Regional and Firm Level Human Capital Effects on the Rate of Innovation in Food Processing Firms in Canada.

By

Vahid Omidvar

A Thesis

Submitted to the Faculty of Graduate Studies

In Partial Fulfillment of the Requirements

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Abstract

Regional and Firm Level Human Capital Effects on the Rate of Innovation in Food Processing Firms in Canada. By Vahid Omidvar
(Adviser: Derek Brewin[1])

Maintaining a competitive edge in the food processing sector requires continued innovation. This thesis explored various factors which might determine innovative activity within food processing firms in Canada. It included data from the Innovation in the Food Processing Industry Survey by Statistics Canada. The central theme of this thesis was to study the effect of different education levels and regional effects on the probability of innovation in food processing firms in Canada. Using several alternative probit estimations, this paper found that firm size and market competition scales had a positive effect on innovation. Rural firms and firms with lower internal or regional education levels had fewer product innovations but these firms did not appear to have fewer process innovations.

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Table of Contents

List of Tables

List of Figures

List of Graphs

Chapter 1

1.1 Introduction

Solow (1957) argued that economic growth is not caused by conventional endowments of labor and capital but by changing the quality of labor through advances in technology and better use of capital. This argument was supported by the rapid economic growth of the so called Asian Tigers. Lucas (1993) claimed that the rapid economic growth and development in East Asian countries was not a miracle but a calculated movement which started years earlier by investing in education of all people regardless of sex, class and income. These investments have increased the quantity and the quality of education in these countries and, according to a World Bank's report (1993), these investments have caused the cognitive skill levels of secondary school graduates in East Asian economies to be comparable to or, even higher than, graduates in high-income countries.

The importance of education and human capital to economic growth has been brought out in many studies. Lucas (1988) and Solow (1957) developed models that specify education as a critical force that generates technological progress in any industry. In these models, education, or more generally human capital, which includes experience and less formal training, can be viewed as a critical input for innovation and R&D activities (Van Den Berg, 2001). From these perspectives, education is seen as an intentional effort to increase the resources needed for creating new ideas, and thus any increase in education will directly accelerate technological progress by creating new knowledge.

Human capital has redefined and reshaped the structure of many industries in advanced countries. In the past, most firms believed that there are two methods that can ensure continuous profit and future survival in the market. These two methods are: reducing the costs of production or improving the quality of the products. By reducing the cost of production, firms compete on price and this will attract new customers. In addition, by maintaining or improving the quality of product, they can keep their current customer's happy which would assure future profitability. Companies discovered that in order to maintain a competitive edge in the market and attract new customers and maintain their old customers, they need to innovate regularly (Porter and Stern, 2001). This implies that human capital and knowledge are key elements in the innovation process and a major tool for growth (Van Den Berg, 2001).

There is a strong link between human capital and productivity in any industry. Unlike physical capital which is subject to diminishing returns, human capital may not have diminishing returns. Through continuous education and learning by doing, employees can increase their stock of knowledge and even generate externalities by interacting among each other. This means that human capital in many industries is seen as part of a continuing cycle of innovation and investment that can generate long term profitability and growth (Van Den Berg, 2001). In addition, human capital not only increases the profitability in the firm by inventing new products but it also ensures the existence of the firm in the future. These characteristics of human capital are the main force in today's knowledge based economy.

The term innovation has taken on many different meanings over the years (Verbees and Meulenberg, 2004). Generally, innovation is defined as "a new or significantly improved product (goods or services) introduced in the firm (Alasia, 2005)." Innovation can occur at any level of a firm or organization such as: marketing, manufacturing, research, finance and personal management (Keegan and Seringhaus, 1999).

Verbees and Meulenberg (2004) suggest there are two categories of innovation: sustaining and disruptive innovation. Sustaining innovations enhance "the performance of established products, along the dimensions of performance that mainstream customers in major markets historically have valued".

Food processing and other agriculture related industries play a critical part in the rural economy as well as a whole country's economy (Munnich and Schrock, 2002). Similar to other industries, innovation in food processing plants plays a very important role in the economic prosperity of firms. However, innovations in food processing establishments face formidable challenges in an increasingly knowledge-based economy and these challenges are caused by many factors. The first factor is globalization and cheap transportation. In the past, most food processing firms had access to inexpensive natural resources and relatively low labor costs because they were located in rural areas. However, with globalization and low transportation costs, these competitive advantages have declined dramatically (Munnich and Schrock, 2002). The inability to achieve an appropriate economic scale is another factor that reduces the innovation rate in food processing firms. It has been reported that large firms can produce more innovation per year than smaller firms (Rogers, 2004). A lack of modern technology is yet another factor that reduces the rate of innovation in food processing plants. Shefer and Frenkel (1998) show that modern technologies do not travel fast enough to rural areas and this would reduce the rate of innovation in food processing establishments in rural areas. However, one successful and recognized plan that can increase the rate of innovation is hiring a more highly educated labor force (Munnich and Schrock, 2002).

The emphasis shown by food processing firms to hire an educated labor force is an indication that they are moving toward a knowledge based economy. The high demand for an educated labor force is due to the fact that an educated employee is better at creating, implementing, and adopting new technologies (Benhabib and Spiegel, 1994). In addition, education enhances one's ability to receive, decode and understand information and these attributes allow firms to generate growth by improving methods of production or creating new products that appeal to greater consumer segments (Lin, 1991). However, there is little empirical research to confirm the effect of education on the rate of innovation in the food processing industry (Lopez, 1985).

1.2 Objective

The importance of education is clearly documented in many empirical articles, but there are not many publications that link the relation between human capital and innovation in the food processing sector of North America, especially in Canada. Thus, it is the goal of this thesis to establish a model that highlights the linkages between skill and innovation in Canada's food processing sector. Using two surveys, this thesis will try to show the link between education and the rate of innovation in food processing firms. The two surveys are the "Survey of Innovation" (Please refer to Appendix A for viewing this survey) conducted by the Agricultural Policy Research Network at the University of Saskatchewan in 2005/2006 and the "Innovation in the Food Processing Industry Survey" (Please refer to Appendix C for viewing this survey) which was conducted by Statistics Canada in 2003.

Unlike past literature on education and innovation, this paper's objective is to study the effect of education on the rate of innovation in the food processing sector in Canada. This paper aims to discover the effect of education on the rate of innovation by two methods: one by analyzing the education levels within each firm on the rate of innovation and secondly, to see the effect of the regional education level on the rate of innovation in the food processing sector. This thesis addresses two main questions: Do employees with a master's degree produce more innovations than employees with a bachelor's degree in food processing plants? The same question can apply to regional education levels. Do firms located in a region with a high number of individuals with post secondary education produce more innovation than firms located in a region with a low number of individuals with post secondary education? This thesis tries to find answers for these two questions by studying the education levels at the firm and regional level for Canadian food processing firms.

This thesis also aims to discover the determinants of innovation at the firm level in the food processing sector. This secondary objective is to understand the functioning of various regional, industrial and firm variables on the rate of innovation. In addition, this thesis tries to specify desirable factors and mechanisms to encourage product and process innovation in food processing establishments in Canada.

Chapter 2: Literature Review

2.1 Education, Human Capital and Innovation

Becker (1993) indicated that training is one of the most important investments in human capital. Schumpeter (1934) argued that an increase in the stock of human capital will increase the innovation rate.

The importance of training and human capital on the rate of innovation has been investigated by many researchers. Baldwin and Johnson (1995), Mincer (1989), Lillard and Tan (1986) and Bartel and Lictenberg (1986) have clearly stated that the human capital and education levels play a significant role in determining the rate of innovation in different sectors. Human capital is the principle element in any innovative activity because it is an employee's capability, motivation, education and vision that generates new product or process innovation in manufacturing sectors.

Bound and Johnson (1992) argued that the demand for skilled workers in developed countries has increased dramatically in the past 30 years and these demands are driven by a greater pace of skill based technological advance. This pattern was also observed by Kahn and Lim (1998). These authors suggest that in the last 25 years, there have been dramatic changes in the way goods are produced by firms. During this period, firms replaced unskilled workers with more educated employees and highly automated equipment. This coincides with a lower demand for low-skilled labor in OECD countries. With the globalization and modernization of many industries, it is not surprising that demand and wages for unskilled labor have declined sharply in the past few decades (Berman, Bound and Machin, 1998). Berman, Bound and Machin (1998) suggest that U.S. real wages for workers with 12 or fewer years of education fell by 26 percent between 1979 and 1993 and had not recovered by 1998.

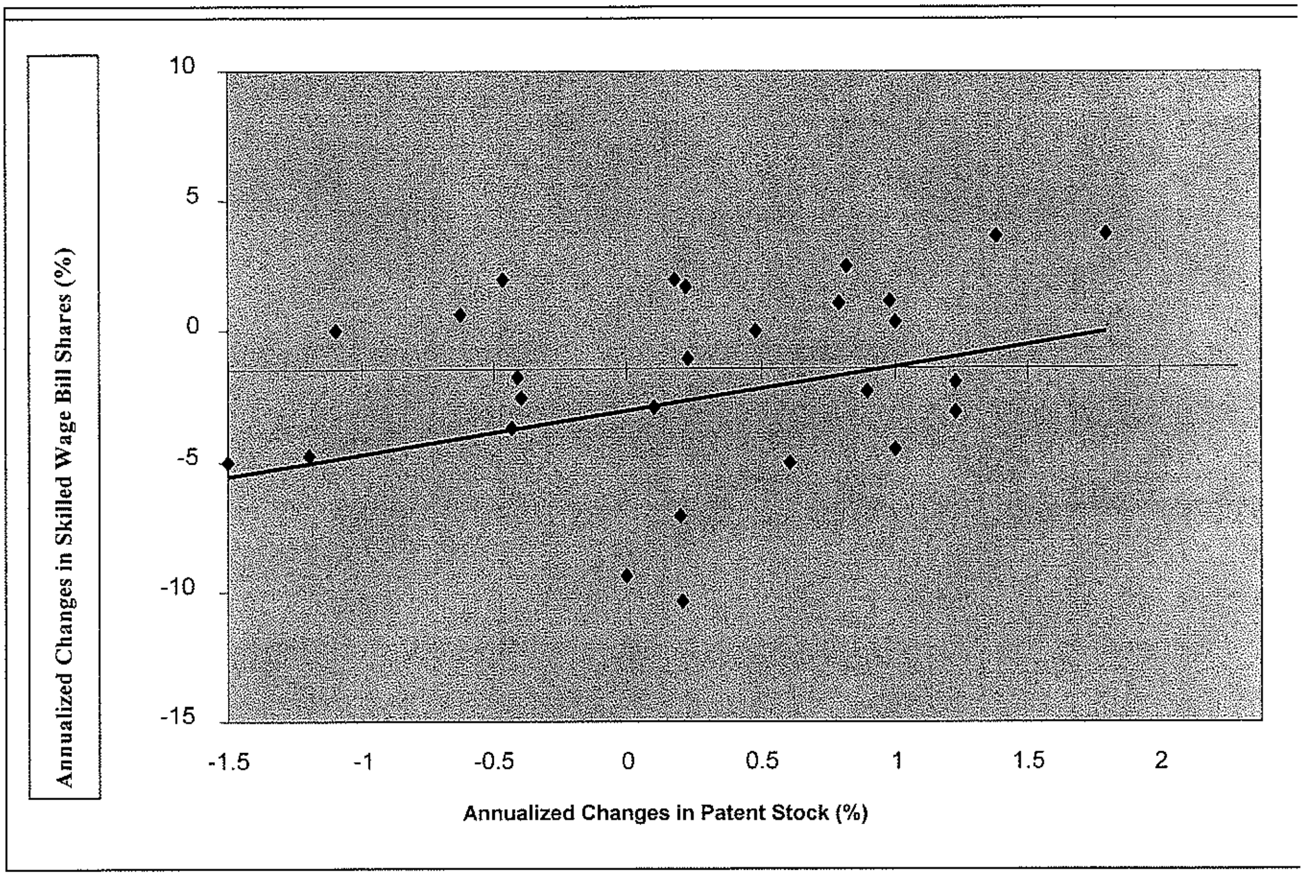
The same pattern was observed in Canada. Gera, Gu and Lin (2001) showed that the wages for skilled workers in Canada increased between 1981 and 1994. However, the wages for unskilled workers declined dramatically in the same period. Table 1 shows that unskilled wages in manufacturing in Canada declined by 6.25 percent during 1981-94, the wages for skilled workers increased by 6.25 percent. The skilled portion of the labor force was credited with increasing the productivity of the manufacturing sector by giving it the ability to adapt to technological changes (Khan and Lim, 1998). Baldwin and Lin (2001) argue that advanced technologies have a wide range of benefits such as: "improving in productivity, product quality and working conditions, reduction in production costs associated with such factors as lower labor requirements and inventory, reduced material and energy consumption, increased equipment utilization and reduced product innovation." In addition, Gera, Gu and Lin hypothesize a positive relationship between new technologies and educated workers in Canada and this relationship is shown in Figure 1.

Table 1 Changes in wage bill share by skill level (percent)

	1981	1986	1987	1988	1989	1990	1993	1994	Change 81 to 94
All Industries									
Unskilled	57.39	53.32	53.48	54.41	53.28	53.25	50.29	50.54	-6.85
Skilled	42.61	46.88	46.52	46.72	46.75	46.75	49.41	49.46	6.85
Managers	8.70	13.32	13.22	12.76	13.15	12.95	14.99	15.65	6.95
Professional	9.67	9.83	10.11	9.83	10.39	9.92	12.28	12.59	2.92
Technical	24.25	26.54	23.19	23.00	23.18	23.88	22.15	21.22	-3.03
Manufacturing									
Unskilled	65.57	62.63	63.71	65.55	64.50	65.29	58.74	59.32	-6.25
Skilled	34.43	37.37	36.29	34.45	35.5	34.71	41.26	40.68	6.25
Managers	8.59	11.82	11.65	10.42	10.90	10.22	13.31	14.27	5.68
Professional	8.38	7.91	8.53	8.02	8.70	8.40	10.71	9.66	1.28
Technical	17.46	17.64	16.11	16.01	15.90	16.09	17.24	16.75	-0.71

Source: Gera, Gu and Lin (2001)

Figure 1 Raw correlation between changes in skilled wage bill and changes in patent stock



Source: Gera, Gu and Lin (2001)

Huiban and Bouhsina (1998) studied the effect of the quality of labor on innovation. They use a linear regression model to evaluate the effect of different education levels on firms' innovation rates. They analyze the effect of managers, technicians, administrative and sales intermediates, foremen and engineers on the rate of innovation and they conclude that education rates have a positive and significant effect on the rate of innovation. However, education rates for managers, administrative and sale intermediates and foremen have a small or no effect on the rate of innovation in the firms. They argue that this correlation is due to the fact that engineers have acquired the skill and the knowledge through their formal education and these acquisitions enable them to play a role in about every case of innovation.

Love and Roper (2001) developed three models to study the relationship between different variables and the rate of innovation in some Western European countries. The first model looks at the importance of industry level effects, the second model looks at the importance of regional factors and the third model looks at the firms' characteristics in determining the rate of innovation within the firms. They discover that the employees with a graduate degree have a positive and significant effect on the rate of innovation. They showed that an increase in the numbers of the graduate workforce increased the rate of innovation by 0.46 percent in Germany. The effect of having an employee with a bachelor degree was negative for the rate of innovation of firms in the United Kingdom and Ireland.

Mincer (1989) claimed that physical capital and technological changes are more complementary with skilled labor than unskilled (raw) labor. This means that an educated worker can deal more "effectively with a rapidly changing environment, or with temporary disequilibria resulting from technological changes" (Mincer, 1989). The food processing sector had one of the lowest productivity levels in the U.S. in past decades. Generally, they hire low skilled labor rather than a more educated labor force. This low skilled labor cannot deal with new technologies and may not have the resources to innovate new products or new operation systems. It is not surprising to see this low productivity level and unskilled labor coincide with a low rate of innovation as estimated by Baldwin and Johnson in 1995 in the food processing sector in Canada.

Baldwin and Johnson (1995) study the effect of human capital development on innovation in small and medium sized firms in Canada. These authors found that training is closely related to innovation productivity in small and medium size firms in Canada.

Their study finds "strong evidence for the hypothesis that human capital development facilitated by training is complementary to innovation and technological change" (Baldwin and Johnson, 1995). In addition, this study finds that training incidence is found to be closely related to the importance that a firm gives to research and development, the use of new technologies and many other strategies that are related to innovation. Human capital that is developed at the firms through training increases the rate of innovation within the firms, possibly because firms have created a conducive atmosphere for innovative activities.

Kelly and Hageman (1999) investigate the effect of research and development on the rate of innovation in different sectors in the U.S. They focus their study on the number of patents that each worker produces in each industry and their results can be viewed in Table 2. From this table, it is clear that food and kindred products have the lowest number of patents produced per worker. These authors also examined the effect of different attributes of labor such as: the employment in the sector, the fraction of adult population with four or more years of college education, the mean number of employees per establishment and the sector's employment as a fraction of manufacturing employment in the state on the rate of innovation for 12 different industrial sectors in the U.S. in 1987. They found that 4 years of post secondary schooling had a positive effect on 11 out of 12 sectors in improving the rate of innovation. As a result, they concluded that the education level of the employees in the firms played an important part in determining the rate of innovation within the firms. In addition, this study showed that employees with a bachelor degree would increase the rate of innovation.

Love and Roper (1999) investigate three possible routes by which firms may obtain ingredients for innovation: training and hiring educated workers, technology transfer and networking. These authors consider these three models because they strongly believe that external and internal networks of information and collaboration are the key elements for successful innovation outputs. The internal network refers to the amount of education available within the firms and the amount of research and development budget available to carry out innovative activities. These authors argued that external factors such as sectoral innovation intensity and regional innovation intensity will have some effect on the rate of innovation in the firms. The results showed that undertaking research and development in the firm will increase the rate of innovation activity. Surprisingly, these authors found that firms with a research and development department in the plant have a lower rate of innovation. Once again, these authors study the effect of graduate education among workers in the firm on the rate of innovation. This model shows that increasing the graduate labor force increases the rate of innovation.

Table 2 Number of patents per works in 12 American manufacturing sectors in 1987.

Name	Number of patents Per 10,000 workers
Food and Kindred Products	0.353
Textile Mill products	0.630
Chemicals and allied producers	0.542
Petroleum and natural gas	0.569
Rubber and miscellaneous plastic products	0.670
Stone, clay, glass and concrete products	0.470
Primary metal	0.923
Fabricated metal products	0.504
Machinery, except electrical	0.526
Electrical and electronic machinery	0.644
Transportation equipment	0.579
Professional and scientific instruments	0.742

Source: Love and Roper (1999)

2.2 Location and Innovation

A central issue discussed in the scientific literature is the question whether geographic boundaries within the country play an important part in determining the rate of innovation. Many researches such as: Little and Tries (1996), Gale (1998) and McGranahan (2002) have studied the effect of rural areas on the rate of innovations in manufacturing firms in North America. These authors concluded that rural areas mainly focus on primary production and manufacturing that require low skilled labor, lower education levels and use older equipment.

