on changes in aggregate capital and labour inputs (Dennison, 1962; Jorgenson, 1990).

New strains of research have extended our understanding of the forces leading to productivity growth. These studies move beyond aggregate constructs to study productivity growth in underlying producers.

On the one hand are those studies that examine the behaviour of individual firms and establishments. Productivity growth at the aggregate level comes from productivity growth in individual plants and the reallocation of output across plants. Recent empirical work using plant and firm level data concludes that productivity growth at individual plants and the reallocation of output across plants are both important sources of productivity growth (see Foster et al., 2003 for a recent review; Baldwin and Gu, 2003a, 2003b for recent Canadian evidence). Competition that shifts resources from the less productive to the more productive firms accounts for a considerable portion of aggregate productivity growth. The competitive environment is therefore important to productivity growth.

On the other hand are those studies that focus on innovative activities of producers. These studies attempt to understand the determinants of productivity growth by focusing on the innovation process. Some of these studies focus on R&D or on patents and examine how they are related to productivity growth. The weakness of previous studies on the link between R&D and productivity growth relates to the inadequacy of using R&D or patents to measure the incidence of innovation.

R&D is only an input into innovation. Not all firms performing R&D produce innovations and not all innovations come from R&D expenditures (Baldwin and Hanel, 2003, ch. 5). In particular, R&D is focused more on producing product than process innovations. Firms obtain ideas for innovation from a number of sources in addition to R&D—such as customers, suppliers, marketing or sales departments, and production departments. The weakness of studies that use patents is that this variable also imperfectly measures whether an innovation has been introduced. Patents are a complementary product of the innovation process. But not all innovations are patented (Baldwin and Hanel, 2003, ch. 9), and therefore patents also provide only a partial measure of innovation.

This paper addresses these weaknesses and provides a more direct test of the link between productivity growth and the nature of the innovation process. It does so, first, by using an innovation survey that provides direct measures of innovation output. Second, the paper uses data derived from the innovation survey that are linked to measures of firm performance derived from the Census of Manufactures. This permits us to examine the connection between innovation and productivity growth at the level of individual producers.

Before we proceed to outline our model and estimation procedure, it is useful to put our paper in context. A set of previous studies for Canada have reported that the innovative capabilities of individual firms are related to measures of performance.[1]

The first set investigated the difference in the competencies found in growing and declining small- and medium-sized firms. 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 firms from the less successful firms was the degree of innovation taking place in a firm. Measuring success as a vector of characteristics such as market-share 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 also give more importance to developing new technology.

Baldwin and Johnson (1998, 1999) use a survey of entrants and report that in new firms, growth in output was closely related to innovation. They report that faster growing entrants are twice as likely to report an innovation, and are more likely to invest in R&D and technology than slower growing firms.

These findings, which emphasize the connection between success and the importance that firms give to innovative strategies and activities, are confirmed by three other studies that employ data at the plant level on the use of advanced technologies (Baldwin, Diverty and Sabourin, 1995; Baldwin and Sabourin, 2001; Baldwin, Sabourin and Smith, 2004). Advanced technology use is a form of innovation. Indeed, in Statistics Canada's 1993 Survey of Innovation and Advanced Technology, most plants reporting that they had introduced advanced technologies did so in conjunction with an innovation. These studies report that plants using advanced technologies both grow faster and increase their productivity relative to plants not using advanced technologies.

A growing number of studies in other countries have also used innovation surveys to examine the relationship between innovation and productivity performance at the plant and firm level.[2] These studies focus both on the determinants of innovation and on the connection between innovation and performance.

In the first case, they find that R&D is closely related to innovation. Crépon et al. (1998) report that the share of sales from product innovation is positively related to R&D capital in French manufacturing firms. Van Leeuwen (2002) finds similar evidence for Netherlands, as do Criscuolo and Haskel (2003) for the U.K., and Lööf and Heshmati (2001) for Sweden. Similar evidence is reported for Canada (Baldwin, Hanel and Sabourin, 2000).

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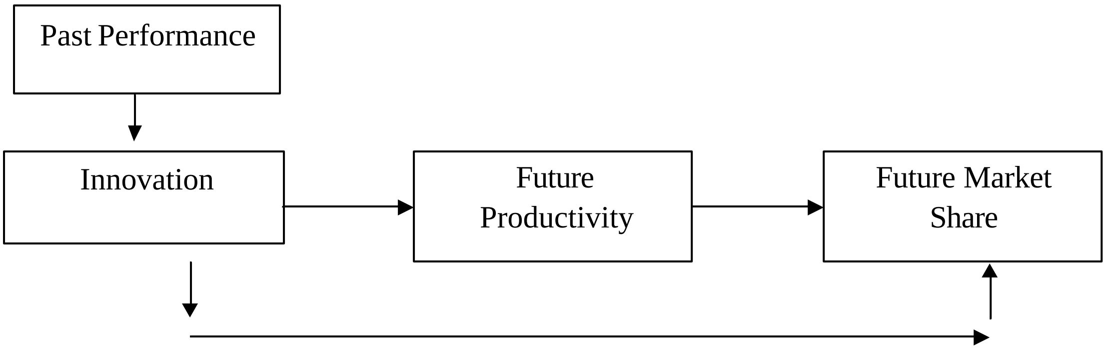
1. For a summary, see Baldwin and Gellatly (2003).
2. Studies on innovation and firm performance have been undertaken for France by Crépon, Duguet and Mairesse (1998); for the United Kingdom by Criscuolo and Haskel (2003); for Sweden, Lööf and Heshmati (2001); for Finland, Leiponen (2002), for Netherlands, van Leeuwen (2002).

Second, these studies find that innovating firms are more productive than non-innovating firms. Crépon, Duguet and Mairesse (1998) find that the share of sales accounted for by innovative products is positively related to the level of productivity across French manufacturing firms. Lööf and Heshmati (2001) find a strong relationship between the share of sales from innovations and value added per worker for both manufacturing and service firms.

Third, while innovative firms tend to have higher productivity *levels*, the results on the relationship between innovation and productivity *growth* are mixed. Lööf and Heshmati (2001) find a positive relationship between innovations new to the market and labour productivity growth across Swedish manufacturing firms. In contrast, van Leeuwen (2002) finds that process innovation does not appear to be linked to productivity growth while product innovation does for Dutch manufacturing firms. Criscuolo and Haskel (2003) show that process innovation is related to productivity growth while product innovation is not in a sample of U.K manufacturing firms.

This paper asks two questions that are at the heart of these studies. First, what are the characteristics of producers who introduce innovations? Second, is innovation linked to performance—i.e., productivity growth, market-share changes and survival of individual firms? The framework for our analysis is straightforward and has been adopted in previous work by Baldwin and Sabourin (2001) and Baldwin, Sabourin and Smith (2004) (see Figure 1 below). Firms are seen to make a choice as to whether they will try to be innovative. Some firms that do so will succeed in introducing an innovation. Past performance may condition the likelihood of success in doing so. In turn, the introduction of an innovation may affect labour productivity in the future—particularly if the innovation involves the use of new processes. Productivity gains will then impact on market share through its effect either on relative prices or on the quality of product. Innovation may affect market share indirectly through its impact on productivity but also directly through its effect on the introduction of new products.

Figure 1. Framework for analysis of innovation and performance



While the focus of this paper is on questions that are at the heart of the debate over the importance of innovation, the paper has a number of novel features. First, we extend our earlier findings by focusing not just on small firms but on both large and small firms. Second, the panel data allow us to examine new aspects of the dynamic interaction between innovation and firm performance. In previous studies on the effect of innovation (Baldwin 1996; Baldwin and Johnson 1999), we asked whether the innovation characteristics of a firm at time t were related to the performance of the firm in the previous period (t-τ to t). We argued that the stance of a firm does not change rapidly and therefore, asking how performance in the previous time period related to its present profile provided a useful research strategy.

In this paper, we develop a more detailed time profile of firms both before and after the 1993 Innovation Survey. We have in effect three periods—a three-year period over which innovation is measured, the time period prior to innovation, and a time period after innovation. We ask whether past growth is related to the successful innovation during a subsequent period. Strong growth can have positive feedback effects. Growth facilitates learning and leads to the accumulation of the type of internal competencies that are essential for innovation.[3]

The data set also allows us to ask whether innovation affects future growth. Most studies in other countries examine innovation and growth during the same period (van Leeuwen, 2002; Lööf and Heshmati, 2001; and Criscuolo and Haskel, 2003) and their results may be subject to simultaneity bias. Our use of past innovation to predict subsequent growth helps to mitigate the problem of simultaneity.

While the focus of the paper is on innovation, we note that not all innovation might be expected to have the same impact on firm performance. Innovations differ depending on whether they involve new products, new processes or some combination of the two. Equally important, innovations differ in terms of novelty. Some are highly original; others are less so. Therefore, in this paper, we make a distinction between world-first and other innovation, and between product and process innovation.

Finally, we use different measures of the degree to which a firm is innovative—measures of both incidence and intensity of innovation. While innovation surveys offer us a more direct measure of innovation than do studies that use R&D or patents, the innovation surveys do not produce a single definitive measure of innovation.[4] In the innovation survey that is used here, we have available several measures of the innovation—whether a *major* innovation was introduced[5], the percentage of product sales that come from a *major* innovation, and the number of *major* innovations that were introduced. The first can be used to measure *incidence* of innovation—whether an innovation was introduced. The latter two give us measures of intensity—how much innovation occurred. We use all three definitions to examine the robustness of our results to the three different variables. In the first case, we use a binary variable that indicates whether a firm introduced an innovation during the period 1989-93 to measure innovation *incidence*. In the second case, we measure innovation *intensity*. We construct two measures of innovation intensity: the share of sales that come from major product innovations and the number of innovations introduced.

It should be noted that the survey was designed to have firms only report an innovation if it was a major one. This was done by specifically requesting of respondents that they only report major

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[3] The empirical studies supporting this include Cosh et al. (1999), Nickell et al. (2001) and Baldwin and Diverty (1995).

[4] See Baldwin and Hanel (2003, ch. 2) for a discussion of these problems.

[5] See Baldwin and Hanel (2003, ch. 2) for a discussion of the reason that the survey focused only on the concept of a ‘major’ innovation.

innovations, by indicating that cosmetic changes were to be ignored, and by presenting a set of questions on the nature of the major innovation which would be unlikely to be answered for innovations that only involved a minor, pedestrian update of existing products and processes.

The rest of the paper is organized as follows. In the next section, we present a model of innovation, productivity growth and shifts in market share. In Section 3, we discuss the data and measurement of variables. Section 4 presents empirical results. In Section 5, we summarize the results.

2. A model of innovation, productivity growth and shifts in market share

The conceptual framework for our analysis was presented in Figure 1. In this section, we present a formal theoretical model on the link between innovation, productivity growth and market-share changes.

Our model adapts Dixit and Stiglitz's (1977) model of monopolist competition to allow for the choice of innovation and R&D. Although this modelling approach has not been used in most previous studies of innovation,[6] it is quite common in the international trade literature (see Melitz, 2003). In addition, this model is consistent with two main features of our data for individual firms. First, there is large dispersion in prices across firms.[7] Second, there are large and ongoing shifts in market shares across firms. The ongoing shifts in market share are a key prediction of our model that allows for innovation and R&D.

2.1 Demand

Consider an industry that consists of N firms producing differentiated products. We assume that each firm produces a single product and firm i produces product i. For a multi-product firm, we might think of the firm's product as representing an aggregate of various products that the firm produces. The preferences of a representative consumer are given by a C.E.S. utility function:

$$U = \left[\sum_{i=1}^{N} \left(q_i D_i \right)^{r} \right]^{1/r} \tag{1}$$

where q_i represents demand for product i, D_i represents consumer's taste parameter for product i. We might think of D_i as product quality and changes in D_i as product innovation. The elasticity of substitution between products is $s = 1/(1-r) > 1$.

