Innovation and Advanced Technology Use in the Canadian Forest Sector

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Abstract

The forest sector is traditionally viewed as stagnant and non-innovative in comparison to higher-value added industries. The sector is being challenged by environmental, market and consumer changes at home and internationally. To combat these challenges, forestry firms must undergo a transformation in their activities, including their production methods by producing innovative and sustainable products and materials. This involves investing in innovation, advanced technologies and new products.

The purpose of this study is to understand the impact of adoption of advanced manufacturing technologies on firm performance in the Canadian forest sector. The study is based on data from the 2007 Survey of Advanced Technology and interviews with technology adopters. The differences between technology adopters and non-adopters in terms of capital investment, R&D, training, management practices and innovation were analyzed. The findings suggest that the adoption of advanced technologies is important for the realizations of innovations. Firms which were both innovative and adopted technology were most likely to report improvements in performance post-adoption.

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1. Introduction

The forest industry is facing the worst crisis in its history and needs to adapt in order to survive. The Canadian forest sector is characterized by falling exports, plant and mill closures and job loss (Benoit, 2008). The US housing crisis and the strengthening of the Canadian dollar coupled with the shift to electronic media has resulted in a collapse in the demand for Canadian forest products (Natural Resources Canada, 2013c). The socio-economic impacts of this decline are widespread, but they are most strongly felt in almost 200 communities, in which at least 50% of the workforce is dependent on the forestry industry (Tulloch, 2008; FPAC, 2012). The loss of employment often forces people to relocate to different communities. Since 2006, over 86,900 jobs were lost in the forest sector, which represents about 27% of the total workforce in 2006 (FPAC, 2012). Many sectors are indirectly dependent on the forest sector itself and total employment represents 593,200 people. There are several different factors that have contributed to the crisis facing the forest sector, such the mountain pine beetle infestation, increasing transportation and energy costs, the rise of international competitors and underinvestment in research and development (Benoit, 2008). Sustainable forest management and environmental regulations have also increased the cost of production for forestry firms (Binkley, 1995).

The current state of the industry and the relative importance of the forest sector to the Canadian economy is indicated in the figures below. The forest sector represents 1.9% of Canadian GDP and has a trade surplus of $17 billion, which is second to only oil and gas (FPAC, 2012). The industry's exports are primarily directed to the US, capturing about 65% of total exports (FPAC, 2012). Therefore, the sector was greatly affected by the US economic crisis, particularly by the decrease in demand in the construction industry.

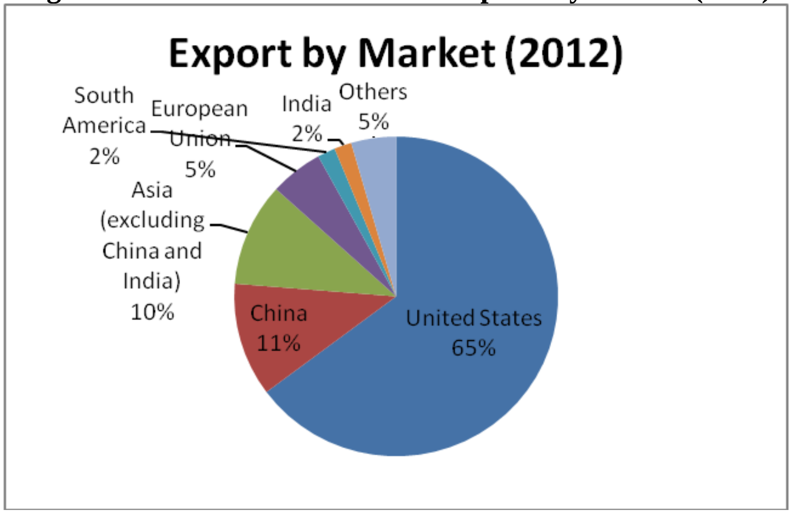
Figure 1: Forest Industry Facts

Key Facts	**Exports**
Forest Sector Revenues: $57.1 Billion Forest Sector GDP: $24 Billion Share of GDP: 1.9% Wood Products and Pulp and Paper GDP: $18.9 Billion Share of Manufacturing GDP: 12%	Total Exports: $26.4 Billion Total Exports as % share of GDP: 1.6% Trade Surplus: $17 Billion (2nd only to Oil and Gas) **Export by market:** United States: 65% China: 11% Asia (excluding China and India): 10% European Union: 5% South America: 2% Others: 4%
Employment	**Research and Development**
Forest Dependent Communities: 192 (>50% of regional GDP) Total Direct and Indirect Employment: 593,200 Total Direct Employment: 233,800 Direct job losses since 2006: 86,900	Wood Products Manufacturing (2011): $95 Million Pulp and Paper (2011): $56 Million Forestry and Logging (2011): $6 Million