Alderman and Davies (1990) show that there are some key regional variations in determining the rate of innovation in manufacturing sectors. Baptista (2000) establishes a model with the regional density of technologies close to firms in order to examine the effects of the geographical environment on the speed of innovation. This model concludes that basic research infrastructure and information infrastructure have a positive and significant effect on the speed of innovation. For instance, having other firms in the region that have already adopted a technology may increase the rate of subsequent adoption.

Adutertsch and Feldman (1996) also investigated the rate of innovation in different geographic regions in the U.S. In their model, they study the effect of natural resources, scale of production, transportation costs and skilled labor of different regions on the rate of innovation. These authors discover that coastal states such as California and New England produce more innovations per year than other states. Silicon Valley in California is a frontier in developing computers and computer components and New England is a leader in innovation in heavy machinery and equipment. These coastal states are also leaders in investment in education in the nation. On the other hand, states that generally produce agricultural products in the Midwest and central part of the US create very few innovations per year and invest less in their people. This lack of investment in innovation and education in regions with high agricultural production may cause fewer new product and process innovations in the agri-food sector. This study shows that the education level of regions with high investments in education has a positive and significant effect on the rate of innovation.

Feldman and Audretsch (1999) studied the effect of the composition of economic activity in a geographic region on the rate of innovation within the firms. By using the United States Small Business Administration Innovation Data Base (SBIDB), they discovered that the specialization of economic activities within a region does not necessarily promote innovative output. Clusters of firms within a region did not increase their rate of innovation. Rather, this study found that "diversity across complementary economic activities sharing a common science base is more conducive to innovation than is specialization" (Feldman and Audretsch, 1999). Furthermore, the results in this study showed that the degree of local competition for new ideas within a region is more conducive to innovative activities than is a local monopoly.

Shefer and Frenkel (1998) conducted a study to analyze the link between location and innovation. They claimed that small cities and rural areas have many disadvantages compared to urban areas because information and economic activities do not reach these non-metropolitan areas at a rapid pace. These authors hypothesize that the diffusion of innovation in space follows a pattern from core regions to a periphery. The rate of innovation tends to gradually decline in intensity from the heart of a core metropolis outward. This decline in the rate of innovation is caused by external factors such as: the quality of labor sources, "the degree of cooperation and collaboration among firms and the degree of economies of localization and agglomeration" (Shefer and Frenkel, 1998). As a result, this study shows that firms located away from the metropolis area will have lower rate of innovation compared to other firms that are located within the metropolis area.

Baptista (2000) argued that firms in major urban cities will have a higher rate of innovation compared to the same firms that are located away from major cities for two main reasons. First, technicians and employees have more interaction with other colleagues in the same fields or closely related areas. These interactions enable people to combine their ideas and use each other's expertise in order to develop a new product. The second reason is that firms in major cities have access to a bigger pool of workers with different capabilities and backgrounds (Baptista, 2000). In contrast, firms in small towns have access to small numbers of potential workers with limited expertise. This observation coincides with Bollman's 1999 study. Bollman shows that 65 percent of people living in metropolitan areas in Canada (with a core of 100,000 inhabitants or more) have grade 12 or higher education. However, only 40 percent of the population living outside metropolitan areas have grade 12 or higher education.

Major cities and urban areas have more resources such as major universities, research facilities, provincial and federal information agencies and modern laboratories (Baptista, 2000). These resources can provide the latest information in different formats to firms, and educated workers in these firms can use these resources in order to invent new products. Similar arguments were also provided by Munnich and Schrock (2002). These authors found that firms closer to urban areas have higher productivity rates because they are closer to big markets where they can sell their goods and they have access to better and highly qualified labor markets. This accessibility means that firms can choose among more competent workers compared to other firms that are located in rural areas. These reasons explain higher innovative activities in these concentrated regions.

Sternberg (2000) states that the long-term growth of a business or any region in highly industrialized nations depends on their ability to continually develop and produce innovative products. Furthermore, innovation requires information and knowledge and these elements are principal factors for successful innovation in a region (Jewkes, Sawers and Stillerman, 1969). One way to increase the stock of knowledge within any region or nation is through collective learning (Keeble and Wilkinson, 1999). Collective learning through local networks enables different participants to combine their information and knowledge and this enables these agents to better recognize successful market information and technologies. Therefore, educated workers recognize the importance of networks in determining the rate of innovation within their own firm and they voluntarily involve themselves within these networks (Lawson and Lornez, 1999).

2.3 Firm Characteristics and Innovation

2.3.1 Size

Rogers (2004) studied the effect of training and education of both employees and managers on the rate of innovation in manufacturing and non-manufacturing firms. Rogers calculates the rate of investment on training in each firm by measuring the expenditure on formal training on full time effective employees and he calls this coefficient "training intensity". Training intensity was negative and insignificant in explaining the rate of innovation in manufacturing and non-manufacturing firms. Interestingly, Rogers (2002) discovered that training intensity does not play any significant role in explaining the rate of innovation regardless of the size of firms. He measured the effect of training intensity for firms with 1-4 employees, 5-19 employees, 20-99 employees and 100+ employees.

Röder, Herrmann and Connor (2000) claim that firm size has a significant role in determining the rate of innovations in food processing plants in the U.S. In addition, Traill and Meulenberg (2002) and Acs and Audertsch (1988) study the effect of firm size on the rate of innovation in food processing plants in Europe and US, respectively. Traill and Meulenberg showed that firms with 50 to 99 employees had the highest rate of innovation among food processing plants in Europe. On average, firms of this size generally produce 2.13 innovations per year which is 2.87 times higher than firms with 0 to 9 employees. The same pattern is observed in the US. Larger firms (firms with more than 500 employees) generally produce more innovation per year than smaller firms (firms with less than 500 employees).

2.3.2 Ownership

Empirical research studying the effect of ownership structure on the rate of innovation show mixed results. Criscuolo and Martin (1998) study the effect of different ownership on businesses in the UK. These authors discover that foreign owned firms operating in the UK produce more output per worker than UK owned firms. Ortega-Argiles, Moreno and Caralt (2005) also studied the relationship between ownership and innovation in firms in Scotland. These authors showed that foreign owned firms had a lower rate of innovation than non-foreign owned firms. In addition, Traill and

Meulenberg (2002) studied the nature of ownership (public, private and co-operative) on the rate of innovation. This study showed that the rate of innovation does not depend on the type of ownership and all three types have a positive and significant effect on the rate of innovation.

Hanel (2000) studied the effect of different ownership structures on the international spillover of technology in Canada. He showed that foreign owned firms do not contribute significantly to the spillover of technology in Canada. This implies that foreign owned firms do not have any advantages over Canadian owned firms in developing new product or process innovations. In addition, Baldwin, Sabourin and Smith (2003) evaluated the effect of different ownership in the food processing sector in Canada. These authors argued that "foreign ownership may not only affect whether more advanced manufacturing technologies are used, but also how effective the technologies are in terms of generating productivity growth" (Baldwin, Sabourin and Smith, 2003).

2.3.3 Research and Development Budget

Rogers (2002) and Acs and Audretsch (1988) found that R&D expenditures play a positive and significant effect in determining the rate of innovation. These authors claim that the more resources devoted to research and development, the higher the rate of innovation. This claim is also confirmed by Schumpeter's model (Schumpeter, 1934). Schumpeter's model shows that an increase in resources devoted to research and development would shift the PVI (Present Value of Innovation) curve upward and this shift, keeping other factors constant, would increase the number of innovations per year. Rogers (2002) empirical work confirms this. He reports that R&D expenditure has a positive effect on the rate of innovation. Acs and Audretsch (1988) also found that an increase in the research and development budget would increase the rate of innovation.

Harris and Trainor (1995) studied the effect of research and development budgets on the probability of innovation in a firm. These authors hypothesized that there was a positive correlation across the firms between research and development budget and innovation outputs. Harris and Trainor found that a one percent increase in a research and development budget would increase the rate of innovation by 1.060 percent. In addition, they evaluate the effect of expenditure on capital such as machinery, equipment and building on the rate of innovation. They show that the expenditure on plant, machinery and building per employee has a positive and significant effect on the rate of innovation in these firms.

2.3.4 Capital Intensity

De Long and Summers (1993) and Temple and Voth (1998) suggest there are strong relations between equipment investment and the rate of innovation in many manufacturing firms. They showed that acquiring the latest technology enabled the firm to capture the technology content of the new equipment and this expanded the stock of information available within the firms. Another benefit of new equipment and machinery is that it enables the firms to expand its stock of knowledge through learning-by-doing on new machines (De Long and Summers, 1992). These investments help the firm to be more competitive and have more resources devoted to innovative activity which would increase the rate of innovation within the firms.

Baldwin and Lin (2001) conclude that advanced technology, machinery and equipment provide a wide range of benefits for innovative firms. In theory, this capital should increase the number of innovations per year because workers' skills have increased after working with the modern technology. This increase in the stock of knowledge within the firms enables workers and innovators to combine more ideas and tools together in order to develop a new product or a new processing method. In addition, the availability of the machinery and equipment in the firms have another benefit for innovative firms because workers are forced to increase the years of their training in order to work with these modern technologies.

Beaumont and Schorder (1997), Rischel and Burns (1997) and Small (1998) show that the availability of the latest technology in the firm increases productivity, improves flexibility, enhances the quality of products and reduces production costs. Firms can acquire these modern and advanced technologies by either purchasing them in open markets or inventing them within the firm (Van Den Berg, 2001). The first option portrays a firm as a follower in the market. These firms usually do not have any competitive advantages in the market because the inventor of the technologies already gains the benefit from these new technologies. However, those firms that invent new technologies within their firm are leaders in the market and these leaders can obtain a temporary monopoly in the market through 'creative destruction' (Schumpeter, 1934). This implies that inventors have the ability to separate themselves from other firms in the market and create a market niche (Van Den Berg, 2001). There are many rewards in obtaining a market niche within the industry. Firms possessing these market niches can use their surplus profits in upgrading their facilities, expanding their operations and investing in their employees. Previous sections show that big firms with highly educated people and modern technologies have better capabilities to invent new products. As a result, a firm that invents a new product or a process innovation has a better chance in developing future innovations (Munnich and Schrock, 2002).

In a study conducted by Lööf and Heshmati (2000), capital intensity had an insignificant effect on the rate of innovation. In addition, Acs and Audertsch (1988) came to the same conclusion that capital intensity did not have any effect on the rate of innovation. The effect of capital intensity on the rate of innovation in Canada is unclear. Baldwin and Johnson (1995) did not find any relationship between capital intensity and rate of innovation in small and large processing firms in Canada. However, Baldwin, Sabourin and Smith (2003) showed that capital intensity plays a significant role in increasing the labor productivity in food processing firms in Canada.

2.4 Market Competition and Innovation

There are many empirical research studies examining the effect of competition on innovation. Park and Weliwita (1999) argue that market competition can have positive and negative effects on the rate of innovation. In addition, Arrow (1962) demonstrated that the rate of innovation should be much higher among firms in competitive industries because increased competition fosters a greater incentive for innovation. However, Reinganum (1981) shows that increased competition delays the process of innovation among many firms.

McNamara, Weiss and Wittkopp (2003) study the degree of competition on the rate of innovation in food processing plants in Germany. These authors show that competition has a negative and significant effect on the rate of innovation. McNamara, Weiss and Wittkopp (2003) argued that firms in highly competitive markets do not invest in innovation because a product's life span and product success rate is very short term and small in the food processing sector. This implies that product and process innovation will have lower attainable prices and profits and these innovations will not meet the performance objectives in the market. In addition, this negative relationship between market competition and innovation is also shown by a number of authors such as: Cooper (1982), Maidique and Zirger (1984) and Hultink et al. (1995).

Chapter 3: Data

3.1 Survey of Innovation

There are three main data sets used in this thesis to analyze the relationship between education and innovation in the food processing sector in Canada. The first set of data is obtained from the Survey of Innovation conducted by the Agricultural Policy Research Network. This survey was conducted in the winter of 2005. In this period, 1200 surveys were mailed to food processing firms in western provinces of Canada including: British Columbia, Alberta, Saskatchewan and Manitoba. The response rate for this survey was 12.5 percent and only 44 complete surveys were used in this thesis. The balance lacked need responses regarding education levels. For the purpose of this survey, innovation is either a new product or process innovation that is new to the business or new to the market.

3.2 Innovation in the Food Processing Industry Survey

The second set of data was obtained from the Innovation in the Food Processing Industry Survey conducted in the winter of 2004 by the Small Business and Special Surveys Division of Statistics Canada on behalf of the Agriculture and Agri-Food Canada. The survey covered about 800 establishments. The objective of this survey was to collect new statistical information on the nature and extent of innovation in the food processing industry, characteristics of organizational change, and data on restructuring practices in the food supply chain that support innovation processes and facilitate the delivery of innovative products and services. For the purpose of this survey, innovation was defined as being the first firms to introduce and/or develop a brand new or significantly improved product or process in North America (Statistics Canada)[2].

3.2.1 Target population

The target population for the Innovation in the Food Processing Industry Survey was all establishments in the North American Industrial Classification System (NAICS) code 311 'Food Manufacturing' with revenues greater than $1 million per year. NAICS 311 includes: NAICS 3111 Animal and Food Manufacturing, 3112 Grain and Oilseed Milling, 3113 Sugar and Confectionary Product Manufacturing, 3115 Dairy Product Manufacturing, 311611 Animal (except poultry) Slaughtering, 311614 Rendering and Meat Processing from Carcasses, 311615 Poultry Processing, 3117 Seafood Product Preparation and Packaging, 3118 Bakeries and Tortilla Manufacturing and 3119 Other Food Manufacturing. There were approximately 2490 establishments in the target population (Statistics Canada).

3.2.2 Instrument design

The Innovation in the Food Processing Industry Survey questionnaire was initially developed by the Microeconomic Studies and Analysis Division of Statistics Canada and Agriculture and Agri-food Canada. The Small Business and Special Survey Division reviewed and revised the questionnaire with input from Agriculture and Agri-food Canada based on feedback from questionnaire testing with Statistics Canada's Questionnaire Design Resources Centre (Statistics Canada).

[2] The exact wording of the definitions for product and process innovations are listed in Appendix C below.

3.2.3 Sampling

This survey is a census with a cross-sectional design. In addition, this was a census of all in-scope companies and the survey frame was built using Statistics Canada's Business Register. All companies with the exception of those that participated in questionnaire testing were surveyed. This maximized the ability to provide revenue, establishment, regional and NAICS breakouts and to ensure a high level of data quality in the event of non-response. Prior to the start of the collection period, all companies in the survey were contacted in order to verify and update the information on the frame as well as to identify a knowledgeable contact person to complete the survey. This process is known as 'pre-contact'. The questionnaire was subsequently mailed to the attention of the person identified during pre-contact. For those companies for which did not have a contact person, the questionnaire was sent to the attention of the company without a contact (Statistics Canada).

3.2.4 Error detection

Questionnaires were initially manually edited and outliers detected as they were received during collection. A series of edit rules were developed and invalid or inconsistent entries were corrected using these rules. Telephone follow-up was conducted for missing entries that could not be manually edited (Statistics Canada).

3.2.5 Imputation

The verification process determined if certain respondents failed to answer certain questions or that their answers were not consistent. These are partial non responses and in this case, the missing data were imputed. The data were imputed using a hot deck technique whereby a donor respondent is selected randomly from a group of respondents with complete responses and similar characteristics. The characteristics used in this survey to establish similarity, as agreed upon by the clients, were the industry code (NAICS), total income as reported, and the "country of origin of the majority owners" collected during the survey. If possible, all three characteristics were used to find a donor, but in certain imputation scenarios only two characteristics, and sometimes only one, had to be used. The imputation rate for each individual variable varies from 1 to 25 percent (Statistics Canada).

3.2.6 Quality Evaluation

The Innovation in the Food Processing Industry Survey was the first survey of its kind collecting data on product and process innovation. Currently there are no published data comparable to the data collected by this survey (Statistics Canada). It is important to note that this thesis used un-weighted data to run regressions. In addition, some observations were deleted from the data set for two main reasons. First, the respondents did not fill out the survey completely. This meant that the respondents did not answer the questions in the survey that were relevant for this thesis. Secondly, a link to the Census Consolidated Subdivision (CCS) region representing the location of the firm was not always available from the Census of Population. The CCS in the Food Processing Industry Survey did not always match a CCS in census of population and this caused 45 observations to be deleted from the data set because there was no geographical information for those particular firms.

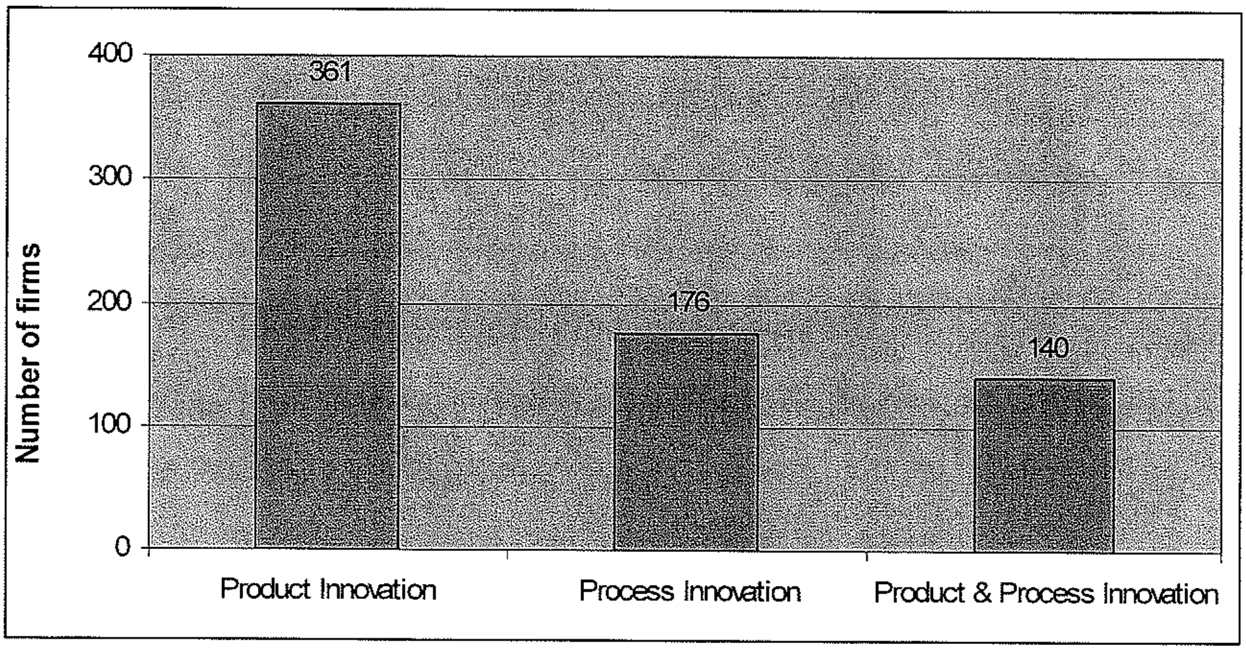
3.3 2001 Census of Population

The third data set used in this thesis is the 2001 Census of Population. This census was used to find the education level in each CCS region and to link each firm to a CCS code of urban, rural or intermediate. Urban and rural are two dummy variables used in models below to see if the location of the firm plays any part in determining the rate of innovation in the firm. If the firm is located in an urban area, it would receive a 1 and a 0 otherwise. The same method is used for rural with intermediate being the base case. In this thesis, rural refers to a CCS region with a population living in places of 1,000 people or less or population living in places with densities of 400 or fewer people per square kilometer (du Plessis *et al.*, 2001). Urban refers to centers with over 100,000 in population plus all the neighboring municipalities where 50 percent or more of the workforce commute to that urban core (du Plessis *et al.*, 2001). The term intermediate refers to the regions that do not meet these definitions for urban or rural locations. In Canada, the Census of Population is conducted every five years. It provides a snapshot of the population; its size and geographic distribution as well as its demographic, socio-cultural and socio-economic characteristics. The data produced are used widely by all levels of government for policy planning and program administration. Population estimates based on census counts are used to determine fiscal transfer between levels of government.