The C.E.S. utility gives rise to the demand for firm i's product:

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6. Exceptions include Criscuolo and Haskel (2003).
7. Abbott (1992) documents the extent of price dispersion within broad industries. Foster, Haltiwanger and Syverson (2003) finds large price differences across producers within narrowly defined industries.

$$q_i = Q\left[\frac{p_i}{P}\right]^{-s} D_i^{s-1} \qquad (2)$$

where p_i is the price for firm *i*'s product, *P* denotes aggregate price which is given by:

$$P = \left(\sum_{i=1}^{N}\left(\frac{p_i}{D_i}\right)^{1-s}\right)^{1/(1-s)} \qquad (3)$$

and *Q* is aggregate output which is defined as the ratio of total expenditures to the aggregate price.

2.2 Production

Firm i is assumed to have a Cobb-Douglas production function with constant returns to scale:

$$q_i = \exp\left(\ln A_i + \sum_j a_j \ln X_{ij}\right) \qquad (4)$$

where A_i captures technology or total factor productivity for firm i, and $X_i = \{X_{ij}\}$ is a vector of inputs including physical capital, labour and intermediate inputs. The assumption of constant returns to scale in production implies $\sum_j a_j = 1$.

We interpret changes in technology A_i in equation (4) as process innovation.[8] We assume that process innovation is produced from R&D input using an innovation production function:

$$dA_i / dt = g_1(A_i, R_{i1}, t) \qquad (5)$$

where R_{i1} is R&D investment on process innovation. Similarly, we assume a firm has an innovation production function that relates product innovation to R&D input:

$$dD_i / dt = g_2(D_i, R_{i2}, t) \qquad (6)$$

The innovation production function (equations 5 and 6) models innovation as a function of knowledge stock within a firm (A_i and D_i) and R&D inputs, and has been used in previous studies on innovation (e.g., Griliches 1998; Klette, 1996). In a review of the innovation process, Dosi (1988) ascribes importance to the firm-specific and cumulative feature embedded in equations (5) and (6). Successful innovations are more closely related to firms' existing ranges of technological and marketing skills than unsuccessful ones. They tend to occur in product fields

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[8] More precisely, changes in technology are a function of process innovation. For notational convenience, we will use changes in A to represent process innovation. Hulten (2001) remarks that changes in *A* capture process innovations.

proximate to firms' current fields (Dosi, 1988, p. 1131). The skills and competencies that a firm builds up over time are important foundations for the conducting of innovative activity.

Total cost for a firm is the sum of input costs in output production, and costs of R&D for process and product innovations,

$$\sum_j w_j X_{ij} + c_1(R_{i1}) + c_2(R_{i2}) \tag{7}$$

where w_j is the price of input j that is common to all firms, $c_{i1}(R_{i1})$ is costs of R&D inputs for process innovation, and $c_{i2}(R_{i2})$ is costs of R&D inputs for product innovation.

In sum, a firm in our model is characterized by output production function (4), production function for process innovation (5), production function for product innovation (6), and total cost equation (7). The choices of the firm include input mix X_i, output q_i, output price p_i, and R&D inputs in process and product innovations R_{i1}, R_{i2}. The firm maximizes its discounted profits as follows:

$$\int_0^\infty e^{-rt} p_i \, dt = \int_0^\infty e^{-rt} \left(p_i q_i - \sum_j w_j X_{ij} - c_1(R_{i1}) - c_2(R_{i2}) \right) dt \tag{8}$$

subject to the constraints that consist of demand function (2), output production function (4), innovation production functions (5) and (6), and total cost equation (7).

We can solve the firm's profit maximization problem in three steps. First, we choose the input mix in each period to minimize the cost of producing a given level of output. Second, we choose a firm's price and output to maximize its profit in each period. Third, we choose R&D investments over the firm's lifetime to maximize its discounted profits.

2.3 Choice of input mix

The first step for solving the firm's profit maximization problem (8) is to choose input mix X_i to minimize the cost of producing a level of output q_i.

$$\begin{aligned} C(w, q_i, A_i) &= \min wx \\ & s.t. \;\; q_i = \exp\left(\ln A_i + \sum_j a_j \ln X_{ij} \right). \end{aligned} \tag{9}$$

As the output production exhibits constant returns to scale, the minimal cost of producing output q_i can be written as the product of unit cost times output,

$$C(w, q_i, A_i) = \frac{j\,(w)}{A_i} q_i \qquad (10)$$

where $j\,(w)/A_i$ is the cost of producing a unit of output.

2.4 Choice of output price and output quantity

As the demand curve for each firm has constant elasticity s , the profit maximizing price is a constant mark-up over marginal cost,

$$p_i = \frac{j\,(w)}{A_i}\frac{s}{s-1} = \frac{j\,(w)}{A_i}\frac{1}{r} \qquad (11)$$

where $s/(s-1) = 1/r$ is the profit maximizing mark-up. Given the choice of price, the choice of output can be calculated from the demand function (2),

$$q_i = \left(\frac{j\,(w)s}{s-1}\right)^{-s} A_i^s D_i^{s-1} Q P^s \qquad (12)$$

and the market share of firm i is given by

$$\frac{p_i q_i}{PQ} = \left(\frac{f(w)s}{s-1}\right)^{1-s} A_i^{s-1} D_i^{s-1} P^{s-1} \qquad (13)$$

This equation shows that the market share of a firm is linked to process and product innovations. Process innovation increases market share through its effect on the cost and price of the output, whereas product innovation raises market share through its effect on the consumer's demand.

The firm's maximal profit is

$$\begin{aligned} p_i &= p_i q_i - \frac{j\,(w)}{A_i} q_i - c_1(R_{i1}) - c_2(R_{i2}) \\ &= BQP^s A_i^{s-1} D_i^{s-1} - c_1(R_{i1}) - c_2(R_{i2}), \end{aligned} \qquad (14)$$

where $B = s^{-s}\left(\frac{j\,(w)}{s-1}\right)^{1-s}$.

2.5 Choice of R&D investment

The last step in solving the firm's maximization problem is to choose R&D inputs on process and product innovations to maximize its discounted profit flows:

$$\max\int_0^\infty e^{-rt}p_i\,dt = \max\int_0^\infty e^{-rt}\left(BQP^s A_i^{s-1}D_i^{s-1} - c_1(R_{i1}) - c_2(R_{i2})\right)dt,$$
$$\begin{aligned} s.t.\quad & dA_i/dt = g_1(A_i,\, R_{i1},\, t), \\ & dD_i/dt = g_2(D_i,\, R_{i2},\, t). \end{aligned} \qquad (15)$$

In a steady state, R&D inputs on process and product innovations satisfy the following conditions,

$$\begin{aligned} c_1'(R_{i1}) &= \frac{BQP^s\,(s-1)A_i^{s-2}D_i^{s-1}\,\partial g_1/\partial R_{i1}}{r-\partial g_1/\partial A_i}, \text{ and} \\ c_2'(R_{i2}) &= \frac{BQP^s\,(s-1)A_i^{s-1}D_i^{s-2}\,\partial g_2/\partial R_{i2}}{r-\partial g_2/\partial D_i}. \end{aligned} \qquad (16)$$

The left-hand side of the equations is the marginal cost of investing in innovation and the right-hand side is the marginal benefit. The firm chooses R&D input on innovation such that its marginal cost equals its marginal benefit. Equation (16) is conventional from the investment literature. The equation implies that an increase in the elasticity of substitution s raises the marginal benefit of investing in innovation and leads to more innovations. This suggests that high substitutability across products increases the incentive to innovate.

In our empirical analysis, we focus on output production function (4), market share equation (13), and innovation production functions (5) and (6). As with most other studies using the plant- and firm-level data, we do not have price and output for individual firms and plants. What we do observe is revenue p_iq_i, deflated with an aggregate price index P. Combining output production function (4) and demand equation (2), we have,

$$\ln\left(\frac{p_iq_i}{P}\right) = \frac{1}{r}\sum_j a_j \ln X_{ij} + \frac{1}{r}\ln A_i + \frac{1}{r}\ln D_i + (1-r)\ln Q \qquad (17)$$

where $1/r$ is the mark-up of price over cost (see equation 11). First differencing the equation over time yields,

$$\Delta\ln\left(\frac{p_iq_i}{P}\right) = \frac{1}{r}\sum_j a_j \Delta\ln X_{ij} + \frac{1}{r}\Delta\ln A_i + \frac{1}{r}\Delta\ln D_i + (1-r)\Delta\ln Q \qquad (18)$$

We can rewrite equation (18) in terms of log changes in labour productivity:

$$\Delta\ln\left(\left(\frac{p_i q_i}{P}\right)\Big/L\right)=\frac{1}{r}\sum_j a_j\Delta\ln\left(X_{ij}/L\right)+\frac{1-r}{r}\Delta\ln L_i$$
$$+\frac{1}{r}\Delta\ln A_i+\frac{1}{r}\Delta\ln D_i+(1-r)\Delta\ln Q \qquad (19)$$

where L denotes labour input. The equation shows that process and product innovations (proxied by $\Delta\ln A_i$ and $\Delta\ln D_i$) both have a positive effect on the revenue- or value-based labour productivity growth. If we observe price and output at the firm level and have defined firm-level labour productivity as output per worker, product innovation would have no effect on productivity. However, we do not observe price and output at the firm level and have defined labour productivity based on revenue deflated by an aggregate price. Consequently, product innovation enters the productivity growth equation through its effect on the output price of individual producers.

In addition to the labour productivity growth equation (19), the second equation that we estimate is market-share changes. First differencing equation (13) over time, we have

$$\Delta\left(p_i q_i/PQ\right)=bA_i^{s-2}D_i^{s-1}P^{s-1}\Delta A_i+bA_i^{s-1}D_i^{s-2}P^{s-1}\Delta D_i+bA_i^{s-1}D_i^{s-1}P^{s-2}\Delta P \qquad (20)$$

where $b=(s-1)\left(\frac{j(w)s}{s-1}\right)^{1-s}$. The equation shows that market-share changes are positively related to product and process innovations. If we interpret A_i as productivity, the equation suggests that market-share increases with productive level and productivity growth. Firms with higher productive level and faster productivity growth tend to grow faster and gain market shares. The productivity level is a function of developed competencies across a number of different areas. Equation (20) also shows that an increase in industry aggregate price P, that comes from a firm's competitors, will lead to an increase in the market share of a firm. A high price charged by the firm's competitors makes the firm's product more attractive and thus increases its demand.

2.6 Extensions of the model

To examine the link between innovation and firm performance, we have abstracted from firm entry and exit in our model. However, the model can be extended to allow for firm entry and exit. The model will have a basic structure that is similar to the model of Ericson and Pakes (1995). Productivity, product quality and thus revenue of a firm are assumed to follow a probability distribution. A firm's investment in process and product innovation is assumed to increase the revenue of the firm through its impact on productivity and product quality (A_i and D_i in Equation 14).[9] It can be shown from the results in Ericson and Pakes (1995) that firms with a higher productivity level are firms that innovate and are more likely to survive:

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[9] More precisely, the probability distribution of firm revenue associated with high R&D investment is assumed to stochastically dominate the probability distribution associated with lower R&D investment.

$$Prob(SURV_i = 1) = \Phi\left(A_i, \Delta A_i, D_i, \Delta D_i\right) \tag{21}$$

where the term on the left-hand side is the probability that firm i survives over a period. In our empirical analysis, we interpret A_i as the productivity level of a firm, and ΔA_i and ΔD_i as process and product innovations.