Source: Forest Products Association of Canada (FPAC, 2012)

The Canadian forest sector has since diversified its exports to other areas of the world, namely China. Between the years 2002 and 2012, the share of exports to China rose from 1.8% to 16.3%, while the share of exports to the US decreased from 79.7% to 63.1% (Natural Resources Canada, 2013b). Forestry firms have had to upgrade their technology and production processes in order to meet the demands of new customers. According to Kristianto et al., “the era of mass production is being replaced by the era of market niches to meet the demands of a diversified customer base: a short development cycle yielding low cost, high quality goods in sufficient quantity to meet demand” (Kristianto et al., 2012, P.199).

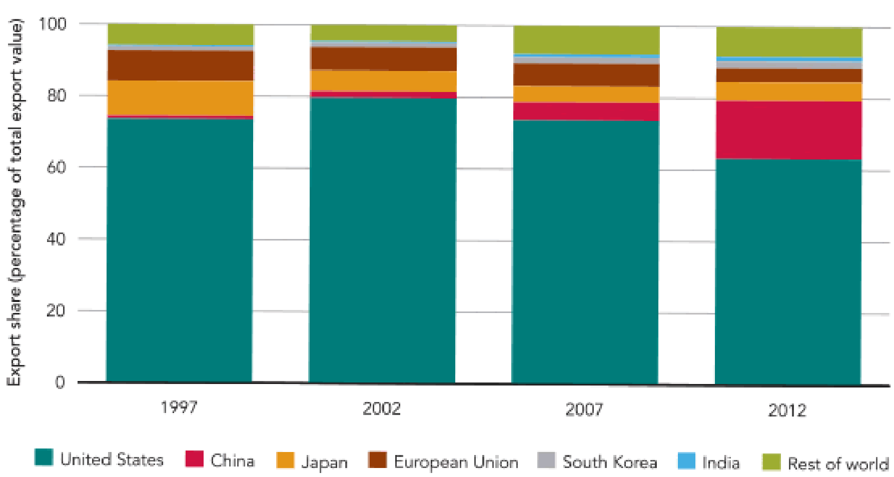
Figure 2: Canadian Forest Sector Exports by Market (2012)



Source: Forest Products Association of Canada (FPAC, 2012)

To combat these challenges, forestry firms must undergo a transformation in their production methods by producing innovative and sustainable products and materials. In *The Report of the Standing Committee on Natural Resources*, Benoit states that "the future health of Canada's forest sector depends on innovation" (Benoit, 2008, P.22). In order to transform the sector, firms will need to invest in innovation, emerging technologies and new products. Innovation can also rely on "highly skilled workers, on interactions with other firms and public research institutions and on an organizational structure conducive to learning and exploiting knowledge" (OECD, 2005, P.28).

Figure 3: Canadian Forest Product Export Destinations (1997-2012)



Source: Statistics Canada merchandise trade data, monthly

This thesis examines how forest sector firms are transforming through innovation and the adoption of advanced technology. The differences between adopters and non-adopters in terms of training, R&D, business management practices, obstacles to adoption, exports and innovation will be studied in order to better understand the impact of technology adoption on firm performance.

A recent report by the Council of Canadian Academies stresses the importance of innovation in Canada's natural resource sector, generally because "resource production itself requires continuous innovation to increase efficiency, extend supply and mitigate environmental impacts" (Council of Canadian Academies, 2009, P.28). Canada's economy has relied heavily on our natural resources, in order for us to maintain a competitive advantage we must innovate continuously, as these resources are limited in supply. Innovation can enable Canadian industries to develop less resource-intensive and environmentally damaging production methods (Council of Canadian Academies, 2009). Future success of Canada's natural resource industries will depend on the type of products we will be able to export, particularly our ability to produce high value-added products. Producing high value-added goods within Canada, rather than exporting them in their primary form, will foster the skills and knowledge necessary for innovation (Hawkins, 2012).