Chapter 4: Food Processing Sector and Innovation

Innovation plays an important part in maintaining a competitive advantage over competitors and sustaining economic benefit over long periods of time. Companies and establishments in the food processing sector understand these concepts and introduce product and process innovations in order to take advantage of these benefits.

Graph 1 Firms reporting an innovation in Canada 2001 to 2003.

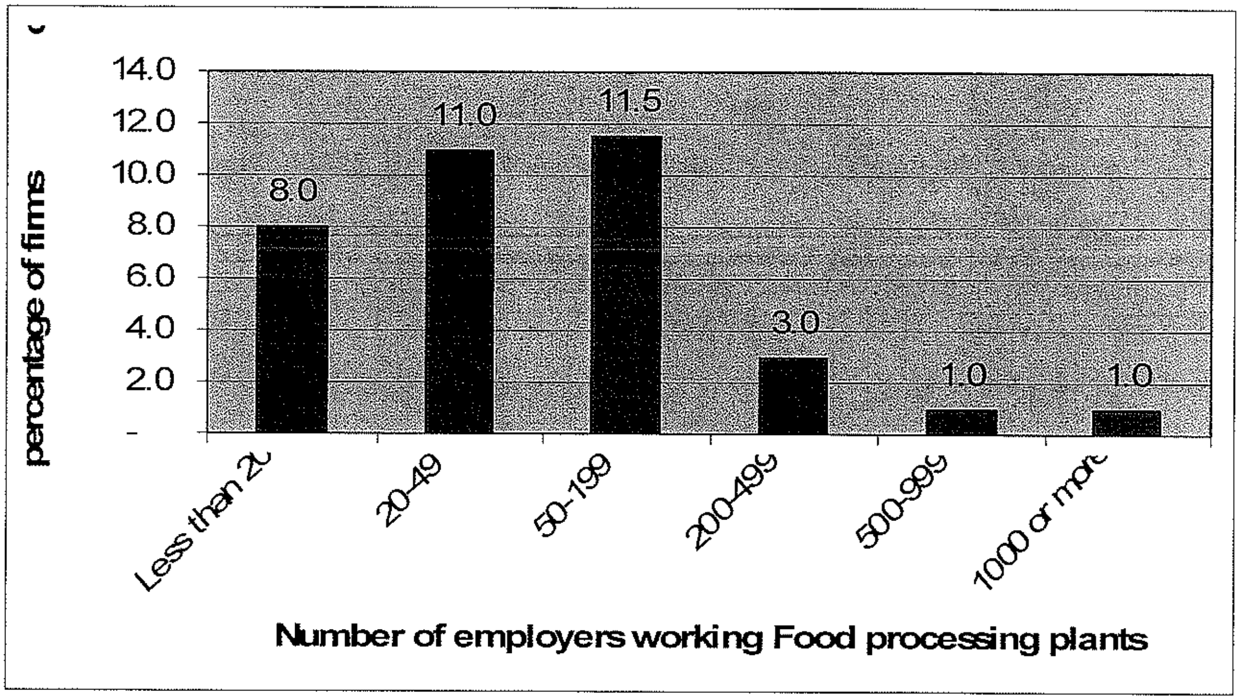


Source: Statistics Canada, Innovation in the Food Processing Industry Survey

Graph 1 shows the number of establishments that reported at least one innovation from 2001 to 2003. 52 percent of the establishments reported that they produced at least one product innovation and 25 percent reported at least one process innovation.

Graph 2 shows the range of workers that are employed in these food processing firms. 33 percent of the establishments in the survey sample reported average employment between 50 to 199 workers per year and 32 percent of the establishments in the survey reported that they employed between 20 to 49 workers per year. Only 4 percent of food processing establishments in survey sample hired 500 or more workers per year. In addition, Graph 3 shows the number of employees engaged in research and development in the establishments. 63 percent of food processing establishments in the survey sample indicated that on average their research group consisted of 20 workers or less per year from 2001 to 2003.

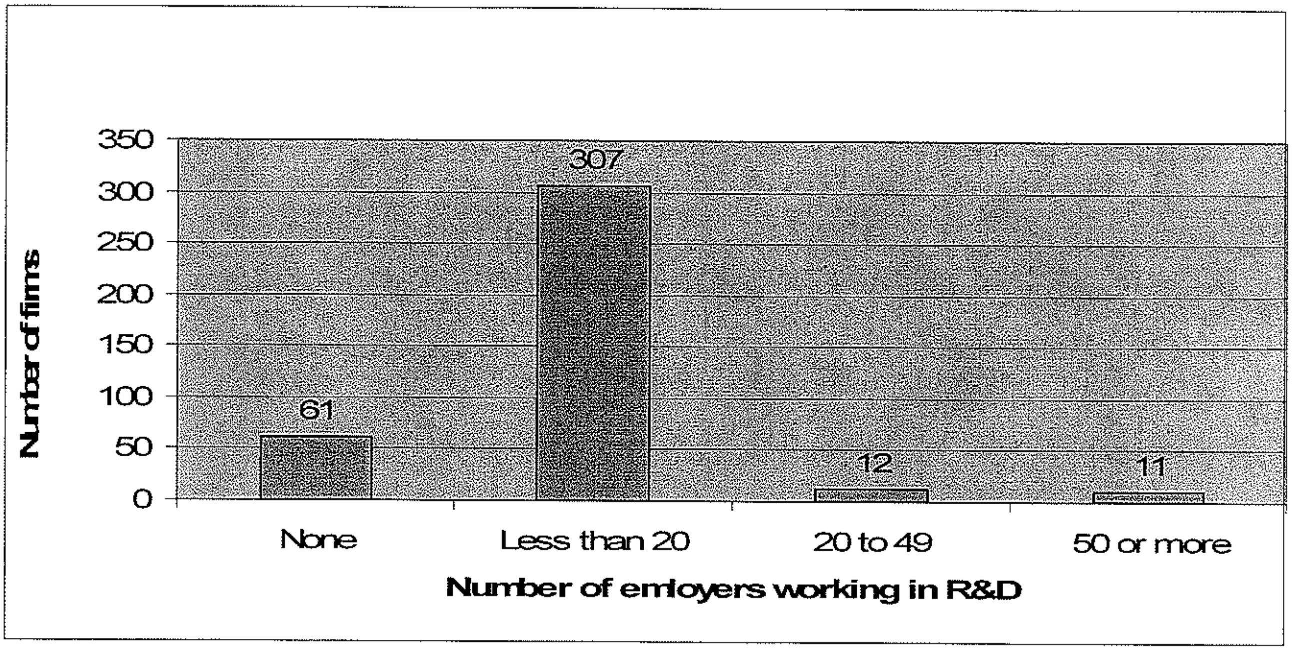
Graph 2 Size of firms in survey sample by number of employers, 2001-2003



Source: Statistics Canada, Innovation in the Food Processing Industry Survey

Table 3 shows different methods used by establishments to develop new products and process innovations. Most of the establishments in this survey indicated that they use their own establishment's laboratory in order to carry out research and development. 32 percent of establishments indicated that they used their own laboratory to invent a new process innovation and 35 percent of establishments indicated that they use their own research facilities to produce a new product innovation. The next preferred method in product innovation is using prototyping scale-up and similar engineering services by their own establishment to produce a new innovation. 35 percent of establishments indicated that they use this method to develop a new process innovation and 28 percent of establishments indicated that they use this method to develop product innovation.

Graph 3 The number of employees working in (R&D) in firms in survey sample, average 2001-2003



Source: Statistics Canada, Innovation in the Food Processing Industry Survey, 2003

Table 3 Methods used by establishments to develop new product and process innovation, Canada, 2001-2003

Category	Process	Product
Laboratory based R&D investigation in this establishment	32	35
Laboratory based R&D investigation by parent company outside	6.7	18.5
Laboratory based R&D investigation contracted out by other establishments	10.7	4.4
Using prototyping, scale-up and similar engineering services	34.8	27.4
Collaborating with other establishments	15.7	14.7
Total	100	100

Source: Statistics Canada, Innovation in the Food Processing Industry Survey, 2003

Table 4 shows the motivations for product innovation in a sub sample of the survey. Product expansion and market expansion are the main motivations for engaging in product innovation. 52 percent of establishments indicated that they invest in product innovation in order to add new products to their existing lines of products (Table 4). In addition, 58 percent of establishments indicated that increasing their market share is another driving force for investing in product innovation.

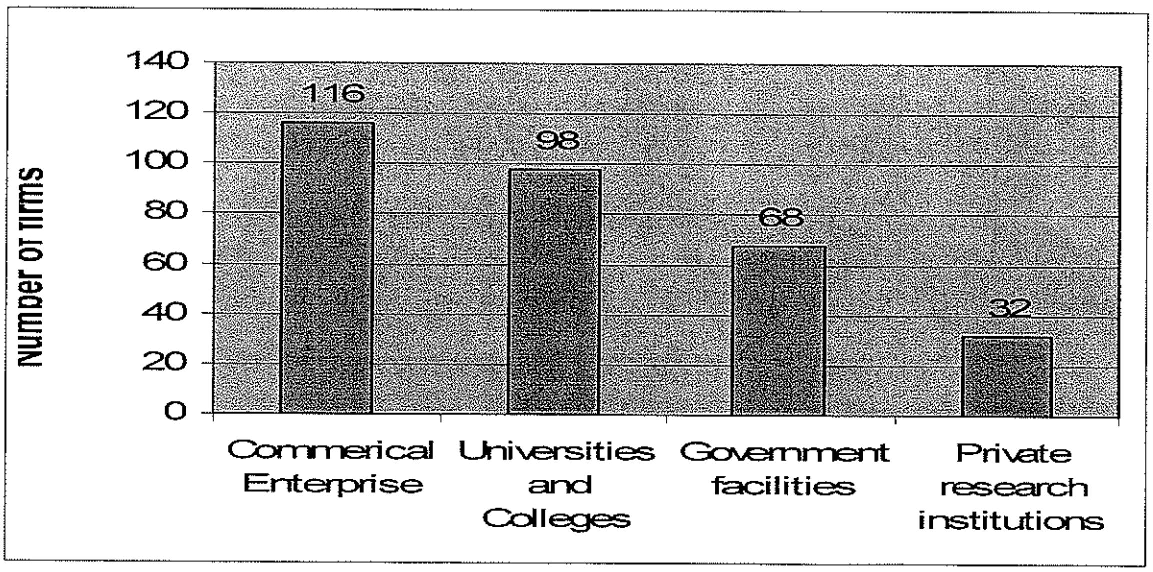
Table 4 Motivations for product innovation in the food processing sector, Canada 2001-2003

Product Expansion	%	Market Expansion	%
Replace old product	2.8	Access to new domestic market	26.9
Add new products	61.5	Access to new foreign market	11.2
Create superior products	34.7	Increase market share	57.7
Not applicable	1	Not applicable	4.2
Total	100	Total	100

Source: Statistics Canada, Innovation in the Food Processing Industry Survey, 2003

Graph 4 shows that the majority of food processing establishments in the innovative sub sample in Canada use commercial enterprises in order to develop product and process innovations. These external sources include: commercial laboratories and research and development enterprises, universities and colleges, federal and provincial government research facilities and private research institutions. Surprisingly, government research institutions are not the most used external source.

Graph 4 External organizations used by establishments to produce new innovation, Canada, 2001-2003



Source: Statistics Canada, Innovation in the Food Processing Industry Survey, 2003

Chapter 5: Hypothesis

The main objective of this thesis is to determine the effect of education on the rate of innovation in food processing plants in Canada. There are secondary objectives in this thesis; such as, the effect of firm size, ownership, market structure and location on the rate of innovation but the majority of this thesis will focus on the effect of education.

Previous sections show that the effect of education on the rate of innovation is not very clear. Some studies find a positive relationship and some studies find a negative relationship between education and the rate of innovation. However, this thesis will hypothesis that higher education will have a positive effect on the rate of innovation in food processing plants in Canada. An educated worker with a bachelor or a master degree has more skills and expertise and these tools help these workers to combine their past knowledge in order to develop a new product or process. In addition, an educated worker is more talented in learning the latest technology which aids the workers in acquiring the most recent techniques in innovation. This talent assists the educated workers in producing innovations by the most effective methods.

Education will have a positive effect on the rate of innovation because an educated person has better communication skills, interpersonal skills and analytical reading and problem solving ability. Better communication skills enable the educated employees to share their ideas with their colleagues and supervisors clearly and efficiently. In addition, educated workers have better interpersonal skills and these capabilities enable employees to work more efficiently in groups or by themselves. Superior analytical reading abilities in educated individuals enables them to read, understand and use the information presented to them more efficiently. Finally, educated individuals can easily understand a problem and find a solution for that particular problem very quickly and implement that solution by the most efficient means. As a result, educated employees have more effective resources and are better trained in developing new innovations.

Education will have a positive effect on the rate of innovation as educated individuals can increase their stock of knowledge through different means. Schumpeter showed that increasing the stock of knowledge among individuals will increase the rate of innovation. Educated individuals can increase their stock of knowledge through networking, the years that they spend in university or college and belonging to different professional groups and organizations. In conclusion, this thesis hypothesizes that education will have a positive effect on the rate of innovation in food processing plants in Canada.

A secondary objective in this research is to identify some of the firm, market and regional characteristics that affect the rate of innovation in the food processing sector in Canada. This thesis will test if establishment characteristics such as: size, the resources devoted to training, the capital intensity and R&D budget play a role in the rate of innovation. In addition, the model will include market structure features such as price competition or product competition importance, as surveyed, determine whether establishments in highly competitive markets tend to produce more innovations than establishments in non-competitive markets (Hanel, 2000). In addition, the location of a establishment is expected to play an important part in determining the rate of innovation. This thesis hypothesizes that establishments that are located in rural areas will have a lower innovation rate than establishments located in urban areas because rural areas have challenges attracting skilled labor and getting their products to market.

Chapter 6: Theoretical and Analytical Framework[3]

6.1 A model of costly innovation driven by profits

The models of endogenous technological progress usually model technological progress as the stream of products x_1, x_2,............., x_n , where each new product replaces the product preceding it because it is in some way superior to its predecessor. The models generally assume that innovators engage in innovative activity up to the point where the expected marginal gains from innovation equal the marginal costs of innovation. Suppose that the market consumes one product, denoted as x_t, at time t, and that the innovator who created x_t reaps a profit because the innovation made x_t preferable to x_{t-1}. This latter assumption includes the assumption that all consumers are identical (they are not distributed all along a downward-sloping demand curve) and that the markup is marginally less than the increase in value provided by the latest innovation.

In the Schumpeterian environment of creative destruction, profit from innovation depends on (1) the future profit markup u, (2) the level of production X, which is the total quantity of the product x_t, and (3) the number of days τ that the innovator can produce and enjoy the profit markup before her market position is destroyed by a subsequent innovation. Thus, profit π is equal to:

$$(1)\ \pi = uX\tau$$

The level of production depends on how many resources are devoted to production rather than research and development (R&D) activities. That is, daily production of x_t is directly related to the economy's total amount of productive factors

[3] The theoretical part of this thesis was provided by Dr. Van Den Berg's class notes, University of Nebraska, 2005

and resources, R, and inversely related to the fraction of those resourced devoted to innovation, n. Specifically, the total resources devoted to innovative activity are equal to:

$$(2)\ N = nR$$

Suppose for simplicity, that one unit of resources R produces one unit of output x_t. The total level of production in time t is therefore:

$$(3)\ X = (1-n)R$$

The opportunity cost of innovation is the lost production of product x_t caused by shifting scarce resources to innovative activities.

6.2 The Cost of Innovation (CoI)

The rate of innovation in the economy is determined by solving a maximization problem that takes into consideration the costs of innovation and the expected benefits of innovation. Innovating establishments must purchase labor and other productive resources at market prices in competition with the producers of x_t who demand those same resources to earn a profit producing the most recently-developed product, x_t.

The cost of resources will be less, *ceteris paribus*, the more factor and resources, R, are available in the economy. And, the cost of resources will be higher, *ceteris paribus*, the greater is innovation because total demand for resources depends on the level of production and the level of innovation. The price of the resource w is therefore some function of N and R as follows:

$$(4)\ w = g(N, R)$$

The process of innovation is normally subject to a high degree of uncertainty. Devoting resources to R&D activity does not guarantee that something useful will actually be created, nor is there any neat time schedule that says how long it will take to make a new scientific discovery or when the search for a more attractive product will result in a successful creation. In short, there is a large risk associated with innovative activities. To make our maximization problem tractable, suppose that new products are developed according to some process that has a known average outcome that is a function of the amount of resources devoted to innovative activity. Suppose also that the exact timing of new products and creations fluctuates randomly around the timing predicted by the mean of the linear function. Since we are interested in modeling the long-run growth process, we can therefore solve for the average outcome. A further justification is that potential innovators can be assumed to have rational expectations, which means that they predict the future correctly on average. The assumptions of rational expectation permit us to substitute expected values for future values.

Another simplifying assumption that we make is that each innovator is a perfect competitor in the market for resources and in the innovative process, and that each innovator employs resources to the point where marginal profits are zero. Thus, the economy's average cost and profit functions are viewed as the marginal functions by each individual innovator. Note that this assumption also effectively implies that innovators are risk-neutral and they do not require a premium to induce them to undertake the inherently risky innovative activities.