Our model can also be extended to allow for the effect of past growth performance on innovation. Successful and growing firms may find it easier to raise capital for their investments in innovation, thus lowering the cost of innovation (see equation 16). This lower cost of innovation will in turn lead to high innovation. Strong growth in the past also facilitates learning, which leads to the accumulation of competencies within a firm (Bahk and Gort, 1993).

3. Empirical formulation

The objective of our empirical investigation is to estimate the innovation production function (5) and (6), the survival equation (21), the value-based productivity growth equation (19), and the market-share equation (20). In this section, we discuss data and measurement of variables in estimating these equations.

3.1 Data

The data used for this paper come from two micro data sources: the Survey of Innovation and Advanced Technologies (SIAT) and a longitudinal file developed from the Annual Survey of Manufactures (ASM). The Survey of Innovation and Advanced Technologies was conducted in 1993 and randomly surveys the universe of manufacturing firms. There are five sections in the innovation section of the questionnaire: section 1 contains general questions on firm characteristics and the emphasis given to certain competencies; section 2, R&D questions; section 3, innovation questions; section 4, intellectual property questions; and section 5, technology questions. These five sections provide a comprehensive overview of firms' innovative and technological capacities.[10]

The Survey of Innovation and Advanced Technologies was designed to randomly sample all plants in the manufacturing sector and their parent firms and to provide a coefficient of variation of around 5%. The sampling procedure was two-stage—focusing separately on larger and smaller plants and providing stratification at the 2-digit industry level. There were 1,954 plants of larger firms sampled and 2,180 small firms sampled in the SIAT. Of the 1,954 large plants, 1,467 were matched with the longitudinal file of manufacturing plants.[11] These 1,467 plants form the sample used for this paper.[12] For plants that belong to multi-plant firms, the questions

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[10] See Baldwin and Hanel (2003) for more details and a copy of the survey questionnaire.

[11] 434 small firms were also matched between the SIAT and ASM longitudinal file. But these plants were excluded from our sample as they were not required to answer the section on innovation.

[12] The sample used in a particular regression will differ across specifications because some observations may be missing for some variables.

on innovation and R&D were sent to their head offices, and only the fifth section on technology use was addressed to plant managers. As such, innovation activities for these plants represent those of its parent firms. The plants in our matched sample accounted for 36 percent of total shipments in the manufacturing sector, and 13 percent of total employment. We use the sample weights from the survey for our estimates reported herein.

The SIAT provides a rich set of measures of innovation for individual firms in the manufacturing sector. However, the SIAT has no information on performance and survival for those firms. To examine the link between innovation and performance and survival, we have linked the SIAT to a longitudinal file of plants from the ASM, which provides information on productivity growth, market-share changes and survival for all Canadian manufacturing plants. The ASM collects information on nominal value added of individual plants. To obtain real value added, we have deflated nominal value added using value-added implicit prices for the 4-digit industries to which the plants belong. Because the ASM is linked to Statistics Canada's Business Register that was used to derive the representative sample of the population used in the innovation survey, we can link the innovation survey to the ASM database.

In what follows, we conduct our analysis on the determinants of innovation at the firm level and on the link between innovation and performance and survival at the plant level. In other words, we ask whether the performance and survival of a plant is related to innovation of its parent firms. We recognize that this introduces a potential ambiguity into the analysis since ultimately we are interested in whether a firm's overall performance is related to its innovation activity. But as soon as performance measures are introduced, working at the plant level considerably simplifies the analysis. Plants either continue to exist or die. As such, their performance is relatively easy to measure. On the other hand, firms not only die; they also undergo dramatic amounts of restructuring as plants are sold off and others are acquired. It is therefore much more difficult to measure the performance of a firm. For this reason, we focus here on the performance of a plant for the analysis.

3.2 Innovation production function

The innovation production function (equations 5 and 6) models innovation in a period as a function of existing knowledge stock within the firm and R&D inputs. We have two measures of knowledge stock within the firm: sets of competencies and past innovation of the firm. The competencies can be thought of as firm-specific knowledge assets, often accumulated over a long period of time, that distinguish innovators from non-innovators.

The competencies in areas of technology, production, human resources management, and marketing have been shown to be essential for innovation (Äkerblom, et al., 1996; Baldwin and Hanel, 2003; Leiponen, 2000). Innovators require technical competencies related to production processes that often reside in engineering departments. They also need skilled workers, which requires the development of human resource management strategies for training and the retention of knowledge workers. Innovating firms also have to penetrate new markets, and this requires special marketing capabilities. Innovating firms require a special type of capital that supports soft assets related to knowledge development and this in turn requires a special type of financing skills.

The second measure of knowledge stock within a firm is the past innovation of a firm, as proxied by the use of patents or trade secrets in the past. We use both forms of intellectual property protection because firms protect product innovations and process innovations in different ways. Patents are used more frequently to protect product innovations and trade secrets are used more frequently to protect process innovations (Baldwin and Hanel, 2003). Since a considerable lag exists between the date that a patent application is filed and the date it is granted, finding that a firm is using patents indicates that the firm was innovative in the past and thus has developed innovation competencies.

As we have discussed, strong growth in the past may contribute to high innovation. We have constructed two measures of past growth: labour productivity growth and market-share changes over a period before the introduction of an innovation. Baldwin and Diverty (1995) find that strong past growth is related to technology use and process innovation in Canadian manufacturing plants.

In sum, our estimation equation for innovation production becomes

$$\begin{aligned} PROC\_INNOV_i &= a_1 + a_2 RD_i + a_3 COMP_i + a_4 INNOV\_PAST_i \\ &\quad + a_5 GROWTH_{i,-1} + b X_i + e_i \\ & \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (22) \\ PROD\_INNOV_i &= b_1 + b_2 RD_i + b_3 COMP_i + b_4 INNOV\_PAST_i \\ &\quad + b_5 GROWTH_{i,-1} + g X_i + e_i \end{aligned}$$

where $PROC\_INNOV_i$ and $PROD\_INNOV_i$ are measures of the incidence of process and product innovation for firm i, RD_i measures R&D input to innovation, $COMP_i$ firm-specific competencies, $PAST\_INNOV_i$ past innovation, and $GROWTH_{i,-1}$ past growth in productivity and market share. The set of control variables X_i includes firm size, the age of the firm, ownership (foreign- vs. domestic-controlled plants) and an indicator for export intensity. Each of these (size, age, ownership and export intensity) is a proxy for firm-specific knowledge assets that are not captured by our measures of competencies and past innovation activities of a firm. We also include a set of industry fixed effects that control for industry specific demand-pull and technology-push factors that are common to all firms within the industry.

The 1993 Survey of Innovation and Advanced Technologies provides information on whether the firm has introduced an innovation during the period 1989-1991. As such, our measures of innovations ($PROC\_INNOV_i$ and $PROD\_INNOV_i$) refer to the period 1989-1991. The past growth variables are calculated over the period 1985-1989.[13]

The technique chosen here for estimating equation (22) varies depending on whether we use the incidence of innovation or the intensity of innovation as dependent variable. For the incidence of

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[13] To test the robustness of our results, we will experiment with different choices of periods for calculating past growth.

innovation, we use Probit regression, as the dependent variable is a binary variable, which takes a value of one for innovating firms and zero for non-innovating firms. For the intensity of innovation (the number of innovations and the share of sales from product innovation), we use ordered Probit regression as the dependent variable is constructed as intervals. For the share of sales from product innovation, we use 0%, 1-5%, 6-20%, and 21-100%. For the number of innovations, we use the intervals 0, 1-2, 3-4, 5-6, and >6.

3.3 Plant survival

In estimating the plant survival equation (21), we interpret the variable A_i as the total factor productivity (TFP) level of a firm. As the information on capital stock and investment are not available from our data, we do not include TFP in the plant survival equation. We use labour productivity instead. If we interpret the variables ΔA_i and ΔD_i as process and product innovation, a Probit model for plant survival becomes,

$$Prob(SURV_i = 1) = \Phi\begin{pmatrix} a_1 + a_2 LP_i + a_3 PROC\_INNOV_{i,-1} + \\ a_4 PROD\_INNOV_{i,-1} + bZ_i \end{pmatrix} \tag{23}$$

where $SURV_i$ represents plant survival that takes a value of one for plants that survived during the period 1993-1997 and zero for plants that did not, Φ is cumulative normal distribution, LP_i is the labour productivity of plant i in 1993, and Z_i includes observed plant characteristics in 1993 such as plant size, the age of the plant, export status, and ownership.[14] A set of dummy variables is also included to control for industry fixed effects on the survival of plants within an industry. $PROC\_INNOV_{i,-1}$ and $PROD\_INNOV_{i,-1}$ are measured over the preceding period 1989-1991 to address the issue of simultaneity bias in estimating the effect of innovation on plant survival.

3.4 Labour productivity growth

Labour productivity in our empirical analysis is defined as value added per worker. Equation (19) suggests that labour productivity growth is a function of process and product innovations. The estimation equation for labour productivity growth becomes,

$$\begin{aligned} LPCHG_i = b_1 + b_2 PROC\_INNOV_{i,-1} + b_3 PROD\_INNOV_{i,-1} \\ + b_4 Z_i + s\, f\left(aX_i\right)/\Phi\left(aX_i\right) + m_i \end{aligned} \tag{24}$$

where $LPCHG_i$ represents labour productivity growth in a period. We have included in the equation the inverse Mills ratio $(s\, f\left(aX_i\right)/\Phi\left(aX_i\right))$ from the plant Survival Probit (22) to correct for sample selection bias. This sample selection bias arises because we use a sample of

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[14] Export status and ownership is based on the year 1991.

continuing plants to estimate the productivity growth equation.[15] The set of control variables Z_i includes plant size, plant age, export status, ownership (all proxy measures of firm competencies), and a set of industry dummies.

In estimating the labour productivity growth equation, we include initial labour productivity to take into account the natural process of regression-to-the-mean. Plants that have high (low) productivity at the beginning of a period tend to regress to the mean over the period. If this phenomenon is not taken into account, coefficient estimates on product and process innovations may be biased.

We have excluded the capital/labour ratio in estimating the labour productivity growth equation. Consequently, the estimated coefficients on innovation variables capture the combined effects of innovation on TFP and changes in the capital/labour ratio. But changes in both of these variables tend to be closely associated and therefore combining the effects of both together is appropriate. Innovation, particularly process innovations often involve the purchase of new machinery and equipment and increases in capital labour ratios. Innovation is expected to raise labour productivity growth both through its impact on production efficiency and capital intensity.

3.5 Market-share changes

The market share of a plant is defined as the share of the plant's sales in total sales of the 4-digit industry to which the plant belongs. Our model suggests that the growth in market share is related to product and process innovation. It is also related to initial productivity and productivity growth. The regression equation for market-share growth is,

$$\begin{aligned} MSCHG_i = {} & b_1 + b_2 PROC\_INNOV_{i,-1} + b_3 PROD\_INNOV_{i,-1} \\ & + b_4 REL\_LP_i + b_5 REL\_LPCHG_i + b_6 Z_i + s f\left(aX_i\right)/\Phi\left(aX_i\right) + m_i \end{aligned} \qquad (25)$$

where $MSCHG_i$ represents market-share changes in a period. The inverse Mills ratio ($s f\left(aX_i\right)/\Phi\left(aX_i\right)$) is included to correct for sample selection bias. REL_LP_i is the labour productivity of plant i relative to the average labour productivity growth of the 4-digit industry to which the plant belongs; and REL_LPCHG_i is the relative labour productivity growth. The set of control variables Z_i, which includes plant size, plant age, export status and ownership, are proxy measures of firm competencies. This set of control variables also includes initial market share to account for the natural process of regression-to-the-mean.

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[15] Similar models for firm growth were estimated by Hall (1987) and Doms et al. (1995).

4. Empirical results

In this section, we first present empirical results on the determinants of innovation. We then present results on the relationship between innovation and growth or survival.