One of the challenges in conducting studies on innovation, is that innovation is difficult to measure. Innovation is a dynamic process, not a static activity (OECD, 2005). In surveys, proxies are frequently used to measure innovation, for example level of R&D investment or patenting. There is a high level of sectoral variation when it comes to innovation (Malerba, 2002). Technology adoption patterns can differ even within the same industry or the same production process (Beede and Young, 1995). In some sectors, technological change occurs rapidly, while in others it is incremental. Technological breakthroughs occur after long periods of incremental change and have a significant impact on the organizational environment (Tushman and Anderson, 1986).

Innovation in high-tech sectors is in part linked to R&D, while low and medium-technologically intensive sectors are more dependent on the adoption of knowledge and technology (OECD, 2005). R&D plays an important role in innovation, but not all innovation is R&D based.

Innovation in low-tech firms, such as those in the forest sector, often involves the incorporation of high-technology products and technologies. Non-R&D innovative activities include: development of human skills; investment in equipment and the reorganization of management systems. Innovation taxonomies which are purely based on R&D measures ignore the contribution made by these non-R&D activities (OECD, 2005).

Unfortunately, there has been a bias in innovation policy making towards high-tech firms, because they are perceived to be more innovative than low-tech firms. However, innovation requires not only the creation of new technology, but also the adoption of these technologies by consumers and industries. The Conference Board of Canada defines innovation as "a process through which economic or social value is extracted from knowledge—through the creating, diffusing, and transforming of ideas—to produce new or improved products, services, or processes" (Conference Board of Canada, 2012, para.1). National research and technology policies have been influenced by the belief that promoting high-tech industries will result in long-term growth, competitive advantage and employment effects (Hirsch-Kreinsen, 2008b; Heidenreich, 2009). Academics and policy makers have historically focused on the importance of scientific knowledge and research-intensive sectors in technological innovation, although traditional industries continue to represent a large proportion of employment and production. The research on innovation in low and medium-tech (LMT) industries has been limited (Chesbrough and Crowther, 2006; Hansen and Winther, 2011). The role of innovation conducted by the LMT sector must also be taken into consideration in order for us to gain a full understanding of the innovation process and its influence on productivity.

This "innovation research bias" has led to the misconception that LMT industries are not innovative, in part, because they do not perform formal R&D. LMT industries sometimes engage in "hidden-innovation," innovation that is not accounted for by standard innovation metrics, such as R&D expenditure and patents awarded (Halkett, 2007; Barge-Gil et al., 2011). Innovation does not have to be based on developing new scientific knowledge, but can involve exploiting the existing knowledge. As stated by Heidenreich (2009) "learning and innovation can take place without R&D" (Heidenreich, 2009, P.483). Innovation in the LMT sector often arises from daily routines performed within the firm, as a result of internal experimenting with existing technologies, the adoption of new technologies and of new processes or procedures.

Technological change in LMT firms mainly comes from suppliers of machinery and equipment (Hirsch-Kreinsen, 2008). Suppliers are an important source of knowledge for LMT firms. Knowledge is embodied in products, machines, and raw materials, which are developed in other industries and transferred to the firm (Hansen and Serin, 1997).

Historically, much of the research conducted in the area of innovation is based on the linear model of innovation, which emphasizes the role of formal R&D as an input to innovation and focuses primarily on the manufacturing sector, not including services (Salazar and Holbrook, 2004; Barge-Gil et al., 2011). The linear model does not take non-R&D related innovation activities, such as design, training and use of advanced machinery into serious consideration. These non-R&D related activities have a positive impact on innovation outcomes, particularly process innovation (Barge-Gil et al., 2011). The innovation process is complex and cannot solely be reduced down to R&D figures, as innovation is a collaborative and multi-level process, which rarely takes place within a single firm, or even a single country (Kirner et al., 2009; Malerba, 2002). The process of technological change is cumulative (Cohen and Levinthal, 1990; Castellacci, 2008). Technological trajectories of sectors are determined by what has been done in the past (Pavitt, 1984; Tushman and Anderson, 1986).