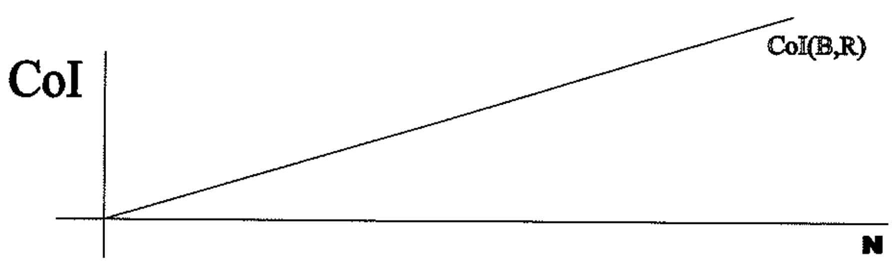
Suppose that it takes, on average, β unit of resources to produce an innovation. We are here assuming that the production function of innovations is linear with respect to the productive resources, R, employed in innovative activity. The average cost of innovation, CoI, that an entrepreneur expects to incur in generating an innovation is therefore:

$$(5)\ \text{CoI} = w\beta$$

The more research is undertaken, the more labor and other resources need to be hired. If the total supply of productive factors and resources are fixed at R, increasing innovation increases total demand for factors and resources, which drives up the prices of factors and resources. Hence, the cost of innovation, CoI, increases as innovative activity increases. Figure 2 shows a typical upward-sloping CoI curve relating marginal costs of innovation to the amount of factors and resources used in innovation, N. All other things equal, the CoI curve shifts up if β, the average amount of resources needed to generate an innovation increases. In general notation, the cost of innovation is:

$$(6) = h\ (N, R, \beta)$$

Figure 2 The Cost of Innovation (CoI)



6.3 The Present Value of Innovation (PVI)

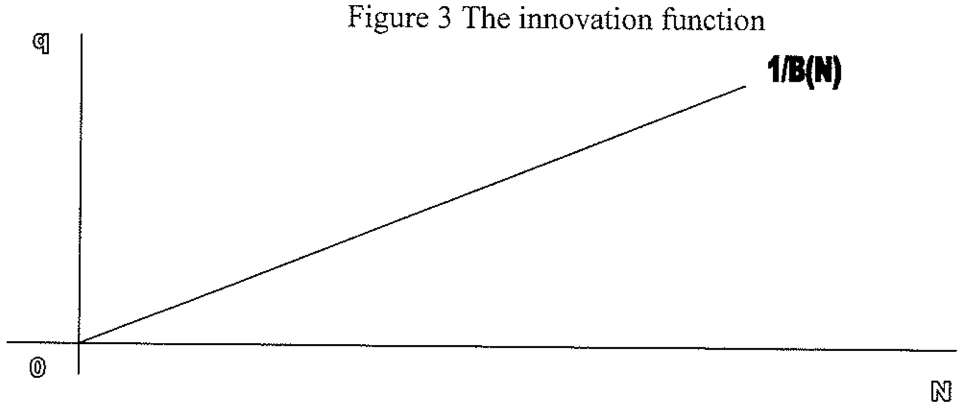
In accordance with equation 1, the expected profit from an innovation is a positive function of the average markup, u, the amount of output produced, X, and length of time τ that an innovator expects to enjoy the monopoly profit. The length of time τ depends on how fast new innovations are created. Since we have assumed that it takes β units of resources to generate an innovation, the expected number of innovations, q, is:

$$(7)\ q = (1/\beta)N$$

Figure 3 provides a graphic illustration of the relationship between amounts of resources devoted to innovation, N, and the average quantity of innovations, q, generated. It follows from equation 3 that the time that an innovator expects to enjoy his/her profit is equal to:

$$E(\tau) = 1/\,q = \beta/N$$

Figure 3 The innovation function



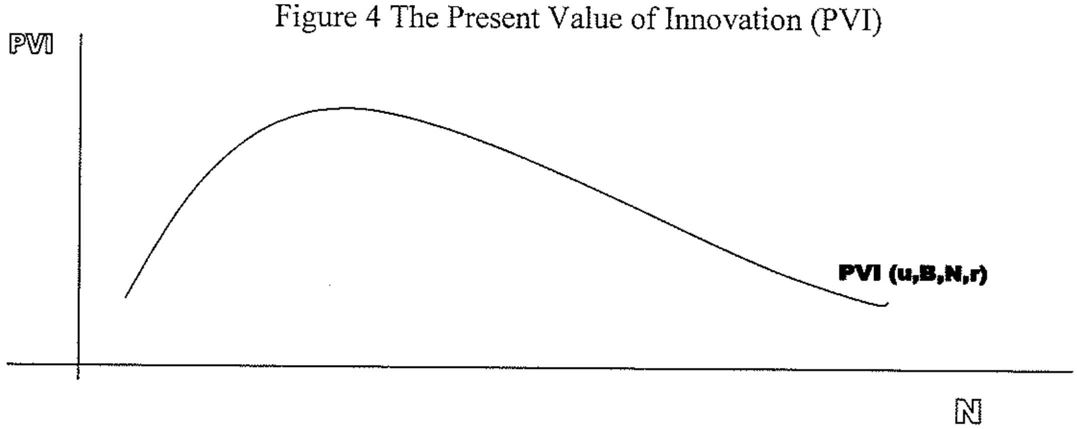
Expected future profit also depends on the amount of production X, which competes for the use of resources in R and D. The more resources used for innovation, the fewer are available for producing profitable products derived from the innovations. Hence, there are two reasons why the present value of an innovation is inversely related to N: (1) a higher N reduces the amount of resources available to produce profit-generating output. An increase in total resources, R, permit more future production X, which implies that expected profits are positively related to R.

Finally, because innovations require current expenditures on research and development that must be paid from future profits, expected future profits must be discounted. The annual discount rate is r; the higher the discount rate, the less is the present value of an innovation. In general, the present value of future profit from innovation, denoted as PVI, takes on the following general form:

$$(9)\ PVI = f(u, R, N, \beta)$$

PVI declines as more resources are applied to innovative activity, that is, as N increases. All other things equal, in a rational world profit will eventually diminish the greater is N, and thus the lower is the PVI. This function is drawn in Figure 4. Note also that an increase in u, R or β raises the entire PVI curve. An increase in r lowers the curve.

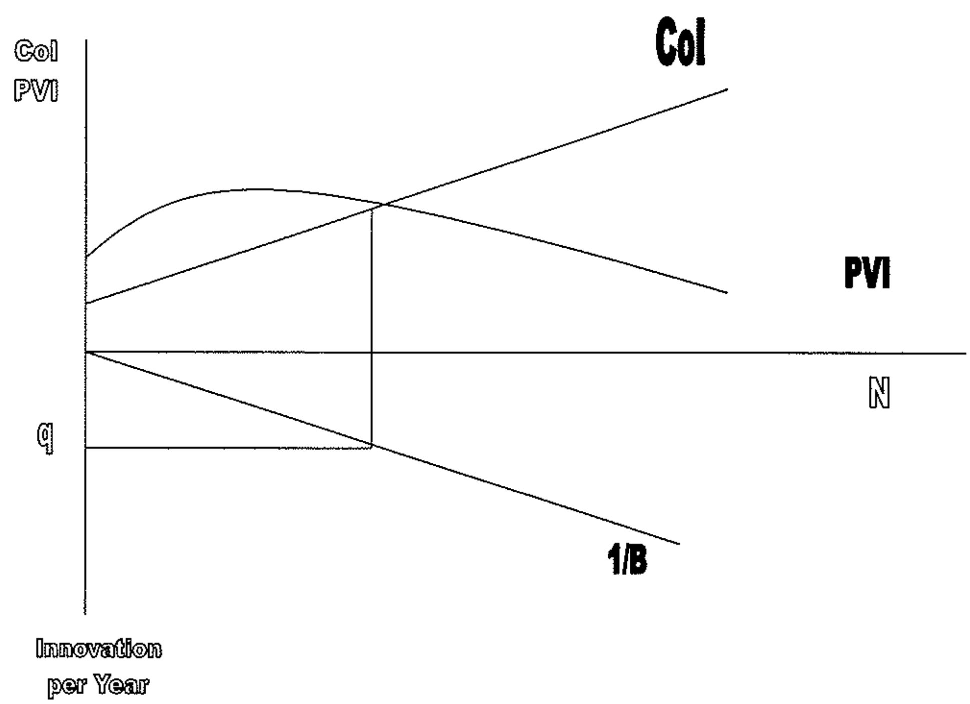
Figure 4 The Present Value of Innovation (PVI)



6.4 The equilibrium level of R&D activity

Figure 5 combines Figure 2, 3 and 4. The top part Figure 5 combines Figure 2 and 4. The intersection of CoI and PVI curves determines the equilibrium N, the amount of resources that competitive entrepreneurs devote to innovative activity. Then, the bottom half of Figure 5 is simply Figure 3 turned upside down and conveniently attached along the horizontal axis that it shares with Figure 2 and 4. The 1/B curve translates N into the number of innovations. Given the values of the parameters that determine the CoI and PVI curves in the upper half of Figure 5 and the productivity of the innovative process as given by β, the economy produces q innovations per year.

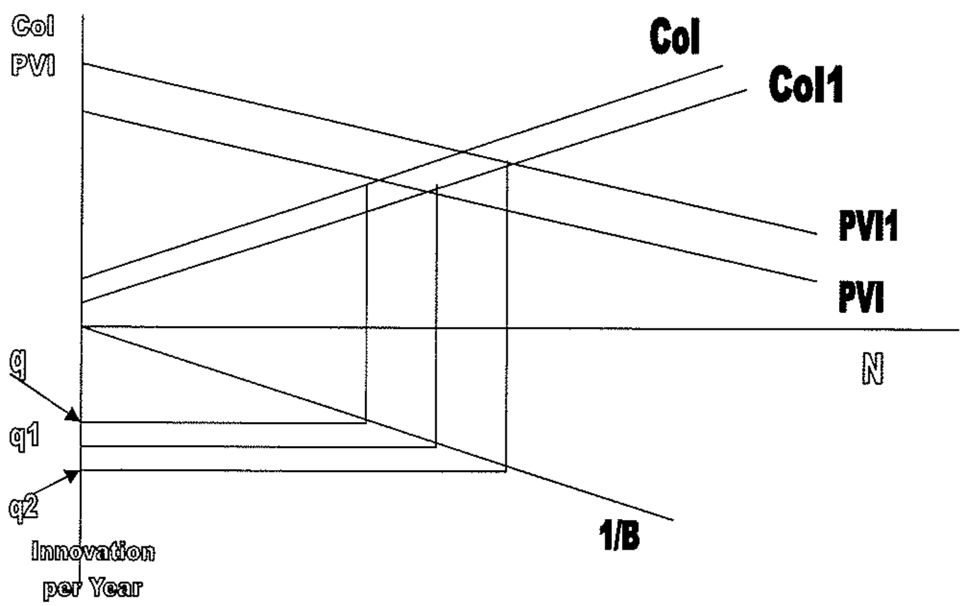
Figure 5 Schumpeter Equilibrium Innovation



6.5 The Effect of Change in R on Innovation

Figure 6 illustrates how a change in R affects shifts in both CoI and PVI curves. For example, an increase in R by increasing the stock of knowledge among workers through education and training, lowers w, which according to equation 6, shifts the CoI curve down to CoI1 and thus causes the equilibrium value of N and the number of innovations to increase to q_1. However, an increase of R also shifts up the PVI curve because an increase in productive resources implies more production of new products and, therefore, more profit, all other things equal. This effect increases N further, and thus the number of innovation rises further to q_2. To clarify, q_1, the number of innovations increases as we increase resources, including education, dedicated to research and development as well as many regional and establishment characteristics.

Figure 6 The effect on Innovation of an Increase in R (Resources)



Chapter 7: Analytical Models

There are two dimensions regarding the importance of education in any economy. One dimension of education is the ability to adjust to changing conditions and another dimension may be the ability to innovate (Nelson and Phelps, 1969). However, unlike physical capital, the contribution of education on output is not clear. The purpose of this thesis is to show the effect of education on total output and innovation activities in food processing establishments in Canada. This thesis has already discussed the relationship between the numbers of innovations and education level at the end of chapter. Unfortunately, the number of innovations per firms was not a ge4nerally available measure so this thesis uses the rate of innovation (or a binary measure of yes or no to the question: did you innovate in the last 3 years.)

The general model to explain the rate of innovation in food processing establishments can be written as:

$$(10)\ \Pr(y=1|x) = \Phi(xb),$$

Where y is the probability of innovation within the firm, x is the matrix of explanatory variables, b is a vector of coefficients of interest (Rogers, 2004). This model shows that innovation output is related to innovation inducing inputs in each food processing establishment. However, a general formula can be obtained from equation 10 and this general formula follows as:

$$(11)\ \Pr(y=1|x) = \Phi\ (L_{firm}, X_{firm}, X_{sector}, , X_{location})$$

Where L_{firm} represents the quality of labor factor employed by the firms, X_{firm} represents the structural characteristics of firms and X_{sector} represents the sectoral market structures and $X_{location}$ represents the regional effect on the rate of innovation (Huiban and Bouhsina, 1998).

Central to this model is the determination of a firm's probability of innovation. This probability of innovation can be represented by:

$$(12)\ \Pr(y=1|x) = \Phi\,(\beta_{i1} \sum L_{firm} + \beta_{i2} \sum X_{firm} + \beta_{i3} \sum X_{sector} + \beta_{i4} \sum \text{Location})$$

In this model, y represents the probability that a firm would produce an innovation given the explanatory variables. The degree to which the education levels within the firm affect the rate of innovation is characterized by β_{i1} where β_{i1} can be positive or negative. A positive sign indicates that the higher education level would increase the probability of innovation and a negative sign means that the higher education level would reduce the probability of innovation per year. Furthermore, B_{i2} can have a positive or a negative sign as well. A positive sign indicates that the firm's characteristics such as size, ownership structure and capital intensity within the firms would increase the number of innovations per year. This can be further clarified by Schumpeter's model. For instance, increasing the number of employees within the firm would have a positive effect on the probability of innovation if it increases the stock of knowledge. This increase in knowledge would push the PVI curve upward. This shift suggests an increase the resources devoted to innovative activity. This increase in resources N, in turn, raises the number of innovation per day to q_1.

The same concept can be applied to β_{i3}. When $\beta_{i3} > 0$, the market structure measures would increase the probability of innovation and when $\beta_{i3} < 0$, the market structure reduces the probability of innovation within the firms. In addition, when $\beta_{i3} = 0$, market structure does not have any effect on the probability of innovation. The same concept can be applied to β_{i4}.

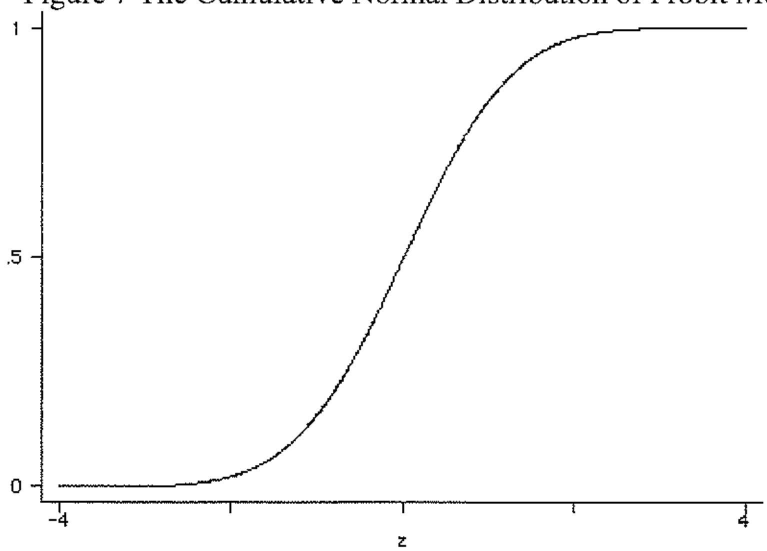
These theoretical models follow the definition provided by Schumpeter's well-known definition of innovation. Schumpeter's (1934) new combinations of productive means not only provide a formal definition of innovation but also present and identify a certain number of exogenous variables which are presented in the following section. Some of these variables have a direct effect on the probability of innovation and some have a secondary effect on the probability on innovation.

Chapter 8: Probit Model

8.1 Probit

The probit model represents another type of widely used statistical model for studying data with binomial distribution. Its "employment in the social science goes back at least to econometrics in early 1960" (Liao, 1994). In the probit model, the dependent variable, Y, is assumed to be binary, taking on two values, 0 and 1 (Aldrich and Nelson, 1984). The outcomes on Y are assumed to be mutually exclusive and exhaustive. The question of interest hinges on the value of the parameter P, the probability that Y equals one (or P = P (Y = 1)). In addition, the probit model uses the cumulative normal probability distribution which is shown in Figure 7.

Figure 7 The Cumulative Normal Distribution of Probit Model



Y is assumed to depend on K observable variables, X_k, k = 1, ….., K. That is, the exogenous variables account for the variation in P. This is indicated by:

$P = P(Y = 1 \mid X_1 \ldots\ldots X_k)$, or simply $P = P(Y \mid X)$, where X donates the set of K independent variables (Aldrich and Nelson). This assumption is analogous to the standard regression model in which exogenous variables account for the variation in the mean, or expectation, of Y (Aldrich and Nelson).

The Probit model assumes that the data are generated from a random sample size N, with a sample point donated by i, i = 1 ... N. This assumption requires that the observations on Y be statistically independent of each other, ruling out serial correlation (Aldrich and Nelson). Furthermore, in probit model, the independent variable may be random variables, for example responses to survey questions, or they may be fixed, as in an experimental setting (Aldrich and Nelson). Probit model requires only that there be no exact linear dependence among the X_{ik}'s. This assumption implies that N > K, that each X_k must have some variation across observations and no two or more X_k's be perfectly correlated (Aldrich and Nelson, 1984).

8.2 Maximum likelihood estimation

Probit parameters are typically estimated by a method called Maximum Likelihood Estimation (MLE) in contrast to ordinary regression models which are estimated by the method of Least Square Estimation (LSE). MLE and LSE are two different methods with different objectives (Aldrich and Nelson, 1984). The MLE objectives can be explained as follows. Let $P_i = P(Y_i = 1 \mid X_i)$ which means that $P(Y_i = 0 \mid X_i) = 1 - P_i$. This implies that the probability of observing outcomes Y_i is given by $P(Y_i \mid X_i) = P_i^Y (1 = P_i)^{1-Y}$ (Aldrich and Nelson). Furthermore, P_i, and thus $P(Y \mid X)$ depends on the values of the K coefficients in b. Since the objective is to estimate b, the probit makes this dependence on b explicit by defining the likelihood function, $L(Y \mid X, b) = P(Y \mid X)$ (Aldrich and Nelson). If this function were to be evaluated using the sample observations on Y and X and a particular numerical value or set of K values for b, it would yield a number between zero and one which would represent the probability or likelihood of observing that particular sample Y if the employed value b were indeed the true value (Aldrich and Nelson). The principle of MLE, quite simply, is to choose an as estimate of b that set of K numbers say β, which would make the likelihood of having observed this particular Y as large as possible.