4.1 Descriptive statistics

Sample statistics on innovation, plant survival and plant growth are presented in Table 1. We find that 36 percent of the plants in the sample belong to firms that introduced innovations (product or process) during the period 1989-1991. We divide innovators into three major groups: 1) product innovators that introduce product changes without changes in manufacturing technologies: 2) process innovators that introduce process changes without product changes; and 3) comprehensive innovators that introduce both product and process innovations. The largest group consists of comprehensive innovators. Some 23 percent of the plants were comprehensive innovators, compared with 6 percent that were product innovators only and 7 percent for process innovators only.

Table 1. Sample statistics on innovation, plant survival and plant growth

Variable	Mean	Standard errors
Innovation incidence		
Innovation	0.36	0.48
Product no process	0.06	0.24
Process no product	0.07	0.25
Product and process	0.23	0.42
World-first	0.06	0.24
Non-world-first	0.27	0.44
Innovation intensity		
% of Innovative sales		
0%	0.74	0.44
1-5%	0.08	0.28
6-20%	0.10	0.30
21-100%	0.08	0.27
Number of Innovations		
0	0.77	0.42
1-2	0.09	0.28
3-4	0.06	0.24
5-6	0.04	0.19
>6	0.04	0.19
Plant growth and survival		
Share of plants surviving in 1993-1997 Period (%)	86.38	34.31
Labour productivity growth (% per year)		
1993-1997	1.34	15.25
1989-1993	-0.77	16.83
1985-1989	1.20	15.78
Market-share shifts (% points per year)		
1993-1997	-0.01	0.17
1989-1993	0.04	0.31
1985-1989	0.02	0.36

Note: Establishment-weighted sample statistics are reported.

We also divide innovators into those who introduced world-firsts and those who introduced others types of innovations. The majority of innovators introduced innovations that had already been introduced elsewhere (either in Canada or in other countries). Only 18 percent of all innovators were world-first innovators while some 82 percent were non-world-first innovators.[16]

In this paper, we examine both the incidence of innovation—whether or not firms introduce innovations, as well as the intensity of innovation—whether firms introduced large number of innovations or reported that a larger share of their sales came from product innovations. We find that the distribution of innovative sales is skewed. Only 8 percent of plants derive more than 20 percent of their sales from major, product innovations (Table 1). More innovators introduced 1-2 innovations (39%) than introduced more than 6 innovations (17%) during the period 1989-1991.

In the bottom panel of Table 1, we report sample statistics on plant survival and plant growth. Eighty-six percent of the plants survived over the period 1993-1997. The survival rate in our sample is higher than for all Canadian manufacturing plants (see, Baldwin and Gu, 2003b). This reflects the fact that our sample consists of plants belonging to larger firms.

Sample statistics on plant characteristics, firm-specific competencies, R&D inputs, and past innovation are presented in Table 2. Some 23 percent of plants are foreign-controlled plants, 50 percent are older plants that entered the manufacturing sector before 1983, and 35 percent are larger plants with more than 100 workers. We also find that 33 percent of firms have more than 500 workers, and 51 percent are exporters.[17]

Table 2. Sample statistics on plant characteristics, competencies and R&D

Variable	Mean	Standard errors
Plant and firm characteristics		
Foreign-controlled plants	0.23	0.42
Domestic-controlled plants	0.77	0.42
Exporters	0.51	0.50
Age cohort: 1983-1993	0.50	0.50
Age cohort: pre-1983	0.50	0.50
Plant size: 1-100 workers	0.65	0.48
Plant size: 100+ workers	0.35	0.48
Firm size: 1-500 workers	0.67	0.47
Firm size: 500+ workers	0.33	0.47
Firm-specific competencies		
Marketing	3.24	0.96
Technology	3.09	0.91
Production	3.53	0.78
Human resources	3.08	0.96
Inputs to innovation process		
R&D	0.37	0.48
Separate R&D Department	0.29	0.45
Past innovation activity		
Patents or trade secrets use	0.30	0.46

Note: Establishment-weighted sample statistics are reported.

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[16] The sample used for measuring whether innovators were world-first or non-world first is slightly smaller than the sample used to define innovators because some innovators do not indicate whether their innovations were world-firsts or non-world-firsts.

[17] In this paper, we define exporters to include those plants that derive at least 10 percent of their sales from exports. We find there is little difference between the plants that do not export and the plants that export less than 10 percent of their total shipments. See also Baldwin and Hanel (2003, chapter 10).

To measure a firm's competencies in marketing, technology, production and human resources, we use the firm's responses to questions about the importance that a firm gives to the strategies in each of these areas. For marketing strategy, three questions are used: the importance that a firm gives to introducing new products in present markets, current products in new markets or new products in new markets. For technology strategy, four questions are used: the importance that a firm gives to developing new technology, improving others' technology, or using others' technology, and improving own existing technology. For production strategy, four questions are used: the importance of using new materials, using existing materials more efficiently, cutting labour costs, or reducing energy costs. For human resources strategy, two questions are used: the importance of continuous staff training or innovative compensation packages.

Each question on the importance given to a particular strategy is scored by the firm on a Likert scale that ranges from 1 (not important) to 5 (crucial). The scores to the questions in each area are then averaged to yield a measure of firm competencies in the area. The mean value of the competency measure in each of the four areas (marketing, technology, production and human resources) is between 3 and 4 (Table 2). An average producer in the sample gives a score of between important (3) and very important (4) to the strategies in these four areas.[18]

Previous studies on innovation often use R&D expenditures as an input to the innovation process. However, information on R&D expenditures was not collected in the 1993 Survey of Innovation and Advanced Technology. Instead, we use discrete variables indicating whether a firm performed R&D and whether a firm had a separate R&D unit. Some 37 percent of the firms in the sample performed R&D continuously[19], and 29 percent had a separate R&D department.

4.2 Empirical results for the determinants of innovation

The results from estimating a probit equation (1) for innovation are presented in Table 3. These results use a discrete binary dependent variable indicating whether or not a firm introduced innovations during the period 1989-1991. Two measures of past growth are included as independent variables. They are productivity growth during the period 1985-1989 and market-share changes during the period. The sample used for estimating the innovation equation (1) excludes the plants that entered the manufacturing sector after 1985.[20] The growth performance over the 1985-1989 period is not defined for these plants. We have also excluded from our sample sixteen plants with unusually large annual productivity growth rates.[21] The final sample for estimation includes 983 plants.

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18. For a study that makes extensive analysis of how a firm's strategic emphasis relates to its performance, see Baldwin and Gellatly (2003).

19. We consider only those plants doing R&D continuously (as opposed to performing R&D occasionally) because firms rated themselves as being much more competitive with regards to R&D when they did the former and not the latter (see Baldwin and Hanel, 2003).

20. This may introduce a sample selection bias. We will address the issue at the end of this section.

21. We used the command Hadimvo in STATA software to identify those plants. See Hadi (1992, 1994) for detailed discussion of the method.

Table 3. Probit model of innovation incidence

	Innovation	Product innovation	Process innovation	World-first innovation	Non-world-first
	(1)	(2)	(3)	(4)	(5)
R&D input					
R&D performer	0.124*	0.137*	0.123*	0.054*	0.042
	(2.39)	(2.85)	(2.55)	(3.56)	(0.88)
R&D department	0.044	0.104*	-0.029	0.005	0.012
	(0.81)	(2.03)	(-0.58)	(0.44)	(0.25)
Competencies					
Marketing	0.031	0.005	0.045*	0.007	0.006
	(1.27)	(0.23)	(1.98)	(1.18)	(0.29)
Technology	0.076*	0.073*	0.067*	0.011	0.054*
	(2.70)	(2.71)	(2.55)	(1.49)	(2.12)
Production	-0.019	-0.029	0.012	-0.013	0.020
	(-0.63)	(-1.03)	(0.43)	(-1.88)	(0.71)
Human resources	0.028	0.016	0.002	0.000	0.033
	(1.17)	(0.67)	(0.11)	(0.01)	(1.51)
Past growth					
Productivity Growth, 1985-1989	-0.046	-0.003	-0.028	-0.029	-0.052
	(-0.35)	(-0.02)	(-0.25)	(-0.81)	(-0.45)
Market-share Change, 1985-1989	0.008	-1.430	1.629	-0.472	0.796
	(0.00)	(-0.35)	(0.44)	(-0.66)	(0.22)
Past innovation					
Use of patents or trade secrets	0.230*	0.232*	0.184*	0.021	0.164*
	(5.10)	(5.59)	(4.33)	(1.73)	(3.98)
Firm characteristics					
Foreign-controlled plants	0.054	0.045	0.031	0.014	0.014
	(1.15)	(1.02)	(0.71)	(1.15)	(0.32)
Large firms (more than 500 workers)	0.104*	0.053	0.144*	0.024	0.049
	(2.20)	(1.22)	(3.36)	(1.87)	(1.17)
Older firms (entered pre-1983)	-0.030	-0.012	0.002	-0.007	-0.027
	(-0.73)	(-0.32)	(0.04)	(-0.66)	(-0.73)
Exporters	0.085*	0.077*	0.047	-0.001	0.051
	(2.05)	(2.01)	(1.20)	(-0.12)	(1.38)
Log likelihood	-523.34	-479.00	-504.12	-179.62	-529.63
No. of observations	983	983	983	874	983

Note: All regressions include a set of dummy variables for 22 industries at the two-digit level of industry aggregation. Marginal effects are reported. Robust t-statistics are in parentheses. One asterisk denotes statistical significance at the 5 percent level.

The marginal effects from estimating the probit model of innovation are presented in Table 3. In the first specification, we present probit estimates for all innovations. In the next two specifications, we present results for product and process innovations. Product innovators are defined as those firms that introduced product innovations over the period 1989-1991, which include pure product innovators and comprehensive innovators that introduced both product and process innovations. Process innovators are defined as those firms that introduced changes in manufacturing technology, which includes pure process innovators and comprehensive innovators. As shown in Table 1, 29 percent of the producers in our sample are product innovators while 30 percent are process innovators.[22] In the last two specifications reported in

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[22] These numbers differ slightly from those reported in Baldwin and Hanel (2003) because our sample is slightly smaller because it has been matched to longitudinal data. Nevertheless, the results are quite similar.

Table 3, we divide innovators into those who introduced world-first innovations as opposed to non-world-first innovations.

Consistent with most previous studies on R&D and innovation, our results show that R&D is an important determinant of innovation. The innovation rate for the firms that perform R&D is 12 percentage points higher than those not performing R&D. The difference is statistically significant at the 1 percent level. Our results also show that having a separate R&D department within a firm is not related to innovation. The latter confirms Baldwin and Hanel's (2003) observation that firms with a separate R&D unit did not assess themselves as having a more effective R&D program than those without a separate R&D department.

The importance of R&D for innovation differs across types of innovations. R&D is more important for product innovations than for process innovations. Our results show that having an R&D department is associated with a 10 percentage point increase in product innovation rates. However, the presence of an R&D department is not as important for process innovations. Our results also show that the firms that perform R&D have a product innovation rate that is 14 percentage points higher that those that do not. In contrast, the difference in process innovation rates is only 12 percentage points. This is probably because process innovations are more likely to originate in engineering departments than in R&D departments (Baldwin and Hanel, 2003). Nevertheless, R&D is important in both cases.[23]

The technology competency variable is related to innovation. The relationship is statistically significant at the 5 percent level for product and process innovation but not for world firsts. Firms that place more emphasis on their technology strategy are more innovative. While the commitment of firms to R&D is important for innovation, the technological competencies that are accumulated over time are also essential. In contrast, the emphasis on marketing, production and human resources is not significantly related to innovation.