The standard indicators used to measure innovation may have contributed to the innovation research bias. R&D intensity "measures the ratio of R&D expenditure to the turnover of a company or the output value of a sector" (Hirsch-Kreinsen, 2008, P.19). According to OECD classification, the high-tech sector has an R&D intensity greater than 5% and the low and medium-tech sector has an R&D intensity less than 3% (OECD, 2005; Hirsch-Kreinsen, 2008). However, low R&D intensity, does not necessarily mean low innovativeness – it could simply be an indication that low and high-tech firms innovate differently (Kirner et al., 2009). The high-tech sector is dominated by a small number of large international enterprises dependent on codified science-based knowledge, with a focus on product and service innovations. In contrast, the low and medium-tech sector consists of SMEs without their own R&D facilities or scientific knowledge base. Therefore, their innovation process is not as highly structured, which results in high flexibility to react to market requirements (Hirsch-Kreinsen, 2008). Although low-tech firms may not conduct in-house R&D, they regularly innovate through adoption and adaptation processes. Santamaria et al. (2009) observed that LMT firms play an important role in innovation, because they transform “the general stock of knowledge into economically useful knowledge” (Santamaria et al., 2009, P.508). This means that LMT firms may not be producing scientific breakthroughs or new inventions on their own, but they are adapting the innovations developed by the HT sector. These firms produce incremental innovations, which can have a much greater practical impact than radical innovations. LMT firms modify products and processes during the diffusion and adoption process in order to fit their needs, which often results in productivity gains (Santamaria et al., 2009). Radical innovations are relatively rare and once a new technology is developed, “technological progress is driven by numerous incremental, improvement innovations” (Tushman and Anderson, 1986, P.441).

Due to their reliance on external sources of innovation, open innovation is particularly relevant for LMT firms. Their own R&D capabilities may not be well developed; therefore need to constantly screen the external environment for new technology and knowledge (Spithoven et al., 2010). The ability to combine internal and external knowledge is an important contributor to competitive advantage in many industries (Santamaria et al., 2009). Some of the external sources of knowledge for LMT firms are use of consultants, hiring of skilled personnel, collaboration agreements and external R&D (Santamaria et al., 2009). In order for firms to benefit from this external knowledge, they need to develop an absorptive capacity, which is “the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to a commercial ends” (Cohen and Levinthal, 1990, P.28). Companies in the LMT sector may lack absorptive capacity, as they often lack experienced personnel and their R&D capacities are limited. The risks and costs of R&D are perceived to be high by LMT firms. They are likely turn to third parties, such as collective research centers, to develop their absorptive capacities (Spithoven et al., 2010).

The aim of this research study is to understand the use of advanced manufacturing technologies in select natural resource industries, namely the extraction logging industry and wood and paper manufacturing industries. The use of advanced technologies and the effect on firm performance in the forest sector will be compared to the use of advanced technologies in a high-tech sector, the Information and Communications Technology (ICT) manufacturing industry. This comparison to similar and non-similar industries is useful given the modest level of research into low technology industries and the relative abundance of literature on innovation in high-tech sectors. There is a need to determine the extent to which previous research, focused on high-tech innovation, is relevant and useful for understanding innovation in LMT. Is the forest sector as far behind in innovation as the standard classification systems suggest it to be? Is R&D intensity a suitable measure for innovation in the forest sector, or are other indicators, such as advanced technology use, more appropriate for measuring innovation in LMT sectors? The answers to these questions would provide valuable information for evidence-based policy making and the development of an innovation strategy for the forest sector.

The study will use the *2007 Survey of Advanced Technology,* conducted by Statistics Canada as its main source of data, combined with a qualitative analysis based on interviews with two forest sector firm managers. The survey has extensive forest sector coverage and is a near census for the logging sector. The results of the mixed methods study will be useful for both public and private sector institutions. The study will be contributing to the academic literature on innovation in low-technology and natural resource sectors. The Canadian government, firms and industry can benefit from the results of the study, as it can help identify the impacts of technology adoption on the firm and inform innovation policy.

The literature review is divided into six sections beginning with innovation taxonomies, leading into high and low-tech sector interdependency, with an explanation of absorptive capacity and open innovation. The policy implications of the bias towards high-tech firms and lack of effective measurement tools for innovation will be examined. The study will also focus on the Canadian forest sector and its transformation over the years. The final section will provide more detail on advanced technology adoption, the variables influencing adoption and the barriers to adoption. The literature will be supported by the findings from past surveys of innovation and advanced technology. The literature review will be followed by an explanation of the research objectives and a description of the methodology. The results of the survey and qualitative study will then be presented and analysed. The thesis will conclude with an explanation of the findings and suggestions for future research.

2. Literature Review

2.1 Innovation

"The generation, exploitation and diffusion of knowledge are fundamental to economic growth, development and well being of nations" (OECD, 2005, P.3).