As a result, the conceptual difference between LSE and MLE is that LSE is concerned with parameter estimates that yield the smallest sum of squared errors in the fit between the model and data, while MLE is concerned with picking parameter estimated that imply the highest probability of likelihood of having obtained the observed sample Y (Aldrich and Nelson).

8.3 Marginal Effect on the Probability of an Event

The probit model can be written as: $\Pr(y=1|x) = \Phi(xb)$, where Φ is the standard cumulative normal distribution function and xb is called the probit score or index (Liao, 1994). Since $\Phi(\cdot)$, is a function of all the x's, the probit can only compute marginal effects by assigning certain values to all of the x's. Marginal effects measure the effect of a small change in the regressors on the standardized probit index associated with the event.

Chapter 9: Model specification

There are two models in this thesis. The first model will use the data from Survey of Innovation by Agricultural Policy Research Network. This model consists of two equations: product innovation and process innovation.

$$(13)\ \Pr(\text{Product Innovation} = 1|x) = \Phi(\beta_0 + \beta_1 \text{Budget} + \beta_2 \text{Equipment} + \beta_3 \text{Training} + \beta_4 \text{Education} + \beta_5 \text{Institutional} + \beta_6 \text{Other} + \varepsilon_t)$$

$$(14)\ \Pr(\text{Process Innovation} = 1|x) = \Phi(\beta_0 + \beta_1 \text{Budget} + \beta_2 \text{Equipment} + \beta_3 \text{Training} + \beta_4 \text{Bachelor Degree} + \beta_5 \text{Master Degree} + \varepsilon_t)$$

These two equations consist of five independent variables including: Budget, Equipment, Training, Bachelor's Degree and Master's Degree. Budget is measured by the amount of dollars each firm spent on intramural research and development over the three years surveyed. Equipment refers to the amount of money, measured in dollars, each firm has spent over the past three years in order to acquire advanced machinery, computer software or hardware or generally any equipment that was specifically purchased to produce new or significantly improved products and/or processes innovation.. Training is the amount of dollars each firm spent in the past three years on internal or external training for employees. The purpose of training is to increase employees' capability for development or introduction of new or significantly improved products and process innovation. In addition, there are two dummy variables in these two equations and these dummy variables are: bachelor's degree and master's degree. These variables indicate the answer to the question, "What is the highest level of education among any of the firm's employees?" Previous research suggests the education level in food processing sectors will be important. 20 percent of firms indicated that a high school diploma was the highest education level within their firms. 62 percent of firms reported that a bachelor's degree was their highest education level and only 18 percent of firms had a master's degree as their highest education level. In these two equations, high school education was omitted to prevent perfect correlation between the dummy variables. Table 5 shows these variables and the unit of measurements.

Table 5 Variables used for survey of Innovation

Variable	Dummy Variable	Definition	Unit of measurement
Budget	No	The amount of spending on R&D	Dollar
Equipment	No	The amount of spending on acquiring machinery and new technology	Dollar
Training	No	The amount of spending on training the staff	Dollar
Bachelor Degree	Yes	The highest education level within the firm	Binary
Master Degree	Yes	The highest education level within the firm	Binary

The second model in this thesis will uses the data from Statistics Canada's Innovation in the Food Processing Industry Survey. This model consists of three equations with three dependent variables: product innovation, process innovation and both product and process innovation. The last equation is simply referred to as innovations.

$$\text{(15)}\quad \Pr(\text{Product Innovation} = 1|x) = \Phi(\alpha_0 + \alpha_1 \text{ Size} + \alpha_2 \text{ Ownership} + \alpha_3 \text{ Price Competition} + \alpha_4 \text{ Product Competition} + \alpha_5 \text{ University Facility} + \alpha_6 \text{ Urban} + \alpha_7 \text{ Rural} + \alpha_8 \text{ High school} + \alpha_9 \text{ Post Secondary Education} + \varepsilon_t)$$

$$\text{(16)}\quad \Pr(\text{Process Innovation} = 1|x) = \Phi(\alpha_0 + \alpha_1 \text{ Size} + \alpha_2 \text{ Ownership} + \alpha_3 \text{ Price Competition} + \alpha_4 \text{ Product Competition} + \alpha_5 \text{ University Facility} + \alpha_6 \text{ Urban} + \alpha_7 \text{ Rural} + \alpha_8 \text{ High school} + \alpha_9 \text{ Post Secondary Education} + \varepsilon_t)$$

$$\text{(17)}\quad \Pr(\text{Innovation} = 1|x) = \Phi(\alpha_0 + \alpha_1 \text{ Size} + \alpha_2 \text{ Ownership} + \alpha_3 \text{ Price Competition} + \alpha_4 \text{ Product Competition} + \alpha_5 \text{ University Facility} + \alpha_6 \text{ Urban} + \alpha_7 \text{ Rural} + \alpha_8 \text{ High school} + \alpha_9 \text{ Post Secondary Education} + \varepsilon_t)$$

Size in this model refers to the number of employees working in each establishment. Ownership in this model refers to the majority of ownership of each establishment. This dummy variable will be 1 if majority ownership is Canadian and 0 if the establishment is non Canadian. Price competition and product competition are two dummy variables used to evaluate the affect of market structure on product and process innovation. University in this thesis is a dummy variable and refers to the collaboration between food processing firms and local universities and colleges. Urban and rural are two dummy variables in this model that try to understand if the location of the firm plays any part in determining the probability of

Table 6 Variables used for the Innovation in the Food Processing Industry Survey model

Variable	Dummy Variable	Source of Data	Definition	Unit of measurement
Size	No	Food Processing Industry Survey	The number of employees working in each establishment	# of employees
Ownership	Yes	Food Processing Industry Survey	Ownership of firms either Canadian or Foreign	binary
Price competition	No	Food Processing Industry Survey	Intensity of price competition in food processing	Scale
Product competition	No	Food Processing Industry Survey	Intensity of product competition in food processing	Scale
University Facility	Yes	Food Processing Industry Survey	Using university or colleges to produce innovation	binary
Urban	Yes	CCS region in census of population 2001	population living outside places of 1,000 people	binary
Rural	Yes	CCS region in census of population 2001	over 100,000 person population plus all the neighboring municipalities where 50 percent of more of the workforce commute to the urban core	binary
Population Density	No	CCS region in census of population 2001	Number of people living in each Kilometer square	# of people
High School	No	CCS region in census of population 2001	Percentage of people with high school education in each CCS region	Percentage
Post secondary	No	CCS region in census of population 2001	Percentage of people with post secondary education in each CCS region	Percentage

innovation in the firm. In this thesis, intermediate variable was deleted from the data set to prevent perfect collinearity in the model. This elimination has implication for the interpretation of the results. The last two variables in this model are designed to evaluate the affect of education on the probability of innovation. Table 6 shows these explanations.

Chapter 10: Results

In this section, the results using the Innovation in the Food Processing Industry Survey models are presented.

10.1 Innovation in the Food Processing Industry Survey

10.1.1 Descriptive statistics

Size in this model refers to the number of employees working in each establishment. Respondents could choose from six different employment categories: 1) less than 20, 2) 20-49, 3) 50-199, 4) 200-499, 5)500-999 and 6) 1000 or more.

Table 7 shows the number of employees working in food processing firms in Canada and Table 8 provides a breakdown by province. From this table, it is clear that the vast majority of food processing firms in Canada consist of less than 200 employees.

Table 7 Distribution of food processing establishments by number of employees, Canada, 2001-2003

Number of employees	Number of firms	Percentage of firms
Less than 20	159	0.23
20 – 49	224	0.32
50-199	225	0.32
200-499	65	0.09
500 or more	25	0.04
Total	698	1.00

Data Source: Statistics Canada, Innovation in the Food Processing Industry Survey

Ownership in this model refers to the majority of ownership of each establishment. This dummy variable will be 1 if majority ownership is Canadian and 0 if the establishment is non Canadian. The respondents had 7 options to indicate their ownership and these options were: Canadian, U.S., Mexican, European, Asian, other foreign and Don't know. The 3 respondents reporting "Don't know" were eliminated from the analysis. To keep this model simple and maintain a high degree of freedom, only Canadian and foreign ownership were used rather than six different categories. The results indicate that 86 percent of respondents had establishments with majority Canadian ownership. The breakdown of ownership for each province is shown in Table 9.

Table 8 Distribution of firms by number of employers, Provinces, 2001-2003 (Percentage)

Province	< 20	20-49	50-199	200+	Total
Alberta	24	17	46	13	100
Atlantic Provinces	16	28	40	17	100
British Columbia	14	38	38	10	100
Manitoba	26	49	14	11	100
Ontario	28	32	30	11	100
Quebec	21	33	30	16	100
Saskatchewan	36	32	25	7	100

Source: Statistics Canada, Food Processing Industry Survey, 2003

Table 9 The ownership of firms by province, 2001-2003 (Percentage)

Province	Foreign	Canadian	Grand Total
Alberta	24	76	100
Atlantic Provinces	11	89	100
British Columbia	14	86	100
Manitoba	14	86	100
Ontario	16	84	100
Quebec	10	90	100
Saskatchewan	14	86	100
Grand Total	14	86	100

Data Source: Statistics Canada, Innovation in the Food Processing Industry Survey[4]

Price competition and product competition are two dummy variables used to evaluate the affect of market structure on product and process innovation. In the survey conducted by Statistics Canada, respondents were asked about their intensity of competition with regards to product price and product quality. The respondents had four

[4] Note: Canadian is when the majority ownership of the establishment is Canadian, Foreign is when the majority is not Canadian.

options: not applicable to this company, low, medium and high. In this analysis, each respondent will receive 0 if they answered not applicable, 1 if they answered low and 2 and 3 if they answered medium or high respectively.

Many studies show that universities and research facilities in universities play an important role in determining the probability of innovation in firms. In the survey, respondents were asked if they had worked with universities or colleges over the last three fiscal years ending in 2003 to develop a product or process innovation. In this analysis, if they answered yes, they received a 1 and a 0 otherwise. Table 10 shows the relationship between firms and universities in different provinces. The survey shows that 79 percent of firms in Canada reported that they did not work with universities to introduce an innovation.

Table 10 The Percentage of firms working with post secondary institutions by province, 2001-2003

Provinces	Did not use	Use	Grand Total
Alberta	78	22	100
Atlantic Provinces	83	17	100
British Columbia	83	17	100
Manitoba	71	29	100
Ontario	83	17	100
Quebec	72	28	100
Saskatchewan	75	25	100
Total	79	21	100

Source: Statistics Canada, Food Processing Industry Survey, 2003

The Innovation in the Food Processing Industry Survey provides the data for the first five variables in this model. However, this survey did data for education levels and the location of each firm. By location, this thesis means if a firm is located in an urban area or in a rural area. Since the education level in each firm is not available in this survey, this paper was forced to use the education level within the region that firms operated. The 2001 census of Population provided the data for education levels in this thesis. After converting the postal code for each firm to Census Consdidated Subdivision (CCS) code, the demographic information of each CCS was associated to each firm. The same method was used to discover the location of the firms.

However, to reduce the correlation between these dummy variables, intermediate is omitted from this model. Table 11 shows the location of food processing firms by province. This table shows that 38 percent of food processing firms in Canada are located in urban areas. In addition, this thesis uses population density to see if populated areas have more innovations than less populated areas. Population density is measured by the number of inhabitants per square kilometer in each CCS.

Table 11 The location of firms in by province, Canada, 2001-2003 (Percentage)

Provinces	Urban	Non Urban	total
Alberta	85	15	100
Atlantic Provinces	C[5]	C	100
British Columbia	62	38	100
Manitoba	C	C	100
Ontario	54	46	100
Quebec	29	71	100
Saskatchewan	C	C	100
Grand Total	38	62	100

Source: Statistics Canada, Food Processing Industry Survey, 2003

The last two variables in this model are designed to evaluate the affect of education on the probability of innovation. As it has been mentioned before, the 2001 Census of Population provides the data for these variables. There are five categories that show the education level in each CCS region and these categories are: less than grade 9, high school, university degree, non university degree (colleges and technical schools) and

[5] C: Confidential

post secondary education but no degree. This thesis only looks at the working population of each CCS region which is the age group of 24 to 55. In addition, to observe a correct and accurate result, each category is divided by the sum of all the five groups to obtain the percentage for each education level. Furthermore, this thesis has combined university degree, non university degree (colleges and technical schools) and post secondary education but no degree together to get post secondary education for each region. This strategy will allow this thesis to see the effect of post secondary education on innovation in food processing firms in Canada. Finally, less than 9 years of education was omitted from this model to prevent high correlation with other variables.

Table 12 shows the mean and standard deviation of various variables for Canadian food processing firms that produced a product innovation in the past three years. Unlike the Survey of Innovation, there are few differences between innovative firms and non-innovative firms with regards to product innovation. For instance, 85.7 percent of innovative firms have majority Canadian ownership. This outcome is nearly identical to non-innovative firms which reported that 86.4 percent are Canadian owned.

Table 12 does illustrate the relationship between location and innovation. This table shows that 42.9 percent of innovative firms are located in urban areas and only 28.6 percent of innovative firms are located in rural areas. These observations are reverse for non-innovative firms: 40.9 percent of non-innovative firms are located in rural areas and 36.3 percent are located in urban areas. Moreover, firms that report product innovations are positioned in locations with higher population densities than non-innovative firms. Table 12 indicates innovative firms are located in areas with around 200 more inhabitants per square kilometer than non-innovative firms. There is a significant difference between innovative and non-innovative firms in terms of size of the establishment. Innovative firms on average are closer to the 50 to 199 classification (class 3) while non-innovative firms were closer to the 20 to 49 classification (class 2).

Table 12 shows that innovative and non-innovative firms faced nearly the same regional education levels. Individuals with less than a high school education make up only a fraction of these firms' local work force; 6.7 percent of the labor pool for innovative firms and 7.0 percent of the pool for non-innovative firms were made up of individuals with less than high school education. A total 58.9 percent of the labor pool for innovative firms had post secondary education where 61.4 as percent of the pool for non-innovative firms had post secondary education. As mentioned before, the education levels of the work force for non-innovative and innovative firms are very similar to each other. 34.5 percent of the work force for innovative firms and 31.5 percent of non-innovative firms' fork force had less than a high school education.

Table 12 Descriptive statistics for product innovation, Canada, 2001-2003

Dependent	**Yes**		**No**	
Product	Observation	252	Observation	433
Independent	Mean	S.D.	Mean	S.D.
Size (# of employees)	2.710	1.136	2.208	0.992
Ownership (% Canadian)	0.857	0.351	0.864	0.343
Price Competition (scale)	2.611	0.592	2.492	0.782
Product Competition (Scale)	2.131	0.699	2.083	0.815
University (scale)	0.183	0.387	0.224	0.417
Urban (%)	0.429	0.496	0.363	0.481
Rural (%)	0.286	0.453	0.409	0.492
Intermediate (%)	0.286	0.453	0.229	0.420
Population density	1152.5	1889.7	954.39	1758.9
Less than high school (%)	0.067	0.051	0.070	0.064
High School (%)	0.345	0.151	0.315	0.148
University Degree (%)	0.351	0.219	0.319	0.219
Non university Degree (%)	0.189	0.223	0.233	0.232
Post secondary but no degree (%)	0.049	0.073	0.062	0.077

Data Sources: Statistics Canada, Innovation in the Food Processing Industry Survey and 2001 Census of Population.

Table 13 shows the mean and standard deviation for 685 firms that complete the Food Processing Industry Survey in 2003. These values have the same pattern as values reported in the previous section. For instance, 84.7 percent of innovative firms are Canadian owned compared to 86.5 percent of non-innovative establishments which are Canadian. In addition, the importance of price competition and product quality in innovative and non-innovative firms are equal. Innovative and non-innovative firms consider price competition as high motivators for process innovations. In addition, these two groups believe that product quality only has a medium effect on their effort to produce a new process innovation. Furthermore, Table 13 shows that the majority of innovative firms are located in urban cities, with 42 percent of innovative firms being located in urban cities compared to only 32 percent of innovative firms being located in rural areas. However, non-innovative firms are equally divided in both regions. Moreover, firms that report process innovations are positioned in locations with higher population densities than non-innovative firms. It is clear that innovative firms on average are located in areas with 39,000 more inhabitants per square kilometer than non-innovative firms. In addition, 37.8 percent and 37.6 percent of non-innovative were located in urban areas and rural areas respectively. Finally, firms that reported process innovation tended to be bigger than non-innovative firms. Innovative firms employed about 50 to 199 workers on average whereas non-innovative firms hired between 20 to 49 employees.

Education levels in the regional work force facing innovative and non-innovative firms in the food processing sector followed the same pattern. People with less than high school and post secondary education but no degree only make up a fraction of the workforce in for both types of firms. A majority of the workforce in innovative and non-innovative firm consists of people with some post secondary education. For example, 54.5 percent of the regional work force for innovative firms have post secondary education compared to 54.8 percent for non-innovative firms.

Table 13 Descriptive statistics for process innovation, Canada, 2001-2003

Dependent	**Yes**		**No**	
Process	Observation	150	Observation	535
Independent	Mean	S.D.	Mean	S.D.
Size (# of employees)	2.700	1.116	2.307	1.047
Ownership (% Canadian)	0.847	0.362	0.865	0.342
Price Competition (scale)	2.560	0.670	2.529	0.734
Product Competition (Scale)	2.167	0.727	2.082	0.787
University (scale)	0.207	0.406	0.209	0.407
Urban (%)	0.420	0.495	0.378	0.485
Rural (%)	0.320	0.468	0.376	0.485
Intermediate (%)	0.260	0.440	0.247	0.432
Population density	1137.7	1905.8	996.3	1781.9
Less than high school (%)	0.069	0.053	0.069	0.061
High School (%)	0.335	0.148	0.324	0.150
University Degree (%)	0.340	0.221	0.328	0.219
Non university Degree (%)	0.205	0.233	0.220	0.229
Post secondary but no degree (%)	0.051	0.073	0.059	0.077

Data Sources: Statistics Canada, Innovation in the Food Processing Industry Survey and 2001 Census of Population

Innovation in this context refers to firms that produced at least one product innovation one process innovation in the past three years. The two previous sections only illustrated the firms that produced either product innovations or process innovations. Table 14 presents the mean and standard deviations for different coefficients in this model. This table shows that the difference between innovative and non-innovative firms is not that big and the pattern in this table follows the same pattern in Table 12 and 13. For instance, 86.6 percent of firms that reported an innovation are Canadian owned and 86.0 percent of firms that did not report innovations are Canadian owned. In addition, innovative and non-innovative firms give the same value to price competition and product quality. Price competition is viewed very highly among both innovative and non-innovative firms. In contrast, these two groups believe that product quality only has a medium effect on their effort to produce a new innovation. In this table, it is clear that only 19.3 percent of firms come together with local universities in order to produce an innovation. In addition, the majority of firms that reported an innovation are located in non-urban areas. This table shows that 59.6 percent of innovative firms are located in rural and intermediate areas in Canada and 61.7 percent of non-innovative firms are located in non-urban areas. Finally, firms that reported innovation tend to be bigger than non-innovative firms. Innovative firms employ 50 to 199 workers on average where non-innovative firms hire about 20 to 49 employees on average.