The results show that firms that developed innovations in the past are more likely to innovate. The use of patents and trade secrets, which is associated with past innovation, is a strong predictor of being an innovator today. The firms that have obtained patents or used trade secrets to protect their intellectual property in the past have innovation rates that are 23 percentage points higher than those with no intellectual property rights. The difference is 23 percentage points for process innovations, 18 percentage points for product innovations, 2 percentage points for world-first innovations, and 16 percentage points for non-world-first innovations.

While competencies that require time to build matter, we do not find evidence either for the view that strong growth in the past has feedback effects, or for the view that strong growth reduces the incentive to innovate. Our results show that productivity growth and market-share changes during the period 1985-1989 are not significantly related to the incidence of innovation during the period 1989-1991.

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23. Dividing innovations into process only and product only innovations increases the difference in the effect of the R&D variable (see Baldwin and Hanel, 2003, ch. 14).

The coefficients on the variable representing various firm characteristics indicate that larger, exporting firms are more innovative than smaller non-exporting firms.[24] Our sample statistics show that foreign-controlled firms are more innovative. The foreign-controlled firms have innovation rates that are about 10 percentage points higher than their domestic counterparts. However, the higher innovation rates of foreign-controlled producers are a result of their larger size, higher export participation rates and larger stock of knowledge assets. After controlling for these firm characteristics, the nationality of a firm is not related to innovation.

Overall, these results are consistent with the findings from previous studies on relationship between innovation and firm size, ownership and export participation (Baldwin and Hanel, 2003). The coefficient on firm size for process innovation indicates that large firms tend to have higher process innovation rates than smaller firms. Our results also show that there is no significant difference in product innovation rates between larger and smaller firms. This supports the view of Cohen and Klepper (1996) that firm size is related more to process innovation than to process innovation.

Our probit model of innovation incidence for just those producers that are innovators includes past growth over the period 1985-1989 as independent variables. To estimate the model, we have excluded about 300 plants that entered after 1985 from our sample. When we use the sample that includes all plants to estimate a model of innovation that excludes past growth, the coefficients on other independent variables remain virtually unchanged (Table A1 in the appendix).

The variables on past growth in Table 3 are calculated over a four-year period (1985-1989) prior to the period 1989-1991 during which innovations are introduced. When we define past growth over one-, two-, and three-year periods (1988-1989, 1987-1989, and 1985-1989), we find that the results remain the same. We find no evidence that past growth is related to innovation.

We present our regression results for the determinants of innovation intensity in Table 4. The sample consists of only those 400 producers that introduced an innovation. For the model that includes past growth variables, we further restrict our sample to those plants that entered the manufacturing sector before 1985.[25] Our results show that *within the group of innovators,* R&D is not related to innovation intensity. But the innovators that place more emphasis on human resource strategy have a higher innovation intensity. Those firms tend to introduce more innovations and have a higher share of sales that comes from product innovation.

Our results also show that past productivity growth is not related to innovation intensity. However, past changes in market shares are related to the number of innovations introduced by successful innovators—suggesting perhaps that these firms are occupying as many market niches as possible.[26] Those firms with increasing market shares tend to introduce more innovations than those with declining market shares. While larger firms have a higher innovation incidence, our results indicate that larger firms generally do not have a higher intensity of innovation. The share of innovative sales is smaller for larger firms, while the number of innovations introduced is

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[24] Baldwin and Gu (2003) show that firms that begin exporting or that increase their export intensity become more productive, probably through a learning effect.

[25] Due to the small sample size, we are cautious about our results on the determinants of innovation intensity.

[26] Sutton (1991, ch.8) contains a discussion that this outcome will prevail in product differentiated markets.

similar between larger and smaller firms. Overall, the results on firm size are consistent with findings from previous studies. For example, Crépon, Duguet and Mairesse (1998) find that the share of sales from innovation is not related to firm size in a sample of French manufacturing firms.

Table 4. Ordered probit model of innovation intensity

	% Share of innovative sales		Number of innovations	
	(1)	(2)	(3)	(4)
R&D input				
R&D performer	0.202	0.026	-0.044	0.144
	(0.99)	(0.14)	(-0.19)	(0.66)
R&D department	0.136	0.152	0.071	-0.038
	(0.70)	(0.89)	(0.27)	(-0.17)
Competencies				
Marketing	0.087	0.047	0.172	0.218*
	(0.80)	(0.51)	(1.58)	(2.15)
Technology	-0.206	-0.102	0.108	-0.008
	(-1.45)	(-0.80)	(0.83)	(-0.07)
Production	-0.155	-0.140	-0.122	-0.103
	(-1.22)	(-1.26)	(-0.91)	(-0.90)
Human resources	0.205*	0.177*	0.219*	0.135
	(2.04)	(1.96)	(2.34)	(1.55)
Past growth				
Productivity growth, 1985-1989	-0.015		0.176	
	(-0.03)		(0.29)	
Market-share change, 1985-1989	-15.624		28.090	
	(-1.49)		(1.94)	
Past innovation				
Use of patents or trade secrets	-0.174	-0.128	0.217	0.114
	(-1.01)	(-0.86)	(1.10)	(0.66)
Firm characteristics				
Foreign-controlled plants	-0.179	-0.173	-0.397*	-0.355*
	(-1.00)	(-1.09)	(-1.96)	(-2.01)
Large firms (more than 500 workers)	-0.987*	-0.746*	0.131	0.198
	(-5.25)	(-4.33)	(0.64)	(1.11)
Older firms (entered pre-1983)	0.220	-0.006	0.177	0.198
	(1.29)	(-0.04)	(0.96)	(1.29)
Exporters	0.188	0.183	0.202	0.171
	(1.11)	(1.22)	(0.93)	(0.90)
Log likelihood	-276.76	-373.78	-309.14	-398.21
No. of observations	292	375	259	325

Note: All regressions include a set of dummy variables for 22 industries at the two-digit level of industry aggregation. Robust t-statistics are in parentheses. One asterisk denotes statistical significance at the 5 percent level.

4.3 Empirical results for plant survival

The share of plants that survived over the 1993-1997 period differs for innovating and non-innovating plants (Table 5). Innovating plants have higher survival rates than non-innovating plants. The differences are larger for process than product innovations. However, we find little evidence that world-first and non-world-first innovations have differential effects on plant survival. There are a number of possible reasons for this—including the possibility that world-first innovators are more frequently multinationals and these firms were restructuring during the early 1990s in response to the introduction of the North American Free Trade Agreement between Canada, the United States and Mexico.

Our results in Table 5 also show that plant survival is not monotonically related to innovation intensity among innovating plants. An increase in the share of sales due to a major innovation from 0% to between 1% and 5% is associated with a decline in plant survival. But a further increase leads an increase in plant survival. Similarly, the number of innovations is not found to be monotonically related to plant survival.

Table 5. Innovation and plant survival

	% of Plants surviving in 1993-1997
Innovation incidence	
No innovation	85.29
Innovation	88.35
Product innovation	86.68
Process innovation	89.38
World-first	89.15
Non-world-first	87.84
Innovation intensity	
Share of innovative sales	
0%	86.58
1-5%	82.76
6-20%	84.84
21-100%	90.84
Number of innovations	
0	85.54
1-2	89.80
3-4	91.21
5-6	86.76
>6	87.53

Note: Establishment-weighted sample statistics are reported.

The results from a probit model of plant survival are presented in Table 6. All the regressions include controls for industry fixed effects. In the first specification, we introduce a discrete variable indicating whether the plant's parent introduced any innovation—product or process. The coefficient on the innovation variable is not significant at the 5 percent level, which indicates that innovation in general is not related to plant survival.

Table 6. Probit results of survival on innovation incidence

Variables	(1)	(2)	(3)
Innovation	0.013		
	(0.59)		
Product innovation		-0.064*	
		(-2.02)	
Process innovation		0.060*	
		(2.23)	
World-first innovation			0.020
			(0.52)
Non-world-first innovation			0.007
			(0.30)
Log of labour productivity	0.063*	0.063*	0.064*
	(3.85)	(3.85)	(3.87)
Foreign-controlled plants	-0.104*	-0.102*	-0.104*
	(-3.65)	(-3.61)	(-3.65)
Large plants (>=100 workers)	0.047*	0.049*	0.048*
	(1.98)	(2.04)	(2.03)
Older plants (entered pre-1983)	0.035	0.035	0.035
	(1.61)	(1.60)	(1.61)
Exporters	0.013	0.014	0.013
	(0.59)	(0.67)	(0.60)
Log likelihood	-518.43	-515.74	-511.29
No. of observations	1,382	1,382	1,382

Note: The dependent variable is a binary variable indicating whether or not a plant survived over the period 1993-1997. All regressions include a set of dummy variables for 22 industries at the two-digit level of industry aggregation. Marginal effects are reported. Robust t-statistics are in parentheses. One asterisk denotes statistical significance at the 5 percent level.

In the last column of Table 6, we examine the difference in the effect of world-first as opposed to non-world-first innovations on plant survival. This difference is not statistically significant at the 5 percent level. This indicates that innovations in general, whether they be world-firsts or non-world-firsts, are not related to higher plant survival.

While innovation in general is not positively associated with improving a producer's chances of survival, process innovation in particular does make a difference. Previous studies find that product innovation and process innovation have different effects on plant survival. For example, Cosh et al. (1999) find that while process innovation is associated with higher survival rates, product innovation does not have the same effect in a sample of small and medium-sized firms in the U.K. Our results are consistent with Cosh's findings for the U.K. The effect of process innovation on plant survival is significant. The firms that introduced process innovations during the period 1989-1991 have plant survival rates that are 6 percentage points larger than those that did not. This represents a modest 7 percent increase in plant survival, as the average survival rate in our sample is 87 percent. In contrast, the coefficient on product innovation is negative.[27] One explanation of this finding is that product as opposed to process innovators are at different phases of the product life cycle. Product innovation dominates the early stages of the life cycle when turnover is high: process innovation occurs later when market shake outs have already

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[27] The difference in the coefficients between product and process innovations is statistically significant at the 5 percent level.

occurred and competition no longer depends as much on providing unique product characteristics, but rather emphasizes price advantages because products have become more homogeneous.[28]

The results in Table 6 also show that more productive plants and larger plants have higher survival rates. Age and export participation of a plant are not related to a plant's survival. Our sample statistics show that foreign- and domestic-controlled plants have similar survival rates for the period 1993-1997. Controlling for plant size and productivity, we find that foreign-controlled plants have lower survival rates. This is consistent with the findings from previous studies (Baldwin and Gu, 2003b; Bernard and Jensen, 2002; Doms et al., 1995). This suggests that multinationals have an enhanced ability to shift productions across locations within the firm (Rodrik, 1997).

We have also examined the relationship between the survival rate of a plant and the innovation *intensity* as opposed to innovation *incidence* (percent of sales originating in innovative products) of its parent firm. As shown in Table 7, the share of innovative product sales from product innovation is not related to plant survival. This sales variable only captures the importance of product innovations and therefore the result is consistent with our finding that product innovation is not associated with higher survival rates. We conclude that the survival of a plant is higher when its parent firm is a successful process innovator—but that survival is related neither to whether a producer is a product innovator, nor to the intensity of product innovation.

The innovation activity of a firm may have different effects on survival for large vs. smaller plants, foreign- vs. domestic-controlled plants, young vs. older plants, and more vs. less productive plants. To examine this issue, we introduced interaction terms of the innovation variable and the variable for the size, ownership, age and productivity of a plant in our probit model of plant survival. The coefficients on the interaction terms are not statistically significant. Thus, innovation has similar effects on survival for large vs. smaller plants, foreign- vs. domestic-controlled plants, younger vs. older plants, and more vs. less productive plants.

4.4 Empirical results for labour productivity growth

The results for the growth in labour productivity for plants whose parent firms introduced innovations in the period 1989-1991 and for those that did not is presented in Table 8. Innovating plants had faster productivity growth than non-innovating plants. The plants that introduced a major innovation in the period 1989-1991 had annual productivity growth in 1993-1997 that was 2.23 percentage points higher than non-innovating plants. The largest productivity growth differential was found for world-first innovators, followed by non-world-first innovators and process innovators. However, for product innovators, the difference is quite small.

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[28] For more on differences in the type of innovations that take place across the life-cycle see Abernathy and Utterback (1978) and Gort and Klepper (1982).

Table 7. Probit results of survival on innovation intensity

Variables	(1)	(2)
Share of innovative sales		
0%		
1-5%	-0.031 (-0.84)	
6-20%	-0.020 (-0.53)	
21-100%	0.044 (1.35)	
Number of innovations		
0		
1-2		0.039 (1.03)
3-4		0.048 (1.25)
5-6		0.035 (0.73)
>6		-0.005 (-0.10)
Log likelihood	-516.83	-516.76
No. of observations	1,382	1,382

Note: The dependent variable is a binary variable indicating whether or not a plant survived over the period 1993-1997. All regressions include controls for plant productivity, ownership, size, export status and a set of dummies for 22 industries at the two-digit SIC level. Marginal effects are reported. Robust t-statistics are in parentheses. One asterisk denotes statistical significance at the 5 percent level.

Table 8. Innovation and productivity growth

	Productivity growth, 1993-1997 (% per year)	Productivity growth, 1989-1993 (% per year)
Innovation incidence		
No innovation	0.53	-1.24
Innovation	2.76	0.50
Product innovation	2.24	0.21
Process innovation	3.05	-0.31
World-first	4.70	0.37
Non-world-first	2.54	-0.20
Innovation intensity		
Share of innovative sales		
0%	1.41	-0.68
1-5%	1.12	-3.85
6-20%	-0.53	-0.33
21-100%	3.18	1.33
Number of innovations		
0	0.94	-0.82
1-2	4.39	0.41
3-4	2.92	-1.27
5-6	3.58	-4.12
>6	-2.72	1.44

Note: Establishment-weighted sample statistics are reported.

The evidence in Table 8 shows that innovation *intensity* within the innovator group is not monotonically related to productivity growth. That is true for both measures of innovation *intensity*. This is probably related to the fact that the first of the two variables captures just product innovation and the second captures both product and process innovation. And as the incidence equation indicates, it is process not product innovation that is more closely related to productivity growth. It is also possible that neither of the questions that are used to measure intensity is answered with enough precision to detect the effect that we are investigating. Measuring the precise amount of sales in a large company that come from a product innovation is difficult—especially if the innovation is incremental and is an add-on to an existing product (a new memory chip embedded in a computer).

In this paper, we relate innovation during the period 1989-1991 to plant growth during a subsequent period 1993-1997. Most previous studies relate innovation in a period to growth in the same period. As a result, these studies may introduce the problem of simultaneity. To illustrate the issue, we have calculated the productivity growth of innovating and non-innovating plants during the period in which the innovation was introduced, 1989-1993.[29] Our results in Table 8 show that during the period when the innovation was introduced, there is a much smaller difference in productivity growth between innovating and non-innovating plants.[30] The effect of innovation shows up mainly in the period after the innovation is introduced.

Regression results for productivity growth that control for sample selection due to plant exits are presented in Table 9. The results in the first column indicate that innovation has a positive effect on productivity growth. The effect is strong and statistically significant. Plants whose parent firms introduced innovations during 1989-1991 were characterized by productivity growth in the period 1993-1997 that was 3.5 percentage points faster than those whose parents did not.

The results in the second column show that product and process innovations have different effects on productivity growth—even though there is some overlap in the two categories. As was the case in the survival equation, the significant effect of innovation on productivity growth found in the first column is due to process innovation. Process innovation is a strong and significant determinant of productivity growth. In contrast, product innovation is not related to productivity growth. Our results indicate that process innovators had productivity growth that was 3.6 percentage points higher than non-process innovators. Our finding on the differential impact of process and product innovations for Canada is consistent with the findings of Criscuolo and Haskel (2003) for the U.K. and Leiponen (2000) for Finland. Both studies find that process innovation is related to productivity growth. The findings on product innovation differ between the two studies. Criscuolo and Haskel (2003) find that product innovation is not related to productivity growth for the U.K, while Leiponen (2002) finds it is negatively related to productivity growth for Finland. Consistent with our evidence on product innovation, Griliches (1998, chapter 6) finds that an increase in product R&D share of total R&D investment is associated with a lower rate of productivity growth. He suggests two reasons for this negative relationship. First, new products tend to be disruptive to established production processes and productivity growth is likely to suffer as a result. Second, where new products are an important

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[29] Firms introduced their innovation over the period 1989-1991. The period 1989-1993 used for calculating plant growth is longer and includes the innovation period.

[30] Our regressions also show that the difference is not statistically significant.

aspect of competition, the business may adopt a relatively flexible process technology and some sacrifice in productivity in the interests of flexibility is likely to result.

It should be noted that our analysis investigates how the performance of individual plants relates to the overall innovation performance of their parent firm. Since each plant in a firm may not benefit from that innovative activity of the firm as a whole, we experimented with an innovation variable that was more plant specific. Plants that were introducing new advanced technologies (robots, etc.) indicated whether they did so in conjunction with new product or process innovations. Using this information, we defined two new binary variables—one for process innovation associated with new technologies, one for product innovations associated with new technologies at the plant level—and interacted the plant product binary with the firm product binary and the plant process binary with the firm process binary. The coefficient on each interaction term was positive, thereby suggesting that new technologies (a type of process innovation) when combined with either the introduction of new products or new processes, are positively related to productivity growth.

When we divide innovations into world-firsts and non-world-firsts, we find that both types of innovation are related to productivity growth. However, world-first innovations have a much stronger effect on productivity growth (Column 3). World-first innovations led to a 4.2 percentage point increase in productivity growth, while non-world-first innovations are linked to a 3.5 percentage point increase.

Table 9. Effects of innovation incidence on productivity growth

Variables	(1)	(2)	(3)
Innovation	0.035*		
	(3.52)		
Product innovation		0.000	
		(0.02)	
Process innovation		0.036*	
		(2.81)	
World-first innovation			0.042*
			(2.42)
Non-world-first			0.035*
			(3.26)
Log of labour productivity in 1993	-0.122*	-0.123*	-0.122*
	(-13.01)	(-13.04)	(-12.97)
Foreign-controlled plants	0.060*	0.061*	0.061*
	(4.92)	(4.91)	(4.93)
Large plants (>=100 workers)	0.047*	0.048*	0.048*
	(4.99)	(4.98)	(5.05)
Older plants (entered pre-1983)	0.010	0.010	0.010
	(1.13)	(1.04)	(1.14)
Exporters	0.009	0.009	0.009
	(0.81)	(0.83)	(0.82)
Mills ratio	0.006	0.003	0.006
	(0.43)	(0.25)	(0.45)
Log likelihood	1,418.04	1,446.08	1,423.49
No. of observations	1,251	1,251	1,252

Note: The dependent variable is the annual productivity growth of a plant over the period 1993-1997. All regressions include a set of dummy variables for 22 industries at the two-digit level of industry aggregation. Robust t-statistics are in parentheses. One asterisk denotes statistical significance at the 5 percent level.

The coefficients on competency measures are not statistically significant at the 5 percent level and have not been reported. While a firm's competency in technological development is important for innovation, it has no additional effect on productivity growth.[31]

Our results indicate that there is a substantial regression-to-the-mean in productivity. Plants that start any period with high productivity tend to move back towards the mean over subsequent periods. This occurs because it is hard to maintain a leadership position in a competitive environment. The regression-to-the-mean effects that have been previously reported (Baldwin and Sabourin, 2001; Baldwin, Sabourin and Smith, 2004) are confirmed. It is useful to note that the inclusion of this variable increases both the size and significance of the effect of innovation. The most productive plants tend to be the ones that are more innovative. But the most productive plants also tend to regress to the mean. It is innovation that serves to reduce the inexorable tendency to decline once a firm has moved to the top—and if this process is ignored, innovation appears to have less impact. It is also noteworthy that it is only once regression-to-the mean is taken into account that foreign owned plants are found to have higher productivity growth than domestically-controlled plants.

The regression results on innovation intensity and productivity growth in Table 10 confirm what we have already seen in Table 8. The innovation intensity of innovating firms is not related to the productivity growth of their plants.

Most previous studies on innovation and productivity growth use a sample of surviving plants. As surviving plants are more innovative than exiting plants, this introduces a downward bias on the effect of innovation on plant growth when sample selection is not taken into account. To examine the size of the sample selection bias due to plant exits, we re-ran the productivity growth regression using a sample of plants that survived over the 1993-1997 period without using the sample selection correction procedure and report the results in Table A2 of the appendix. These results show that the effect of innovation on productivity growth is understated but still positive when we do not correct for sample selection. The estimated effect of innovation on productivity growth is smaller.

The other weakness of many previous studies relates to the period chosen for the studies. Due to data constraints, these studies relate innovation in a period to plant growth in the same period. This introduces the problem of simultaneity. To examine the potential importance of this issue, we reestimated our regression using productivity growth in the period when innovation was taking place. In this variant, innovation is not related to productivity growth.

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[31] The results in Table 9 also show that larger plants had faster productivity growth than smaller plants. Productivity growth was similar for domestic- vs. foreign-controlled plants, for older vs. younger plants, and for exporting vs. non-exporting plants.

Table 10. Effects of innovation intensity on productivity growth (controlling for regression-to-the-mean)

Variables	(1)	(2)
Share of innovative sales		
0%		
1-5%	-0.012	
	(-0.78)	
6-20%	-0.018	
	(-1.16)	
21-100%	0.024	
	(1.45)	
Number of innovations		
0		
1-2		0.040*
		(2.57)
3-4		0.031
		(1.92)
5-6		0.040
		(1.76)
>6		-0.007
		(-0.24)
Mills ratio	0.008	0.005
	(0.61)	(0.45)
Log likelihood	1,390.17	1,420.22
No. of observations	1,251	1,251

Note: The dependent variable is the annual productivity growth of a plant over the period 1993-1997. All regressions include controls for regression-to-the-mean, firm competency variables, plant ownership, plant size, plant age and plant export status and a set of dummies for 22 industries at the two-digit SIC level. Robust t-statistics are in parentheses. One asterisk denotes statistical significance at the 5 percent level.

4.5 Empirical results for market-share changes

The sample means of plant growth (percentage point change in market share) by innovation status of the parent are presented in Table 11. Innovation is not related to market-share growth except for the world-first innovation type. For world-first innovations, innovating plants had a 0.13 percentage point increase in the annual growth of their market share, while other plants had a decline in their market shares. For product, process and non-world innovations, there is little difference in market-share growth between innovating and non-innovating plants. Indeed, for these types of innovations, innovating plants appear to have a slightly slower growth in their market shares.

Table 11. Innovation and market-share change

	Market-share change, 1993-1997 (% points per year)	Market-share change, 1989-1993 (% points per year)
Innovation incidence		
No innovation	-0.010	0.043
Innovation	-0.005	0.038
Product innovation	-0.007	0.027
Process innovation	-0.005	0.063
World-first	0.013	0.017
Non-world-first	-0.008	0.044
Innovation intensity		
Share of innovative sales		
0%	-0.008	0.045
1-5%	-0.004	0.003
6-20%	-0.024	0.016
21-100%	-0.000	0.079
Number of innovations		
0	-0.009	0.042
1-2	0.008	0.018
3-4	-0.033	0.021
5-6	-0.005	0.106
>6	-0.013	0.038

Note: Establishment-weighted sample statistics are reported.