Table 14 Descriptive statistics for firms with both types of innovation

Dependent	**Yes**		**No**	
Innovation	Observation	119	Observation	566
Independent	Mean	S.D.	Mean	S.D.
Size (# of employees)	2.765	1.148	2.315	1.043
Ownership (% Canadian)	0.866	0.343	0.860	0.347
Price Competition (scale)	2.580	0.644	2.527	0.735
Product Competition (Scale)	2.135	0.747	2.094	0.780
University (scale)	0.193	0.397	0.212	0.409
Urban (%)	0.403	0.493	0.383	0.487
Rural (%)	0.311	0.465	0.375	0.484
Intermediate (%)	0.286	0.454	0.242	0.429
Population density	1110.4	1921.2	1009.8	1786.1
Less than high school (%)	0.069	0.057	0.069	0.060
High School (%)	0.337	0.150	0.324	0.150
University Degree (%)	0.332	0.223	0.331	0.219
Non university Degree (%)	0.209	0.234	0.218	0.228
Post secondary but no degree (%)	0.053	0.076	0.058	0.076

Data Sources: Statistics Canada, Innovation in the Food Processing Industry Survey and 2001 Census of Population

Education levels in the work forces facing innovative and non-innovative firms were almost identical in each category. Only 6.9 percent of the labor force in both groups consisted of individuals with less than high school education. In addition, 33.7 percent of potential employees in innovative firms had high school education and 32.4 percent of potential workers in non-innovative firms have high school education. Just over half of the regional work force for both innovative and non-innovative firms had some post secondary education.

10.1.2 Probit Results

Tables 15, 16 and 17 show the probit estimates for product, process and total innovation for the 685 firms that completed the Innovation in the Food Processing Industry Survey that could be coordinated geographically with Census locations. The results in these tables are based on this sample of 685 firms that had complete data. This implies that these results are based on a sub-sample of firms that completed the Food Processing Industry Survey.

Table 15 Probit regression of firms reporting product innovation (coded 1) or not (coded 0) in Canada, 2001-2003

VARIABLE NAME	Est. Cof.	T-ratio	Elasticity at means	Marginal Effect[6]	Weighted aggregate elasticity
Size (# of employees)	0.274	5.652	0.683	0.109	0.649
Ownership (binary)	0.093	0.635	0.083	0.037	7.60E-02
Price Competition (scale)	0.112	1.39	0.295	0.0446	0.274
Product Competition (Scale)	-0.016	-0.182	-0.035	-0.0063	-3.26E-02
University (binary)	-0.088	-0.517	-0.019	-0.0359	-1.67E-02
Urban (binary)	-0.073	-0.493	-0.029	-0.0291	-2.83E-02
Rural (binary)	-0.269	-2.015	-0.102	-0.107	-8.54E-02
Population density	3.90E-05	1.089	0.042	1.55E-05	4.05E-02
High School (%)	2.278	2.026	0.773	0.9082	0.724
Post Secondary Education (%)	1.232	1.294	0.775	0.4911	0.705
Constant	-2.729	-2.697	-2.84	-	-2.607
MCFADDEN (Pseudo) R-SQUARE .5431					

Data Sources: Author's calculations, Statistics Canada, Innovation in the Food Processing Industry Survey, 2001 Census of Population.

[6] For calculation, please refer to Appendix D.

Table 16 Probit regression of firms reporting process innovation (coded 1) or not (coded 0) Canada, 2001-2003

VARIABLE NAME	Est. Cof.	T-ratio	Elasticity at means	Marginal Effect	Weighted aggregate elasticity
Size (# of employees)	0.201	3.954	0.657	0.0621	0.6736
Ownership (binary)	-0.015	-0.094	-0.017	-0.0046	-0.0164
Price Competition (scale)	-0.005	-0.055	-0.017	-0.0015	-0.0163
Product Competition (Scale)	0.148	1.551	0.425	0.0457	0.4146
University (binary)	0.211	1.129	0.06	0.0652	0.0573
Urban (binary)	0.034	0.211	0.018	0.0105	0.0180
Rural (binary)	-0.076	-0.524	-0.038	-0.0235	-0.0334
Population density	1.82E-05	0.472	0.026	0	0.0260
High School (%)	0.468	0.39	0.209	0.1446	0.2029
Post Secondary Education (%)	0.116	0.115	0.096	0.0358	0.0913
Constant	-1.837	-1.696	-2.51	-	-2.4034
MCFADDEN (Pseudo) R-SQUARE .4825					

Data Sources: Author's calculations, Statistics Canada, Innovation in the Food Processing Industry Survey, 2001 Census of Population.

Table 17 Probit regression of firms reporting innovation (coded 1) or not (coded 0), Canada, 2001-2003

VARIABLE NAME	Est. Cof.	T-ratio	Elasticity at means	Marginal Effect	Weighted aggregate elasticity
Size (# of employees)	0.216	4.049	0.776	0.203	0.8073
Ownership (binary)	0.106	0.625	0.137	0.0997	0.1307
Price Competition (scale)	0.025	0.27	0.095	0.0235	0.0914
Product Competition (Scale)	0.029	0.289	0.093	0.272	0.0892
University (binary)	0.03	0.153	0.009	0.0282	0.0086
Urban (binary)	-0.074	-0.438	-0.043	-0.0696	-0.0422
Rural (binary)	-0.155	-1.025	-0.085	-0.1458	-0.0724
Population density	2.23E-05	0.547	0.034	2.10E-05	0.0346
High School (%)	0.671	0.53	0.328	0.631	0.3199
Post Secondary Education (%)	0.25	0.234	0.227	0.235	0.2136
Constant	-2.017	-1.77	-3.028	-	-2.8822
MCFADDEN (Pseudo) R-SQUARE .5063					

Data Sources: Author's calculations, Statistics Canada, Innovation in the Food Processing Industry Survey, 2001 Census of Population.

Table 15 shows that size, rurality and the supply of local high school educated workers are significant at the 0.05 confidence level because their t-values are higher than critical value which is 1.645. There are many different methods to interpret these results. However, Shazam's website indicates that the sign of an estimated coefficient gives the direction of the effect of a change in the explanatory variable on the probability of a success (an observation at one). The positive estimated coefficient on size suggests that an increase in number of employees working in each establishment gives a higher probability of producing a product innovation. The same can be said about the effect of regional high school education levels. On the other hand, rural has a reverse effect compare to size and high school. However, it is important to remember that "estimated coefficients do not have a direct economic interpretation." Most economists use marginal effects and elasticities to report their results. An elasticity gives the percentage change in probability of a success in response to a one percentage change in the explanatory variable. Since the elasticities vary for every observation, it is desirable to report a summary measure. It has been reported that a convenient summary measure is to evaluate the elasticity at the sample means of the explanatory variables (Hill, Griffiths and Judge, 2001). This measure is reported as elasticity at means on the Shazam estimation output. It has been suggested that this method is not perfect since "the elasticities are nonlinear functions of the observed data there is no guarantee that the probit function will pass through the point defined by the sample average" (Hill, Griffiths and Judge, 2001). To fix this problem, Hensher and Johnson (1981) argue that the elasticity at means measure tends to over-estimate the probability response to a change in an explanatory variable. These authors recommend evaluating the elasticities at every observation and then constructing a weighted average where the predicted probabilities are the weights. This measure is also reported on the Shazam output.

It has also been suggested that the marginal effect is very good economic indicator for binary exogenous variables. This is arises from the fact that estimates of the marginal effect are calculated by rescaling the estimated coefficients (Hill, Griffiths and Judge, 2001). This means that the scale factor varies with observed values for explanatory variables. Shazam has suggested that, "for reporting purpose, the scale factor can be evaluated at the sample means of the explanatory variables" (Shazam).

For example the high school coefficient can be interpreted, on average, as a one percent increase in number of individuals with high school education in each CCS region would lead to a 0.9082 increase in probability of product innovation. However, this method of reporting has some downfalls. The interpretation of marginal effect is only meaningful when the explanatory variable is continuous (Hill, Griffiths and Judge, 2001). Variables such as the budget devoted to R&D, the budget devoted to acquiring the latest technology or the amount of money spent on staff training are all continuous.

However, marginal effect is a good indicator in interpreting the effect of dummy variables on the probability of innovations. Hill, Griffiths and Judge (2001) have recommended using the probabilities for a typical case. This implies that marginal effect for a dummy variable can be obtained by subtracting the probability values when the dummy variable is equal to 0 and 1. The correct way for dummy variables is not to compute the difference between marginal effects but between predicted probability; that is Pr(y=1)=F(bx) for x=1 and x=0, and other values at their sample means.

Using the weighted aggregate elasticity measure, the Shazam output for the first model for product innovation shows that, on average, a one percent increase in size measure of the firm gives a 0.649 percent increase in the probability of producing a product innovation, holding all else constant. In addition, using the weighted aggregate elasticity measure, a one percent increase in the number of individuals with a high school education in each CCS region gives a 0.724 percent increase in the probability of producing a product innovation, holding all else constant. Furthermore, using the marginal effect, a firm that is located in a rural area, (this implies that firm would receive one for rural dummy variable) on average, would lead to a 0.107 decrease in probability of product innovation, holding all else constant. In addition, price competition and post secondary education are significant at 0.10 confidence level. Using weighted aggregated elasticity, a one percent increase in the price competition score would increase the probability of product innovation by 0.274. In addition, a one percent increase in number of individuals with a post secondary education in each CCS region gives a 0.705 percent increase in the probability of producing a product innovation, holding all else constant.

Table 16 shows that size is significant at a 0.05 confidence level and product competition is significant at 0.10 confidence level. Using weighted aggregate elasticity measure, this result can be interpreted as: on average, a one percent increase in the size score of the firm gives a 0.674 percent increase in the probability of producing a process innovation. Holding all else constant and on average, a one percent increase in the product competition intensity would increase the probability of product innovation by 0.4146.

Table 17 shows that size is once again significant at 0.05 confidence level. This implies that a one percent increase in the size score of the firm gives a 0.807 percent increase in the probability of producing an innovation, holding all else constant.

10.2 Survey of Innovation

10.2.1 Descriptive statistics

Table 18 and Table 19 show the mean and standard deviation for exogenous variables for product innovation and process innovations, respectively, using the data of the Survey of Innovation. Innovation was again measured according to the rate of any innovation in the last three years. Table 18 shows that, on average, innovative firms had higher budgets for research and development as well as more financial resources for training and acquiring the latest technologies and machineries than non-innovative firms. For instance, those firms that reported product innovation spent on average $166,145 more on research and development per year than those firms that did not report any innovation. Furthermore, innovative firms spent more on acquiring and buying the latest technologies and machineries which are needed for producing innovations. From Table 18, it was shown that innovative firms spent $104,442 per year more on equipment and machineries than non-innovative firms. In addition, the labor force in innovative firms had more individuals with bachelor's degrees than non-innovative firms. Three quarters of innovative firms claim that the highest education level in their organization was a bachelor's degree where only one half of non-innovative firms make the same claim. Furthermore, innovative firms have more workers with post secondary education than non-innovative firms: 87 percent of innovative firms claim that the highest education level in their organization is post secondary education where 75 percent of non-innovative firms make the same claim.

Table 18 Descriptive statistics for product innovation in Canada, 2004

Dependent	**Yes**		**No**	
Product	Observation	30	Observation	16
Independent	Mean	S.D.	Mean	S.D.
Budget	257770	571510	91625	168140
Equipment	240130	558880	99688	156420
Training	27503	45801	17875	62350
High School	0.133	0.346	0.250	0.447
Bachelor Degree	0.733	0.450	0.563	0.512
Master Degree	0.133	0.346	0.188	0.403

Source: Agricultural Policy Research Network, Survey of Innovation

Table 19 shows the mean and standard deviation for food processing firms with process innovations in the Survey of Innovation. The same patterns were observed here but the results are more varied. Non process innovative firms on average spent only $4,000 per year on research and development, $43,333 per year on new equipment and machinery and only $111.11 per year on training. These values are small fractions of the resources spent by innovative firms. Innovative firms reported that on average they spent $247,660 per year on research and development, $227,270 per year on acquiring machinery and equipment and $30,003 per year on training. These values indicate that innovative firms spent the money necessary to carry out new and innovative activities. However, innovative firms do not have an advantage over non-innovative firms when it comes to education levels. Innovative and non-innovative firms had a similar percentage of firms were the highest degree was bachelor's degrees.

Table 19 Descriptive statistics for process innovation in Canada, 2004

Dependent	**Yes**		**No**	
Process	observation	37	Observation	9
Independent	Mean	S.D.	Mean	S.D.
Budget	247660	520500	4000	11630
Equipment	227270	509720	43333	63818
Training	30003	56186	111.110	333.330
High School	0.162	0.374	0.222	0.441
Bachelor Degree	0.676	0.475	0.667	0.500
Master Degree	0.162	0.374	0.111	0.333

Source: Agricultural Policy Research Network, Survey of Innovation

10.2.2 Probit results

Tables 20 and 21 show the results of the estimated probit equations for product and process innovation in food processing firms sampled in the Survey of innovation for Western Canada. The most noteworthy highlight of this output is that all the variables in this equation are insignificant in explaining the probability of innovation at 0.05 confidence levels. However, the bachelor degree dummy in product innovation and training expenditures in process innovation are significant at 0.10 confidence level. This implies that having at least one worker with a bachelor degree (dummy takes on the value of 1) within the firm gives it a 0.247 percent increase in the probability of producing a product innovation, holding all else constant. In addition, on average, a one percent increase in the budget devoted for training of the staff within the firm gives a .0334 percent decrease in the probability of producing a process innovation, holding all else constant.

Table 20 Probit regression for product innovation (coded 1) or not (coded 0) in Western Provinces of Canada, 2004

VARIABLE NAME	Estimated Coefficient	T-ratio	Elasticity at means	Marginal Effect	Weighted aggregate elasticity
Budget	8.89E-07	0.895	0.093	2.97E-07	4.88E-02
Equipment	7.29E-07	0.827	0.073	2.43E-07	4.18E-02
Training	-1.15E-06	-0.223	-0.015	-3.84E-08	-1.17E-02
Bachelor Degree	0.741	1.373	0.261	0.247	2.53E-01
Master Degree	0.193	0.26	0.015	0.0645	1.54E-02
Constant	-0.345	-0.691	-0.181	-	-1.76E-01
MCFADDEN (Pseudo) R-SQUARE	0.87412E-01				

Data Sources: Author's Calculations and the Agricultural Policy Research Network, Survey of Innovation.

Table 21 Probit regression for process innovation (coded 1) or not (coded 0) in Western Provinces of Canada, 2004

VARIABLE NAME	Estimated Coefficient	T-ratio	Elasticity at means	Marginal Effect	Weighted aggregate elasticity
Budget	2.03E-05	1.046	0.838	0	1.89E-02
Equipment	-2.51E-06	-1.086	-145.99	0	-1.56E-02
Training	9.46E-04	1.505	0.471	0	3.34E-02
Bachelor Degree	2.172	0.785	0.302	0	0.24327
Master Degree	1.614	0.587	0.506	0	3.83E-02
Constant	-2.366	-0.856	-144.49	-	-0.32595
MCFADDEN (Pseudo) R-SQUARE	0.60338				

Data Sources: Author's Calculations and the Agricultural Policy Research Network, Survey of Innovation.

Chapter 11: Conclusion

This thesis failed to generally support the hypothesis that higher regional education levels would increase the rate of innovation in food processing firms in Canada. At a regional level, it was found that having a large population with high school education will have a more profound effect on the rate of innovation than having individuals with post secondary education. As a result, this paper failed to support the hypothesis that higher education in food processing firms in Canada will lead to a higher innovation rate.

The second objective of this paper was to evaluate the difference on the rate of product and process innovation between firms located in urban, intermediate and rural settings. The results in this paper are not conclusive regarding this objective. The probit results using the Innovation in the Food Processing Industry Survey show that urban and rural dummies had the same negative effect on the rate of innovations in food processing firms when compared to an intermediate urban setting, but the rural coefficient was significant for product innovations.

The Schumpeter model used in this thesis predicts that increasing the resources devoted to innovation would increase the rate of innovation within the firms. Many scholars argue that education and training would increase the stock of knowledge within the firms and this ultimately would increase the rate of innovation. However, this thesis did strongly not support these arguments. In other words, increasing the education level within the firm may not shift the PVI curve in Schumpeter's model. The results from this thesis fail to show that education plays a significant role in the rate of innovation.

The results in this paper do not completely reflect innovation propensity in the food processing sector in Canada. To truly understand the rate of innovation in the food processing sector, many different variables could be evaluated such ownership structure, management, future outlook on the market, the CEO's vision of the company, market structure, industry competition, level of technology and much more. The innovation process is a complex function with several feedback loops (Kilne and Rosenberg, 1986). It would be inappropriate to assume that by looking at one or two variables, one can understand the rate of innovation in the food processing sector in Canada. McNamara, Weiss and Wittkopp (2003) have shown that for a firm to be successful in innovation, many factors within the firms must work in harmony.

However, results from this thesis, and future research, may provide guidelines for future policies for improving the rate of innovation in food processing plants in Canada. The first and most important step is to demonstrate the importance of innovation for any food processing firms. The fact that very few firms invested in innovation shows that food processing firms do not view innovation and innovation activities as vital parts of their operation. This thesis shows that innovation was not given a high priority among food processing firms in Canada.

This thesis shows that the majority of food processing firms that completed the Innovation in the Food Processing Industry Survey are located in non-urban areas. From a technological development standpoint, a prominent shortcoming of rural regions seems to be their low potential to even adopt innovation because of a lack of capital and various types of infrastructure. These regions have few opportunities to confront global best practices which, in turn, prevent technological progress. Without investment in infrastructure and modern equipment, the gap between rural and urban areas will likely expand.