For our multivariate analysis, we model changes in market share as a function of relative productivity, relative productivity growth, plant and firm characteristics and opening period market share to account for regression-to-the-mean (Table 12).[32] The results confirm the previous finding on the close connection between relative productivity growth of a plant and its market share (Baldwin and Sabourin, 2001; Baldwin, Sabourin and Smith, 2004).

Regression-to-the-mean in market share is also found. Plants that start with above (below) average market share lose (gain) market share over the period studied. Large plants also lose market share—even after the effect of market share is included in the regression. Interestingly, once these characteristics are considered, age has a positive and significant effect on market share.

Innovation (particularly process innovation) is positively related to productivity growth, and productivity growth is related to market-share growth. But there is no additional effect of innovation on growth in market share that is statistically significant. Interestingly, if innovation is replaced by R&D status, there is a weakly significant positive effect of R&D on market-share growth. It may be that the type of R&D that serves to permit product adaptation rather than the discovery of brand new products is what is most crucial to market-share growth. And this type of

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32. The market share is defined relative to an industry. As such, we do not introduce industry dummies in the market-share regression. The coefficient on the innovation variable indicates the extent to which innovating plants gain or lose market shares to non-innovating plants *within* the same industry.

R&D may permit adaptation of existing products rather than the introduction of brand new products—the definition of innovation that is used in the survey.

We also examined the link between innovation intensity and market-share growth and found that innovation intensity is not related to market-share growth within the group of innovators.

In the above analysis, we have defined market share as the share of a plant's sales in total sales of a 4-digit industry that the plant belongs to. When we measure market share as the share of a plant's sales in a 2-digit industry, we obtain similar results. World-first innovation is related to growth in market share, while other types of innovation are not.

Table 12. Effects of innovation incidence on market-share changes (controlling for regression-to-the-mean)

Variables	(1)	(2)	(3)	(4)
Innovation	0.012			
	(0.98)			
Product innovation		0.010		
		(0.57)		
Process innovation		0.007		
		(0.47)		
World-first innovation			0.030	
			(1.17)	
Non-world-first			0.008	
			(0.61)	
R&D				0.021
				(1.72)
Market share in 1993	-0.854*	-0.865*	-0.853*	-0.857*
	(-2.52)	(-2.58)	(-2.51)	(-2.53)
Log of relative productivity in 1993	-0.017	-0.016	-0.016	-0.016
	(-1.44)	(-1.40)	(-1.40)	(-1.32)
Relative productivity growth, 1993-1997	0.182*	0.182*	0.183*	0.185*
	(4.49)	(4.46)	(4.52)	(4.55)
Foreign-controlled plants	0.010	0.009	0.010	0.008
	(0.60)	(0.56)	(0.58)	(0.46)
Large plants (>=100 workers)	-0.036*	-0.036*	-0.036*	-0.036*
	(-2.26)	(-2.27)	(-2.25)	(-2.27)
Older plants (entered pre-1983)	0.025*	0.025*	0.025*	0.025*
	(2.18)	(2.17)	(2.22)	(2.22)
Exporters	0.000	0.000	-0.001	-0.001
	(0.03)	(0.00)	(-0.07)	(-0.11)
Mills ratio	-0.067*	-0.062*	-0.067*	-0.065*
	(-2.39)	(-2.14)	(-2.31)	(-2.41)
Log likelihood	-335.40	-308.72	-331.78	-324.00
No. of observations	1,206	1,206	1,206	1,206

Note: The dependent variable is the annual percentage change in the market share of a plant over the period 1993-1997. Robust t-statistics are in parentheses. One asterisk denotes statistical significance at the 5 percent level.

5. *Conclusion*

Innovation surveys are seen to serve two purposes. Some are of the opinion that they will reveal the keys to success, that they will explain the factors that lead some to succeed in introducing an innovation and others to fail. This group of users of innovation surveys, for example, often seeks an answer as to whether R&D is the crucial input to the innovation process, or whether other complementary competencies are critical to the process.

Others tend to stress that innovation surveys allow us to delineate underlying patterns in the firm population that may permit us to discern changes that are occurring therein. Questions in this camp revolve around the following issues: Is there a segment of the economy where innovation is more intense? Are foreign-owned firms more likely to innovate than domestic-owned firms?

In this study, we have addressed both questions. In the first instance, we have found that being a performer of continuous R&D is indeed closely related to innovation of most types—though it is more important for the most novel than the least novel innovations. The location of R&D activity is less important, that is, having a separate R&D department is not as critical as the presence of continuous R&D. But we have also seen that having technological competencies are important to the innovation process. Productivity depends upon the efficiency with which the production operations of the firm are carried out.

Other competencies in the areas of marketing and human resources were not found in this study to be closely associated with a successful innovation. The latter findings need to be set in the context. The sample used in this survey comes from the larger firms within the manufacturing sector. As we have shown elsewhere (Baldwin and Gellatly, 2003, ch. 11), most large firms, whether they be active innovators or not, generally place a great deal of emphasis on both marketing and human resources. This is what distinguishes them from smaller firms who have yet to grow. Differences between innovators and non-innovators in these areas are larger for small firms because these competencies are important factors behind the initial growth of small firms. That we do not see a great deal of difference between large innovators and large non-innovators in this area does not mean the strategies are not important—just that for the type of innovation that these firms generally follow, additional emphasis in these areas is not critical.

The findings of our work on the incidence of innovation also shed light on the general process that has concerned researchers like Nelson and Winter (1982) and Nelson (1987). First, history does matter, but in a particular way. Past innovators are more likely to be future innovators. Thus, building innovation capability matters. But past growth is not particularly related to whether major innovations are reported for the survey period. This suggests that purposive investment can have future effects but that the vagaries of the market that determine growth are less important than the element of chance that is involved in the discovery process.

Other firm characteristics that our analysis has found to be significant are the size of the firms and their export status. It is generally the case that the largest firms in our sample are more likely to be innovators. This occurs in a sample of firms that are already larger than the typical firm in the manufacturing population. But the implications of this finding—that large firms are more innovative—needs to be placed in context. Understanding its implications requires us to turn to the second part of our analysis—the connection between the propensity to innovate and firm performance.

Here the benefits of innovation become evident. Innovation reduces the probability that a plant will fail. Innovation also increases the likelihood that a firm will experience faster productivity growth than its compatriots in the same industry. While innovation does not directly affect changes in market share, it does increase market share indirectly through its impact on labour productivity, because market share responds to increases in labour productivity.

It is noteworthy that it is process innovation more than product innovation that is related to higher plant survival rates and higher rates of productivity growth. The fact that it is process innovation that matters confirms the results found in related research that focuses on the use of advanced manufacturing technologies (Baldwin and Diverty, 1995; Baldwin and Sabourin, 2001; Baldwin, Sabourin and Smith, 2004). These technologies include robots, advanced manufacturing cells, automated process control and many similar state-of-the-art technologies, all of which are integral to new processes. Indeed, the survey respondents indicated that many of these advanced technologies were introduced in conjunction with the introduction of process innovations. Together, the results in this paper and those in the work on technology, stress the importance of process innovation to productivity growth. They also show how it is connected to the dynamics of change that is taking place in the business population. Process innovation leads to gains in productivity and changes in productivity are then translated into gains in market share.

Innovation is often held up to be the panacea to most of the Canadian economy's ills—an elixir that provides a fountain of youth that will regenerate an ageing industrial system.[33] The second part of our analysis might be used to ascertain the extent to which this is true in the Canadian innovation system. After all, if we had found that innovation was unrelated to firm performance, we might have an explanation as to why innovation rates were not higher than they are in Canada. Or, the close connection that has been found between innovation rates and firm performance might be used to argue that Canada's system was functioning as it should—or even that more innovation would be better because there would be even better productivity performance across a wider range of firms.

Despite our belief that innovation is an interesting phenomenon with many ramifications for the economy's performance, we have restrained ourselves from drawing conclusions of this nature in this paper—because we do not believe the research methodology supports either of these conclusions. For example, we do not believe that our findings on the difference in the impact of process as opposed to product innovation warrants strong conclusions about the effectiveness of process innovation and concomitantly the ineffectiveness of product innovation in Canada. Rather, the research that has been reported here needs to be set in context in order that we can see how innovation fits into a larger pattern of firm growth and decline.

Firms, products and industries pass through life cycles. Their focus varies over the life cycle and so too does their success. Early in the life cycle, entry and exit are high. Firms tend to focus on developing new products. Finding the characteristics of the product set that consumers will

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[33] See Trefler (1999), Porter and Bond (2000).

eventually accept is risky. Only later after the shakeout occurs do firms become larger—as they focus more on reducing production costs and competing more on price in a market where products are distinguished less on the basis of unique product characteristics and more on price.

In the early stages of the life cycle, we would not expect innovation to be closely related to productivity gain. Indeed, in the early stages of a firm, productivity gains may not be very important—as firms have their hands full with just meeting rapidly growing demand when product lines suddenly generate interest. At this stage, production often has the characteristic of a craft production system. Indeed in Baldwin and Dhaliwal (2001), we report that firms that are growing their labour force are often not growing their productivity—that it is in the larger plants that are declining in employment size where productivity gains are largest. It is not surprising therefore, that in this paper, we have found process innovation affects productivity growth while product innovation is less likely to do so. Most of the plants in the sample belong to larger firms and are therefore, more likely to be engaging in the type of innovation (process) that leads to productivity improvements. And those firms that are engaging in product innovation are more likely to be in the early stage of their life cycles where productivity growth is not high.

It is also important to interpret some of our other results in a larger context. Our work, like that of others, finds that firm size is related to productivity growth. Here, as elsewhere (Baldwin and Hanel, 2003, ch. 7), we caution readers not to conclude from this that small firms are not innovative. Small firms are at a different stage in their life cycle from large firms. Large producers are about to face inexorable decline. To stave off this fate, large firms enter into some activities more intensively. They are more likely to merge for instance. They enter industries relatively more frequently via merger than via greenfield entry (Baldwin, 1995). The results of this paper also show that they are more likely to indicate that they have introduced an innovation. But this is most likely for process innovation. Large firms are more likely to be at that stage of the life cycle where process innovation is important for both survival and maintenance. The effect of innovation on survival is also higher for the larger plants. While most exit comes from smaller plants, failing to innovate will lead to closure of even the larger plants. Finally, it should be noted that innovation for large plants tends to offset the inexorable dynamics of decline. Larger plants have higher productivity and plants with higher productivity tend to decline in productivity. Process innovation can reduce the amount of this decline.

The same process is at work with regard to changes in market share. Here too, large plants are likely to lose market share because of the forces of competition. And here too, innovations serve, via productivity improvements, to reduce the tendency to lose market share. But this tendency is more pressing for large firms than small firms. Thus process innovation is found to be more effective than product innovation in the population that is being examined in this paper—probably because they are the larger plants in the population.

There is some evidence to suggest that product innovation is aimed elsewhere than at productivity gains. The incidence of product innovation is larger in plants that are exporters. This suggests that product innovation in the early 1990s was particularly important in export markets. And we also have found that R&D is weakly related to market-share gains, though introducing a product innovation is not. But there is clearly more work to be done before we can better disentangle the dynamics of the process at work on the product innovation side.

Appendix

Table A1. Probit model of innovation incidence that excludes past growth as independent variables

	Innovation	Product innovation	Process innovation	World-first innovation	Non-world-first
	(1)	(2)	(3)	(4)	(5)
R&D input					
R&D performer	0.143*	0.135*	0.147*	0.057*	0.041
	(3.20)	(3.29)	(3.52)	(4.32)	(1.01)
R&D department	0.035	0.093*	-0.023	0.005	0.006
	(0.74)	(2.13)	(-0.54)	(0.50)	(0.14)
Competencies					
Marketing	0.025	0.015	0.040*	0.006	0.007
	(1.20)	(0.81)	(2.04)	(1.20)	(0.40)
Technology	0.063*	0.048*	0.052*	0.005	0.046*
	(2.66)	(2.16)	(2.36)	(0.88)	(2.15)
Production	-0.030	-0.026	-0.003	-0.009	0.002
	(-1.17)	(-1.10)	(-0.14)	(-1.65)	(0.09)
Human resources	0.024	0.013	0.003	-0.003	0.034
	(1.14)	(0.63)	(0.15)	(-0.45)	(1.80)
Past innovation					
Use of patents or trade secrets	0.219*	0.222*	0.175*	0.023*	0.159*
	(5.73)	(6.29)	(4.85)	(2.36)	(4.54)
Firm characteristics					
Foreign-controlled plants	-0.012	-0.010	-0.027	0.006	-0.031
	(-0.30)	(-0.28)	(-0.72)	(0.59)	(-0.84)
Large firms (more than 500 workers)	0.089*	0.053	0.132*	0.030*	0.025*
	(2.15)	(1.40)	(3.46)	(2.66)	(0.68)
Older firms (entered pre-1983)	0.015	0.030	0.021	-0.007	0.021
	(0.43)	(0.95)	(0.65)	(-0.81)	(0.70)
Exporters	0.100*	0.088*	0.067*	0.012	0.051
	(2.84)	(2.71)	(2.03)	(1.28)	(1.61)
Log likelihood	-686.64	-617.32	-660.87	-231.37	-687.15
No. of observations	1,280	1,280	1,280	1,205	1,280

Note: All regressions include a set of dummy variables for 22 industries at the two-digit level of industry aggregation. Marginal effects are reported. Robust t-statistics are in parentheses. One asterisk denotes statistical significance at the 5 percent level.

Table A2. Effects of innovation incidence on productivity growth (w/o controlling for sample selection due to plant exits)

Variables	(1)	(2)	(3)
Innovation	0.021	--	
	(1.74)		--
Product innovation	--	-0.012	
		(-0.81)	--
Process innovation	--	0.029*	
		(2.08)	--
World-first innovation	--	--	0.034
			(1.68)
Non-world-first	-	--	0.022
			(1.71)
R Squared	0.04	0.04	0.04
No. of observations	1,093	1,093	1,093

Note: The dependent variable is the annual productivity growth of a plant over the period 1993-1997. All regressions include competency measures, plant ownership, plant size, plant age, plant export status, and a set of dummies for 22 industries at the SIC two-digit level. Robust t-statistics are in parentheses. One asterisk denotes statistical significance at the 5 percent level.

References

Abbott III, T.A. 1992. “Price Dispersion in the U.S. Manufacturing: Implications for the Aggregation of Products and Firms.” The U.S. Census Bureau, Center for Economic Studies Working Paper 92-3.

Abernathy, W.J. and J.M. Utterbach. 1978. “Patterns of Industrial Innovation.” *Technology Review,* 80(7): 41-47.

Äkerblom, M., M. Virtaharju and A. Leppäahti. 1996. “A Comparison of R&D Surveys, Innovation Surveys and Patent Statistics based on Finnish Data.” In *Innovation, Patents and Technological Strategies,* Paris: OECD, pp. 57-70.

Bahk, B.H. and M. Gort. 1993. “Decomposing Learning by Doing in New Plants.” *Journal of Political Economy,* 101(4): 561-583.

Baldwin, J.R. 1995. *The Dynamics of Industrial Competition*. Cambridge: Cambridge University Press.

Baldwin, J.R. 1996. “Innovation: The Key to Success in Small Firms.” In *Evolutionary Economics and the New International Political Economy*. J. de la Mothe and G. Paquette (eds.). London: Pinter.

Baldwin, J.R., W. Chandler, C. Le and T. Papailiadis. 1994. *Strategies for Success: A Profile of Growing Small and Medium-sized Enterprises in Canada.* Catalogue No. 61-523. Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J.R. and N. Dhaliwal. 2001. “Heterogeneity in Labour Productivity Growth in Manufacturing: Differences Between Domestic and Foreign-controlled Establishments.” In *Productivity Growth in Canada 2001.* Catalogue No. 15-204-XPE. Chapter 5. Ottawa: Statistics Canada.

Baldwin, J.R. and B. Diverty. 1995. *Advanced Technology Use in Canadian Manufacturing Establishments.* Analytical Studies Research Paper Series 11F0019MIE1995085. Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J.R., B. Diverty and D. Sabourin. 1995. “Technology Use and Industrial Transformation: Empirical Perspectives.” In *Technology, Information, and Public Policy,* T. Courchesne (ed.). John Deutsch Institute for the Study of Economic Policy. Kingston, Ontario: Queens University. See also Analytical Studies Research Paper Series 11F0019MIE1995075. Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J.R. and G. Gellatly. 2003. *Innovation Strategies and Performance in Small Firms.* Northampton, MA: Edward Elgar, Publishing.

Baldwin, J.R. and W. Gu. 2003a. *Plant Turnover and Productivity Growth in Manufacturing.* Analytical Studies Research Paper Series 11F0019MIE2003193. Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J.R. and W. Gu. 2003b. "Export-market Participation and Productivity Performance in Canadian Manufacturing." *Canadian Journal of Economics,* 36(3): 634-657.

Baldwin, J.R. and P. Hanel. 2003. *Knowledge Creation and Innovation in a Small Open Economy*. Cambridge: Cambridge University Press.

Baldwin, J.R., P. Hanel and D. Sabourin. 2000. "Determinants of Innovative Activity in Canadian Manufacturing Firms." In *Innovation and Firm Performance.* A. Kleinknecht and P. Mohnen (eds.). London: Palgrave, pp. 86-111.

Baldwin, J.R. and J. Johnson. 1998. "Innovator Typologies, Related Competencies and Performance." In *Microfoundations of Economic Growth.* G. Eliasson and C. Green (eds.). Ann Arbor: University of Michigan, pp. 227-253.

Baldwin, J.R. and J. Johnson. 1999. "Innovation and Entry." In *Are Small Firms Important? Their Role and Impact.* Z. Acs (ed.). Boston: Kluwer Academics Publishers.

Baldwin, J.R. and D. Sabourin. 2001. "Advanced Technology Use and Firm Performance in Canadian manufacturing in the 1990s." *Industrial and Corporate Change*, 11(4): 761-789.

Baldwin, J.R., D. Sabourin and D. Smith. 2004. "Impact of Advanced Technology Use on Firm Performance in the Canadian Food Processing Sector." *The Economic Impact of ICT.* Paris: OECD.

Bernard, A.B. and J.B. Jensen. 2002. "The Deaths of Manufacturing Plants." NBER Working Paper No. 9026.

Cohen, W.M. and S. Klepper. 1996. "Firm and the Nature of Innovation within Industries: The Case of Process and Product R&D." *Review of Economics and Statistics,* 78(2): 232-243.

Cosh, A., A. Hughes and E. Wood. 1999. "Innovation in UK SMEs: Causes and Consequences for Firm Failure and Acquisition." In *Entrepreneurship, Small and Medium-Sized Enterprises and the Macro Economy.* Z.J. Acs, B. Carlsson and C. Karlsson (eds.). Cambridge: Cambridge University Press.

Criscuolo, C. and J. Haskel. 2003. "Innovations and Productivity Growth in the UK: Evidence from CIS2 and CIS3." Discussion Paper, Centre for Research into Business Activity, Office for National Statistics, UK.

Crépon, B., E. Duguet and J. Mairesse. 1998. "Research, Innovation and Productivity, An Econometric Analysis at Firm Level." *The Economics of Innovation and New Technology,* 7(2): 115-158.

Dennison, E. 1962. *The Sources of Economic Growth in the United States and the Alternatives Before Us.* New York: Committee for Economic Development.

Dixit, A.K., and J.E. Stiglitz 1977. "Monopolistic Competition and Optimum Product Diversity." *American Economic Review*, 67(3): 297-308.

Doms, M., T. Dunne and M.J. Roberts. 1995. "The Role of Technology Use in the Survival and Growth of Manufacturing Plants." *International Journal of Industrial Organization*, 13(4): 523-542.

Dosi, G. 1988. "Sources, Procedures, and Microeconomic Effects of Innovation." *Journal of Economic Literature*, 26(3): 1120-1171.

Ericson, R. and A. Pakes. 1995. "Markov-Perfect Industry Dynamics: A Framework for Empirical Work." *Review of Economic Studies*, 62(1): 53-82.

Foster, L., J. Haltiwanger and C. Syverson. 2003. "Reallocation, Firm Turnover, and Efficiency: Selection on Productivity and Profitability." Paper presented at a Conference on the Comparative Analysis of Enterprise Data. London: England.

Gort, M. and S. Klepper. 1982. "Time Paths in the Diffusion of Product Innovations." *Economic Journal*, 92(367): 630-653.

Griliches, Z. 1998. *R&D and Productivity: The Econometric Evidence*. Chicago: The University of Chicago Press.

Jorgenson, D. 1990. "Productivity and Economic Growth." In *Fifty Years of Economic Measurement.* E. Berndt and J. Triplett (eds.). Studies in Income and Wealth, Vol. 54. Chicago: The University of Chicago Press.

Hadi, A.S. 1992. "Identifying Multiple Outliers in Multivariate Data." *Journal of the Royal Statistical Society*, Series B, 54(3): 761-771.

Hadi, A.S. 1994. "A Modification of a Method for the Detection of Outliers in Multivariate Sample." *Journal of the Royal Statistical Society,* Series B, 56(2): 393-396.

Hall, B. 1987. "The Relationship Between Firm Size and Firm Growth in the U.S. Manufacturing Sector." *Journal of Industrial Economics*, 35(4): 583-606.

Hulten, C.R. 2001. "Total Factor Productivity: A Short Biography." In *New Developments in Productivity Analysis*. C.H. Hulten, E.R.Dean, M.J. Harper and J. Triplett (eds.). Studies in Income and Wealth, Vol. 63. Chicago: The University of Chicago Press.

Klette, T.J. 1996. "R&D, Scope Economies and Plant Performance." *The Rand Journal of Economics*, 27(3): 502-522.

Leiponen, A. 2000. "Competencies, Innovation and Profitability of Firms." *Economics of Innovation and New Technology,* 9(1): 1-24.

Lööf H. and A. Heshmati. 2001. "On the Relationship between Innovation and Performance: A Sensitivity Analysis." SSE/EFI Working Paper Series in Economics and Finance, No. 446.

Melitz, M.J. 2003. "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity." *Econometrica*, 71(6): 1695-1725.

Nelson, R.R. 1987. *Understanding Technical Changes as an Evolutionary Process*. Amsterdam: North-Holland.

Nelson, R.R. and S.G. Winter. 1982. *An Evolutionary Theory of Economic Change*. Cambridge Mass.: Harvard University Press.

Nickell, S., D. Nicolitsas and M. Patterson. 2001. "Does Doing Badly Encourage Management Innovation?" *Oxford Bulletin of Economics and Statistics*, 63(1): 5-28.

Porter, M.E. and G.C. Bond. 2000. "Innovative Capacity and Prosperity: The Next Competitiveness Challenge." *The Global Competitiveness Report.* New York: Oxford University Press.

Rodrik, D. 1997. *Has Globalization Gone Too Far.* Washington, D.C.: Institute for International Economics.

Sutton, J. 1991. *Sunk Costs and Market Structure: Price Competition Advertising and the Evolution of Concentration*. Cambridge Mass.: MIT Press.

Trefler, D. 1999. "Does Canada Need A Productivity Budget?" IRPP *Policy Options*, July/August: 66-71.

van Leeuwen, G. 2002. "Linking Innovation to Productivity Growth Using Two Waves of the Community Innovation Survey (CIS)." STI Working Paper 2002/8. Paris: OECD.