Future research is needed to fairly assess the effect of education on the rate of innovation in food processing firms in Canada. Future research using linked sources in Statistics Canada has a unique opportunity to explore the effectiveness of human capital investment at the firm level including the contribution of education to regional development, innovation and productivity. That work would benefit public and private sectors because education rates for a regional labor supply may be impacting the effectiveness of the work force. It is very important to understand the significance of education because knowledge is "now the most versatile and the most important of all the factors of production, whether we can measure it or not. Knowledge has now become the real capital of a developed economy (Berkowitz, 2001)."

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Appendix A: Survey of Innovation, Agricultural Policy Research Network, 2005

Survey Part 1	Field Values
Q1. For regional identification, please provide the first three digits of your postal code:	Text
Q2. What year was your business established?	Year
Q3a. Is your business privately owned?	1 - Yes 0 - Other
Q3b. Other	
Q3c. Is your business a foreign affiliate/partner of a Multinational Enterprise (MNE)?	1 - Yes 0 - No
Q3d. Is your business a parent for an affiliate in a foreign country?	1 - Yes 0 - No
Q4. Does your business provide contract services to other firms or organizations?	1 - Yes 0 - No
Q5. Do other firms or organizations provide contract services to your business?	1 - Yes 0 - No
Q5b. If yes, list the types of contracted services and the reasons why you contract out.	Text
Q6a. What products do you produce?	Text
	Text
	Text
Q7. In which geographic markets did your business sell and purchase goods or services during the three years 2002 to 2004?	
Q7a1. Percentage Total Sales (Local)	0.0 - 100.0
Q7a2. Percentage Total Purchases (Local)	0.0 - 100.0
Q7b1. Percentage Total Sales (within Province)	0.0 - 100.0
Q7b2. Percentage Total Purchases (within Province)	0.0 - 100.0
Q7c1. Percentage Total Sales (outside of Province)	0.0 - 100.0
Q7c2. Percentage Total Purchases (outside of Province)	0.0 - 100.0

Q7d1. Percentage Total Sales (United States)	0.0 - 100.0
Q7d2. Percentage Total Purchases (United States)	0.0 - 100.0
Q7e1. Percentage Total Sales (except US)	0.0 - 100.0
Q7e2. Percentage Total Purchases (except US)	0.0 - 100.0
Q8. If your business exports, please rank the top three countries based on sales revenue.	Text
	Text
	Text
Q9. If your business does not export please indicate why.	Boolean (1 = TRUE, 0 = FALSE)
Q9. Other	Text

Web Page (2 of 5)	Field Values
Q10a. During the three years 2002 to 2004, did your enterprise introduce: Product Innovation	1 - Yes (new to business) 2 - Yes (new to market) 0 - No
Q10b. Process Innovation	1 - Yes (new to business) 2 - Yes (new to market) 0 - No
Q10c. Process Innovation	1 - Yes (new to business) 2 - Yes (new to market) 0 - No
Q10d. Process Innovation	1 - Yes (new to business) 2 - Yes (new to market) 0 - No
Q10e. Process Innovation	1 - Yes (new to business) 2 - Yes (new to market) 0 - No

Q10f. Process Innovation	Text
Q11. If you are a parent company of a foreign affiliate, did you supply your foreign affiliate with innovations?	1 - Yes 0 - No
Q11b. If yes, what was the estimated R&D value associated with the adopted innovation?	Dollars
Q11c. Don't know	Boolean (1 = TRUE, 0 = FALSE)
Q12. During the three years 2002 to 2004, did your business undertake the following innovation activities?	Dollars
	Percentage
Q13. During the three years 2002 to 2004, how important to your business's innovation activities were each of the following as a source of information or new ideas? Please also indicate if they worked with you on the innovation activities. Degree of Importance	1 - Not important 2 - 3 - 4 - 5 - Very Important
Not Used	Boolean (1 = TRUE, 0 = FALSE)
Worked with you (n/a for a, b, k, l)	Boolean (1 = TRUE, 0 = FALSE)

Web Page (3 of 5)	Field Values
Q14. Who developed the product innovations?	1 - Mainly your business 2 - Your parent MNE or Your foreign Affiliate 3 - Your business together with other businesses or institutions 4 - Mainly other private businesses or institutions 5 - Mainly other public businesses or institutions
Q15. Who developed the process innovations?	1 - Mainly your business 2 - Your parent MNE or Your foreign Affiliate 3 - Your business together with other businesses or institutions 4 - Mainly other private businesses or institutions 5 - Mainly other public businesses or institutions
Q16. What degree of impact did new or significantly improved goods/services or processes developed and introduced during the	0 - n/a 1 - Low Impact 2 - 3 -

three year period between 2002 and 2004 have on your business?	4 - 5 - High Impact
Q17. During the three years 2002 to 2004, how damaging were the following factors in hampering your innovation activities or projects or influencing a decision not to innovate?	0 - n/a 1 - Not Damaging 2 - 3 - 4 - 5 - Very Damaging

Q18. During the three years 2002 to 2004, how damaging were the following factors for hampering your competitiveness within your industry?	0 - n/a 1 - Not Damaging 2 - 3 - 4 - 5 - Very damaging
Q19. During the three years 2002 to 2004, did your business	1 - Yes 0 - No
Q20. During the three years 2002 to 2004 did your business use any of the following types of programs sponsored by the federal or provincial governments?	1 - Federal Government 2 - Provincial Government 3 - Did not use Government program
	1 - Federal Government 2 - Provincial Government 3 - Did not use Government program
	Text

Q21. What was the number of full time equivalent (FTE) staff employed by your business?	Numeric
Q22. Were you raised locally (within 100km of the business's location)?	1 - Yes 0 - No
Q23. Are you the manager of this business or of a research and development department within the business?	1 - Yes, General Manager 2 - Yes, Manager of Research and Development 0 - No, I am neither of the above
Q24. What is the highest education level of you or any of your employees?	1 - Less than high school 2 - High school graduate 3 - Post-secondary degree or diploma

	4 - Masters degree 5 - PhD
Q25. What was your business's total revenue for the three years 2002 to 2004?	1 - $0 - $250,000 2 - $250,000 - $1,000,000 3 - $1,000,000 - $2,000,000 4 - $2,000,000 - $5,000,000 5 - $5,000,000 - $10,000,000 6 - > $10,000,000

Appendix B: The Correlation Coefficients Matrix

	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	-0.08	-0.09	0.07	0.09	-0.03	0.05	0.06	-0.12	0.07	-0.05	0.03	0.08	-0.01	0.23	0.60	0.47	1.00
2	-0.04	-0.03	0.02	0.03	0.00	0.03	0.01	-0.05	0.04	0.00	0.05	0.02	-0.02	0.15	0.87	1.00	
3	-0.03	-0.01	0.00	0.03	0.00	0.02	0.04	-0.05	0.02	-0.02	0.02	0.03	0.01	0.16	1.00		
4	0.05	0.03	-0.04	-0.02	0.00	-0.03	0.06	-0.02	-0.03	-0.11	0.07	0.12	-0.09	1.00			
5	0.03	0.02	-0.07	0.02	0.09	-0.03	-0.01	0.06	-0.05	0.02	-0.06	0.09	1.00				
6	0.01	0.03	-0.02	-0.05	0.05	0.01	0.04	0.01	-0.05	-0.39	0.40	1.00					
7	0.08	0.08	-0.05	-0.10	0.06	0.03	0.04	0.00	-0.03	-0.64	1.00						
8	-0.09	-0.09	0.06	0.12	-0.05	-0.01	-0.01	0.02	0.00	1.00							
9	-0.41	-0.48	0.68	0.03	-0.22	0.59	-0.46	-0.60	1.00								
10	0.41	0.43	-0.55	-0.12	0.16	-0.41	-0.44	1.00									
11	0.01	0.07	-0.16	0.10	0.07	-0.21	1.00										
12	-0.36	-0.44	0.71	-0.17	-0.08	1.00											
13	-0.25	-0.18	-0.16	0.24	1.00												
14	-0.67	-0.68	0.20	1.00													
15	-0.69	-0.82	1.00														
16	0.84	1.00															
17	1.00																

1. Product
2. Process
3. Innovation
4. Size
5. Ownership
6. Price Competition
7. Product competition
8. University
9. Urban
10. Rural
11. Intermediate
12. Population
13. Less than high school
14. High school
15. University Degree
16. Non-university Degree
17. Post secondary but no degree

Appendix C: Innovation in the Food Processing Industry Survey, Statistics Canada, 2003

The Purpose of the Survey

Statistics Canada is conducting this survey on behalf of Agriculture and Agri-Food Canada. The purpose of the survey is to collect statistical information on the nature and extent of creative innovation in the Canadian food processing industry. Results from this survey may be used by businesses or trade associations to study industry performance, government departments and agencies to assist in policy formation and by the academic community for research purposes.

Note of Appreciation

Canada owes the success of its statistical system to a long standing co-operation involving Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued co-operation and goodwill.

Your Participation is Important

Participation in this survey is voluntary. However, your co-operation is essential to ensure the accuracy of the information collected.

The Data you Report are Confidential

Statistics Canada is prohibited by law from publishing or releasing statistics that could reveal information obtained from this survey relating to an identifiable individual business or person. The data reported on the questionnaire will be treated in strict confidence, used for statistical purposes and released in aggregated form only. The confidentiality provisions of the Statistics Act are not affected by either the Access to Information Act or any other legislation.

Who Should Complete this Questionnaire?

A Plant Manager, Quality Assurance Manager, Research and Development Manager or someone familiar with the products and general activities of this company should complete this questionnaire. If you have any questions regarding this survey or the questionnaire, please contact the Survey Manager, Shelley Harman, toll-free at 1-877-679-2746 or by e-mail at shelley.harman@statcan.ca

Please Complete the Following Information

Name of Respondent:

Title of Respondent:

Telephone Number: ( ) - Ext.:

Please correct the pre-printed information, if necessary, using the corresponding boxes:

002 Business Name

004 Number and Street

005 City

006 Province

007 Postal Code

5-5203-2.1: 2004-10-15 STC/SSB-524-75365

Statistics Canada Statistique Canada

Canada

General Information

1. **Which of the following markets is the dominant one for this establishment?**
Please check one only.

1 ◯ Atlantic region (Newfoundland and Labrador, Prince Edward Island, Nova Scotia, New Brunswick)

2 ◯ Central (Quebec, Ontario)

3 ◯ Western (Manitoba, Saskatchewan, Alberta, British Columbia)

4 ◯ National Canadian market

5 ◯ U.S. market

6 ◯ Mexican market

7 ◯ Other foreign market

2. **How many employees (including permanent, seasonal and casual but excluding contract employees) did this establishment employ during its last fiscal year ending in 2003?**
(Please report your highest level for 2003.)
Please check one only.

1 ◯ Less than 20

2 ◯ 20-49

3 ◯ 50-199

4 ◯ 200-499

5 ◯ 500-999

6 ◯ 1000 or more

3. **What were your establishment's annual total sales from food/feed production for the fiscal year ending in 2003?**
Please check one only.

1 ◯ $0 to $999,999

2 ◯ $1,000,000 to $4,999,999

3 ◯ $5,000,000 to $9,999,999

4 ◯ $10,000,000 to $14,999,999

5 ◯ $15,000,000 to $19,999,999

6 ◯ $20,000,000 to $24,999,999

7 ◯ $25,000,000 +

4. **What is the principal food/feed manufacturing activity of your establishment based on proportion of annual total food sales?**
Please check one only.

1 ◯ Primary processing of raw agricultural products (e.g., flour milling, feed milling, animal slaughter, oilseed processing)

2 ◯ Supplying semi-prepared food products for use in further processing (e.g. flour mixes, fruit desert fillings, dairy based ingredients)

3 ◯ Manufacturing food products ready for human or animal consumption (e.g. breakfast cereal, frozen dinners, canned foods, sausages, salad dressing, pet food)

4 ◯ Other, please specify

General Information - Concluded

5. **Please indicate the percent distribution of your establishment's total food sales to the following markets for the fiscal year ending in 2003?**

Please complete for all applicable countries and regions.

a. Canada [%]

b. U.S. [%]

c. Mexico [%]

d. Europe [%]

e. Asia [%]

f. Other countries [%]

Total [100%] [Total of (a) to (f) should equal 100%]

6. **Please indicate the majority ownership of your company.**

Please check one only.

1 ◯ Canadian

2 ◯ U.S.

3 ◯ Mexican

4 ◯ European

5 ◯ Asian

6 ◯ Other foreign

7 ◯ Don't know

7. **What is the ownership structure of your company?**

Please check one only.

1 ◯ Private corporation

2 ◯ Public corporation

3 ◯ Sole proprietorship

4 ◯ Unincorporated partnership

5 ◯ Other, please specify

Competitive Environment

4. Please rate how each of the following factors constrained your establishment's ability to compete over the last three fiscal years ending in 2003.

Factor	Not Applicable to this Company	Impact: Minor	Impact: Moderate	Impact: Major
a. Lack of access / availability of competitively priced raw agricultural products for processing	0 ○	1 ○	2 ○	3 ○
b. Mergers and acquisitions by competitor firms	0 ○	1 ○	2 ○	3 ○
c. Consolidation of equipment suppliers and/or packaging suppliers	0 ○	1 ○	2 ○	3 ○
d. Consolidation of food retailers and/or wholesalers	0 ○	1 ○	2 ○	3 ○
e. Restricted access to distribution channels because of listing fees, exclusivity, etc..	0 ○	1 ○	2 ○	3 ○
f. More stringent buyer requirements /standards for food safety and quality	0 ○	1 ○	2 ○	3 ○
g. More stringent buyer requirements / practices concerning the environment	0 ○	1 ○	2 ○	3 ○
h. Outdated/inflexible food safety regulations (CFIA, USDA etc.)	0 ○	1 ○	2 ○	3 ○
i. Lack of food safety regulations/national standards	0 ○	1 ○	2 ○	3 ○
j. Increased value of the Canadian dollar against the U.S. dollar	0 ○	1 ○	2 ○	3 ○

5. Please rate the intensity of competition in your industry in the following areas:

Factor	Not Applicable to this Company	Intensity of Competition: Low	Intensity of Competition: Medium	Intensity of Competition: High
a. Product price	0 ○	1 ○	2 ○	3 ○
b. Product quality	0 ○	1 ○	2 ○	3 ○
c. Flexibility in responding to customers needs	0 ○	1 ○	2 ○	3 ○
d. Customer service	0 ○	1 ○	2 ○	3 ○
e. Customization of products	0 ○	1 ○	2 ○	3 ○
f. Offering a wide range of related products	0 ○	1 ○	2 ○	3 ○
g. Frequently introducing new/improved products	0 ○	1 ○	2 ○	3 ○

Competitive Environment - Concluded

10. **On what basis does your establishment primarily compete?**
(Please answer with respect to your principal product lines.)

Please check one only.

- 1 ○ Product price
- 2 ○ Product quality
- 3 ○ Flexibility in responding to customer needs
- 4 ○ Customer service
- 5 ○ Customization of consumer products
- 6 ○ Offering a wide range of related products
- 7 ○ Frequently introducing new/improved products

11. **From what source do your establishment's principal products currently face the most competition on the domestic market?**

Please check one only.

- 1 ○ Other Canadian produced products
- 2 ○ U.S. imports
- 3 ○ Mexican imports
- 4 ○ Other foreign imports

12. **How do the prices for your principal food/feed products compare to those offered by your main competitors? Relative to the prices of our main competitors, generally our prices are:**

Please check one only.

- 1 ○ Lower by more than 10%
- 2 ○ Lower by less than 10%
- 3 ○ About the same
- 4 ○ Higher by less than 10%
- 5 ○ Higher by more than 10%
- 6 ○ Don't know

Research and Development

Research is original investigation undertaken on a systematic basis, by means of experiment and/or analysis, to gain knowledge. Development is the application of research findings or other scientific knowledge for the creation of new products and processes. Research and Development (R&D) includes prototyping and scale-up, but excludes the final commercial production of the new product or the commercial use of the new process.

13. **Did your establishment conduct/commission any research and development (R&D) during the last three fiscal years ending in 2003?** *(Please note: R&D also excludes: market research and sales promotion; quality control involving routine analysis and testing of products; research in the social sciences; and routine data collection.)*

- 1 ○ Yes
- 2 ○ No — Please go to question 15

14. **Which of the following R&D activities were carried out at your establishment over the last three fiscal years ending in 2003?**

- a. Laboratory based R&D investigation — 1 ○ Yes 2 ○ No
- b. Prototyping and scale-up — 1 ○ Yes 2 ○ No

5-5233-2.1 Page 5

Creative Innovation

> For the purpose of this survey, *Product innovations* are both goods and services introduced by your firm whose fundamental characteristics or intended uses are new or differ significantly from other products or services produced by your industry in North America. Product innovations may be introduced by developing brand new products, by significantly modifying existing products or by purchasing the right to produce/copying products that are not currently available for sale in North America, but can be found elsewhere in the world.

15. Did your establishment introduce to the market any product innovations during the last three fiscal years ending in 2003? *(Please note: changes to your establishment's existing products which only involve minor modifications and/or product differentiation should not be included, i.e., introduction of a common flavour (e.g., chocolate), or ingredients (e.g., nuts, raisins,), or aesthetic packaging changes (e.g., size or shape) do not qualify as product innovation.)*

1 ◯ Yes

2 ◯ No ⟶ Please go to question 22

---

16. How many product innovations did your establishment introduce during the last three fiscal years ending in 2003?

Please check one only.

1 ◯ 1-2

2 ◯ 3-5

3 ◯ 6-10

4 ◯ 11-20

5 ◯ more than 20

---

17. Please indicate the method most often used by your establishment to develop product innovations.

Please check one only.

1 ◯ Purchasing the right to produce and sell the products in North America

2 ◯ Copying products available elsewhere, but not in North America

3 ◯ Significantly adapting, improving or modifying existing products

4 ◯ Developing completely brand new products

5 ◯ Other, please specify

---

18. On average, over the last three fiscal years ending in 2003, what percent of your establishment's annual total sales from food production came from product innovations that were introduced during this time period?

Please check one only.

1 ◯ Less than 5%

2 ◯ 5-9%

3 ◯ 10-19%

4 ◯ 20-49%

5 ◯ More than 50%

6 ◯ Don't know

---

19. In general, are the margins on your recent innovative products higher than those earned on your establishment's traditional products?

1 ◯ Yes

2 ◯ No

Creative Innovation - Continued

The following two questions should be answered in reference only to your most recently introduced product innovation.

20. How was your most recently introduced product innovation developed?

Please check all that apply.

1 ◯ Laboratory based R&D investigation in this establishment

2 ◯ Laboratory based R&D investigation conducted by your parent company outside this establishment

3 ◯ Laboratory based R&D investigation contracted out to other firms

4 ◯ Using prototyping, scale-up and similar engineering services provided by this establishment

5 ◯ Collaborating with other firms/establishments up and down the agri-food supply chain

6 ◯ Collaborating with packaging and equipment suppliers

7 ◯ Licensing / copying products offered outside North America

8 ◯ Other, please specify

---

21. What was the main objective of your establishment's most recently introduced product innovation in the following three areas?

Please check one only.

Product Expansion

1 ◯ Replace product(s) being phased out

2 ◯ Add new product to your existing lines of products

3 ◯ Create superior product differentiation and branding

4 ◯ Not applicable

Please check one only.

Market Expansion

1 ◯ Open up new domestic markets

2 ◯ Open up new foreign markets

3 ◯ Increase market share

4 ◯ Not applicable

Please check one only.

Product Characteristics

1 ◯ Improve food safety aspects

2 ◯ Reduce negative environmental impacts (e.g., choice of packaging)

3 ◯ Meet buyer's standards/requirements

4 ◯ Not applicable

For the purpose of this survey, *Process innovations* include production techniques, production processes, systems monitoring, and biotechnology processes introduced by your firm that are new to your industry in North America. Process innovations may be introduced by developing brand new equipment, techniques and processes, by significantly modifying existing equipment, techniques and processes or by purchasing the right to use/copying equipment, techniques and processes that are not currently used in your industry in North America.

22. Did your establishment introduce any process innovations during the last three fiscal years ending in 2003?
(Please note: purchases of equipment readily available in the market or that are already being used by other firms in your industry in North America and minor modifications to existing equipment and processes that that do not significantly enhance performance should not be included.)

1 ◯ Yes

2 ◯ No —— Please go to question 27

Creative Innovation - Continued

23. **How many process innovations did your establishment introduce during the last three fiscal years ending in 2003?**

Please check one only.

1 ○ 1

2 ○ 2-3

3 ○ 4-5

4 ○ 5+

24. **Please indicate the method most often used by your establishment to develop process innovations.**

Please check one only.

1 ○ Purchasing the right and being the first to use the equipment / technologies / systems in North America

2 ○ Copying equipment / technologies / processes used elsewhere, but not in North America

3 ○ Significantly adapting, improving or modifying existing equipment / technologies / systems

4 ○ Developing completely brand new equipment / technologies / systems

5 ○ Other, please specify

The following two questions should be answered in reference only to your <u>most recently introduced process innovation</u>.

25. **How was your <u>most recently</u> introduced process innovation developed?**
Please check all that apply.

1 ○ Undertaking laboratory based R&D investigation in this establishment

2 ○ Using laboratory based R&D investigation conducted by your parent company outside this establishment

3 ○ Using laboratory based R&D investigation contracted out to other firms

4 ○ Using prototyping, scale-up and similar engineering services provided by this establishment

5 ○ Collaborating with other firms/establishments up and down the agri-food supply chain

6 ○ Collaborating with packaging and equipment suppliers

7 ○ Licensing / copying equipment / technologies / systems used by your industry outside North America

8 ○ Licensing / copying equipment / technologies / systems used by other industries but not in your own industry

9 ○ Other, please specify

 5-5200-2.1

Creative Innovation - Concluded

26. Please rate the impact of your establishment's <u>most recently</u> introduced process innovation on each of the following areas.

Process Innovation	Impact: Not Applicable	Applicable but No Impact	Minor	Moderate	Major
a. Improving production flexibility	0 ○	1 ○	2 ○	3 ○	4 ○
b. Improving productivity/reducing cost of production	0 ○	1 ○	2 ○	3 ○	4 ○
c. Creating ability to produce a new product	0 ○	1 ○	2 ○	3 ○	4 ○
d. Improving ability to comply with buyer's requirements/standards	0 ○	1 ○	2 ○	3 ○	4 ○
e. Improving product safety / quality / consistency	0 ○	1 ○	2 ○	3 ○	4 ○
f. Improving ability to comply with environmental standards / regulations	0 ○	1 ○	2 ○	3 ○	4 ○

27. What percentage of your establishment's annual total gross expenditures on food manufacturing was spent on creative innovation activities, on average, over the last three fiscal years ending in 2005?
(This includes expenses for laboratory based research and development, prototyping, pilot scale-up, and training activities that are linked to the new products and processes.)

Please check one only.

1 ○ None

2 ○ Less than 1%

3 ○ 1-5%

4 ○ 5-10%

5 ○ More than 10%

Company Information

Stop

Important: Please Read Carefully!

The following questions are designed to obtain information at the highest reporting level for this business. If this establishment is owned by a parent company, please answer the REMAINDER of the questionnaire (to the best of your ability) on behalf of your immediate parent. (Note: it is not necessary to forward the questionnaire to head office for completion. If you do not know the answer to a question, please check 'Don't know').

If this establishment represents the whole company, (i.e., does not have a parent company or other head office) please continue answering the question behalf of your establishment, as you completed the first part of the questionnaire.

Company's Research and Development (R&D)

28. Including this particular establishment, please indicate all the countries/regions in which your company has production units and/or laboratory based R&D units.
Please check all that apply in both columns.

	Production Units	Laboratory Based R&D Units
a. Canada	1 ○	2 ○
b. U.S.	1 ○	2 ○
c. Mexico	1 ○	2 ○
d. Europe	1 ○	2 ○
e. Asia	1 ○	2 ○
f. Other	1 ○	2 ○
g. Don't know	1 ○	2 ○

Company's Research and Development (R&D) - Concluded

29. How regularly does your company carry out laboratory based R&D activities?

Please check one only.

1 ○ Never ⟶ Please go to question 31

2 ○ On a continuous basis

3 ○ Occasionally

4 ○ Don't know

30. Please indicate both the number and percentage of employees in your company that were engaged in laboratory based R&D activities during the last fiscal year ending in 2003?

Please check one only in each column.

A. Number	B. Percentage
1 ○ None	1 ○ 0%
2 ○ Less than 20	2 ○ Less than 3%
3 ○ 20-49	3 ○ 3-10%
4 ○ 50-199	4 ○ 11-20%
5 ○ 200 or more	5 ○ 21% or more
6 ○ Don't know	6 ○ Don't know

31. Is your whole company comprised of this one establishment?
(Check 'YES' if you have no parent company and if apart from this particular establishment, there are no other establishments/divisions to the company.)

1 ○ Yes ⟶ Please go to question 33

2 ○ No

32. Does this particular establishment have the authority to make decisions to invest/introduce a product or process innovation as opposed to obtaining approval from head office (i.e., your parent company)?

Please check one only for each category.

a. Product innovation 1 ○ Yes 2 ○ No

b. Process innovation 1 ○ Yes 2 ○ No

Support Activities for Creative Innovation

33. Please indicate the different groups your company has worked with over the last three fiscal years ending in 2003 to develop product and/or process innovations, including innovations not yet introduced on the market.

Please check all that apply.

	Product Innovations	Process Innovations
a. Raw agricultural product suppliers/organizations	1 ○	2 ○
b. Food ingredient suppliers	1 ○	2 ○
c. Equipment suppliers	1 ○	2 ○
d. Packaging suppliers	1 ○	2 ○
e. Food retailers/wholesalers	1 ○	2 ○
f. Foodservice operators	1 ○	2 ○
g. Competitors	1 ○	2 ○
h. Consultants	1 ○	2 ○
i. Commercial laboratories / R&D enterprises	1 ○	2 ○
j. Universities and Colleges	1 ○	2 ○
k. Federal/Provincial government research facilities	1 ○	2 ○
l. Private research institutions	1 ○	2 ○
m. None of the above	1 ○	2 ○

n. Not Applicable - Did not develop product or process innovations 3 ○ — Please go to question 43

If this company did NOT introduce either product or process innovation(s) in the past 3 fiscal years (i.e., answered 'No' to both questions 15 and 22, please go to question 43, otherwise please continue to question 34.

34. Has your company used any of the following methods to protect its product/process innovations that were introduced over the last three fiscal years ending in 2003?

Please check all that apply.

1 ○ Registration of industrial design

2 ○ Trademarks

3 ○ Patent

4 ○ Confidentiality agreement/trade secret

5 ○ Copyright

6 ○ Lead-time advantage on competitors (i.e., first on the market)

7 ○ Bundling innovations with other products or services

8 ○ Don't know

35. How many patents did your company apply for during the past three years?

a. Number in Canada ☐

b. Number in the United States ☐

c. Number in other countries ☐

d. None 1 ○

e. Don't know 2 ○

Government Support/Programs

36. Please rate the importance of each of the following sources of support in respect to carrying out your company's innovation activities during the past three fiscal years ending in 2003?

Source of Support	Did not Use	Used but No Importance	Low	Medium	High	Don't Know
	Importance					
a. R&D tax credits (e.g., Scientific Research and Experimental Development Program (SR&ED))	0 ○	1 ○	2 ○	3 ○	4 ○	5 ○
b. Government R&D grants (e.g., Matching Investment Initiative (MII), Innovation Assistance Programs (IRAP))	0 ○	1 ○	2 ○	3 ○	4 ○	5 ○
c. Government financing support (e.g., Business Development Bank, Farm Credit Canada)	0 ○	1 ○	2 ○	3 ○	4 ○	5 ○
d. Government research facilities (e.g., National Research Council)	0 ○	1 ○	2 ○	3 ○	4 ○	5 ○
e. Export development assistance (e.g., Export Development Corporation)	0 ○	1 ○	2 ○	3 ○	4 ○	5 ○
f. Government-supported training programs	0 ○	1 ○	2 ○	3 ○	4 ○	5 ○

Obstacles to Innovation

37. Please rate the negative impact of the following factors in limiting your company's ability to introduce innovations.

Financial Factors	Not Applicable to this Company	Low	Moderate	High	Don't Know
	Impact				
a. Lack of internally generated cash flow	0 ○	1 ○	2 ○	3 ○	4 ○
b. Lack of external equity funding (including venture capital)	0 ○	1 ○	2 ○	3 ○	4 ○
c. Lack of debt financing	0 ○	1 ○	2 ○	3 ○	4 ○
d. Long gestation period of innovation	0 ○	1 ○	2 ○	3 ○	4 ○
Internal Factors					
e. Lack of marketing capability	0 ○	1 ○	2 ○	3 ○	4 ○
f. Corporate / management resistance to innovation	0 ○	1 ○	2 ○	3 ○	4 ○
g. Lack of idea champions	0 ○	1 ○	2 ○	3 ○	4 ○
Other Factors					
h. Shortages of skilled workers	0 ○	1 ○	2 ○	3 ○	4 ○
i. Insufficient flexibility in regulations or standards	0 ○	1 ○	2 ○	3 ○	4 ○
j. Difficulty in negotiating clear intellectual property (IP) rights	0 ○	1 ○	2 ○	3 ○	4 ○
k. Lack of retail acceptance or access to distribution channels	0 ○	1 ○	2 ○	3 ○	4 ○

38. Did your company attempt to raise capital specifically for innovation during the last three fiscal years ending in 2003?

1 ○ Yes

2 ○ No → Please go to question 43

Obstacles to Innovation - Concluded

39. Was your company successful in reaching its target in funds?

1 ◯ Yes

2 ◯ No

40. What was the main source of the capital raised?

Please check one only.

1 ◯ Canadian based venture capital

2 ◯ American based venture capital

3 ◯ Other foreign based venture capital

4 ◯ Angel investors/family/friends

5 ◯ Initial public offering (IPO)

6 ◯ Post IPO stock issues

7 ◯ Joint venture

8 ◯ Banks, cooperatives and credit unions

9 ◯ Government sources

10 ◯ Don't know

11 ◯ Other, *please specify*

41. Was your company limited or refused any request(s) for funds from any source when raising capital for innovation?

1 ◯ Yes

2 ◯ No ⟶ Please go to question 43

42. What reason(s) did the lender(s) give in limiting or refusing your request for capital?

Please mark all that apply.

1 ◯ Capital not available due to market conditions

2 ◯ Further development or proof of concept required

3 ◯ Lender does not fund development projects

4 ◯ Lack of intellectual property

5 ◯ Lack of long term strategic planning

6 ◯ Lack of marketing analysis

7 ◯ Failed to meet lending criteria

8 ◯ Lack of evidence to support projections

9 ◯ Other

Restructuring Business Relationships

Restructuring business relationships occurs when a company makes changes in the way it does business with other firms/establishments either to provide customers with a product that more closely matches the characteristics that they desire or to generate significant cost savings.

43. Did your company restructure or alter any business relationship(s) that has affected this particular establishment during the past three fiscal years ending in 2003?

1 ○ Yes

2 ○ No ⟶ Please go to end of survey.

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44. Please identify how your company has altered its business relationship(s) with respect to this establishment during the past three fiscal years ending in 2003.

Please check all that apply.

1 ○ Entered into strategic alliances, joint ventures or value chains

2 ○ Engaged in vertical integration (i.e., merging and/or acquiring other parts of your supply chain)

3 ○ Disinvested in upstream/downstream industries

4 ○ Entered into contracts specifying production requirements for raw agricultural inputs (i.e., contracts specifying animal feed/care, crop production method, variety grown, chemical input, etc.)

5 ○ Expanded outsourcing of support functions (logistics, information technology, human resources, customer service, finance/accounting)

6 ○ Other, please specify

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45. What was your company's main objective in restructuring its business relationship(s) with respect to this establishment during the past three fiscal years ending in 2003?

Please check one only.

1 ○ To focus on the provision of low price "consumer-value" goods

2 ○ To focus on new markets or channels

3 ○ To improve product differentiation and branding

4 ○ To improve food safety

5 ○ To develop environmentally-friendly products and processes

6 ○ Other, please specify

Restructuring Business Relationships - Concluded

46. Please rate the impact of restructuring the company's business relationship(s) with respect to this establishment on the following business areas.

	Impact			
Business Area	Not Applicable to this Company	Minor	Moderate	Major
a. Improving interactions with customers	0 ○	1 ○	2 ○	3 ○
b. Improving ability to source raw agricultural products and food ingredients	0 ○	1 ○	2 ○	3 ○
c. Improving interactions with non-agricultural product suppliers (i.e., equipment, packaging and processed food product suppliers)	0 ○	1 ○	2 ○	3 ○
d. Increasing transportation and logistical efficiency	0 ○	1 ○	2 ○	3 ○
e. Improving capital/capacity utilization	0 ○	1 ○	2 ○	3 ○
f. Improving raw materials input usage	0 ○	1 ○	2 ○	3 ○
g. Enhancing track and trace capabilities	0 ○	1 ○	2 ○	3 ○
h. Improving access to state-of-the-art technologies	0 ○	1 ○	2 ○	3 ○
i. Improving inventory control	0 ○	1 ○	2 ○	3 ○
j. Improving market share	0 ○	1 ○	2 ○	3 ○
k. Improving ability to attract skilled workers	0 ○	1 ○	2 ○	3 ○
l. Maintaining/improving exports	0 ○	1 ○	2 ○	3 ○

Comments

Thank you for your assistance.

Please return the questionnaire in the accompanying self addressed pre-paid envelope by November 24, 2004.

Appendix D: Probit Marginal Effect[7]

The probit model is expressed as:

$$\text{Prob}(y = 1) = \Phi(\mathbf{x}_i'\boldsymbol{\beta})$$

Where $\Phi(\cdot)$ is the notation defining the cumulative distribution for a standard normal random variable. This model is known as the probit model. The probit name was first used in the biometrics literature and this term is now generally used to describe it. The use of these models in biometrics predates their use in econometrics by many decades.

In many applications the set of independent variables (regressors) consist of continuous and/or binary (dummy) variables. The interpretation of the probit coefficients for continuous variables requires the calculation of marginal effects. In general, the marginal effect for probit model takes the following form:

$$\frac{\partial \text{Prob}(y_i = 1)}{\partial x_k} = \frac{\partial F}{\partial x_k} = f(\mathbf{x}_i'\boldsymbol{\beta}) \times \beta_k$$

Where $F(\cdot)$ denotes the cumulative distribution function and $f(\cdot)$ is the corresponding probability density function for either the normal probit distribution. The role of the probability density function in this case is to translate the coefficient into probability points, since the density is actually measured in probability points.

The interpretation of probit coefficient for binary/dummy explanatory variables requires the calculation of impact effects. This requires a slightly different set of calculations than for the marginal effects.

[7] The section was provided by Dr. Barry Reilly Applied Econometrics course, University of Sussex, England

The marginal effect for the probit model is given by:

$$\frac{\partial \text{Prob}(y_i = 1)}{\partial x_k} = \frac{\partial \Phi}{\partial x_k} = \phi(\mathbf{x}_i' \boldsymbol{\beta}) \times \beta_k$$

Where $\phi(\cdot)$ denoted the probability density function for the standard normal. The probability density function gives the height of the curve at the relevant index value $\mathbf{x}_i' \boldsymbol{\beta}$. In order to compute the marginal effect we need to specify the value and this is generally taken to be at the mean of the explanatory variables. The marginal effect is than simply the gradient of the standard normal CDF at this mean value.

In this section, I will calculate and show the procedure that is needed for computing the marginal effect for budget in product innovation in survey of innovation. The procedure for other variables follows the same pattern.

The first set in calculating the marginal effect is to compute a mean value for the standardized probit index. This computed as:

Prob (y = 1) = ϕ (0.345+ 8.89E-07 Budget + 7.29E-07 Equipment – 1.15E-06 Training + 0.741 Bachelor degree + 0.193 Master Degree)

Now, the mean for each variable will be added into the equation

= -0.345+ (8.89E-07· 257,770) + (7.29E-07 · 240,130) – (1.15E-06 · 27,503) + (0.741· 0.733) + (0.193 · 0.133) = 0.596

Note that this thesis did not use sample means. Instead this thesis used the means for the group that reported innovation to see the effect of change in variable on the probability of innovation. This method is not wrong, but it is generally accepted that marginal effects are assessed at sample means. This implies that the interpretation is different when means for a specific group of observations are used.

Descriptive statistics for firms regarding process innovation in Canada, 2004

Dependent	**Yes**		**No**	
Product	Observation	30	Observation	16
Independent	Mean	S.D.	Mean	S.D.
Budget	257770	571510	91625	168140
Equipment	240130	558880	99688	156420
Training	27503	45801	17875	62350
High School	0.133	0.346	0.250	0.447
Bachelor Degree	0.733	0.450	0.563	0.512
Master Degree	0.133	0.346	0.188	0.403

Source: Agricultural Policy Research Network, Survey of Innovation, 2004

Than, the marginal effect for an infinitesimal change in Budget spending the probability of producing a product innovation in the probit regression model is given by:

$$= \phi\,(0.596) \times 8.89\text{E-}07 = 0.334 \times 8.89\text{E-}07$$
$$= 2.97\text{E-}7$$

It pays dividend here to explain the calculation that is need to get 0.334. The standard normal density function is:

$$f\,(z) = (1 / (2\pi)^{.5})\; e^{(-.5(z*z))}$$

$$\text{so } f\,(0.596) = (1 / (2\pi)^{.5})\; e^{(-.5(0.596*0.596))}$$
$$= 0.344$$