Understanding how knowledge is created and exchanged is key to developing improved measures of innovation, which can be used to inform policy decisions. During the 1980s and 90s, the OECD undertook a considerable amount of research in order to develop models and analytical frameworks for the study of innovation (OECD, 2005). The first edition of the Oslo Manual, published in 1992, was influential in the development of many subsequent innovation surveys, such as the European Community Innovation Survey (CIS). The framework focused on technological products and process (TPP) innovation in manufacturing. However, the TPP concept did not adequately capture innovation in the service sectors. The issue of non-technological innovation was addressed in the third edition of the Oslo Manual (OECD, 2005). The CIS findings were used to revise the framework and re-define the concept of innovation to include marketing and organizational innovation. In addition, the OECD has developed a manual of "The Proposed Practice for Surveys of Research and Development", also known as The Frascati Manual (2002). The manual contributes to the "best practice" for science and technology policies. It has been used for measuring R&D in OECD member countries and is becoming a standard for developing R&D surveys worldwide.

The OECD classifies the manufacturing industry into four groups based on R&D intensity (the ratio of firm's R&D expenditure to the firm's sales): high-technology (>5%); medium-high technology (3-5%); medium-low technology (0.9-3%); low-technology (<0.9%) (Hatzichronoglou, 1997; Hirsch-Kreinsen, 2008). R&D activities include basic research, applied research and experimental development (OECD, 2002). The main advantage of the OECD classification system is that it provides a "simple and consistent tool for international comparisons" (Hatzichronoglou, 1997, P.4). The classification is based on R&D expenditure, an input to innovation, which does not necessarily provide an indication of the level of innovation output of a firm.

This research study will compare the forest sector, which is classified as low-tech and the ICT manufacturing sector, which is high tech, in order to examine the differences in technology adoption based on R&D intensity. According to the OECD *Information Technology Outlook*, "the ICT sector is the largest investor in research and development and it drives a large part of technical change and innovation across economies" (OECD, 2010, P.170). In 2008, the ICT R&D represented 23.3% of total Canadian BERD (Business Expenditure on R&D) (OECD, 2010). The R&D intensity in the forest sector was 0.38% in the year 2006, which would place it in the low-tech category. However, there is substantial variation in R&D investment depending on the sub-sector. In 2008, the paper manufacturing sector's R&D intensity was 3.14%, which would put it under the medium-high tech category, while in 2009 the R&D intensity for wood products was 1.13% (Mockler and Robichaud, 2011).

The OECD manuals provide some guidance for policy makers on measuring innovation. They assist policy makers in developing a broad understanding of innovation across industries, in particular the role of R&D and non-R&D inputs into the innovation process. This is especially important for understanding innovation in the service sector, where firms do not engage in R&D as frequently. However, the OECD framework classifies industries based solely on R&D intensity, which may have contributed to the perception that only high-tech firms are innovative. Other classification systems, such as Pavitt's taxonomy (1984), take into account the sources of innovation and the linkages between high-tech and low-tech firms.

Pavitt's (1984) seminal paper on sectoral patterns of technical change, presents a classification system designed to identify the sources, nature and directions of technological change. According to Pavitt, variations in technological knowledge can be explained by "sources of technology, requirements of users and the possibilities for appropriation" (Pavitt, 1984, P.343). The framework is often used as an illustrative tool of the determinants of firm performance, such as international competitiveness and innovative performance.

Pavitt's taxonomy focuses on vertical linkages: "the relationships and interactions firms have with enterprises in other sectors of the economy" (Castellacci, 2008, P.7). He identifies four categories of innovating firms based on the sectoral sources of technology used in the sector, the nature of the technology produced and firm characteristics. The first class of sectors includes firms where technical change comes mainly from suppliers of equipment. These he terms "supplier dominated." "Supplier-dominated" firms are usually found in traditional manufacturing sectors and have weak in-house R&D capabilities (Pavitt, 1984). In contrast, "science-based" firms generate their own technology in R&D labs. Their product development depends on prior development of basic science (Pavitt, 1984). These types of firms transfer technology to "supplier-dominated" firms. The third category identified by Pavitt is "production intensive" firms. These firms are involved in mass production and they benefit from economies of scale by replacing labour with machinery (Pavitt, 1984). Production engineering departments are an important source of process technology for production intensive firms, but they also have a strong relationship with, what Pavitt calls, "specialized suppliers". "Specialized suppliers" produce capital goods and innovate in response to customer needs.

Malerba (2002) also developed a concept for the sectoral systems of innovation, based on multidimensional, integrated and dynamic view of sectors. Unlike Pavitt's taxonomy, the framework focused on the interaction between individual "agents," which are firms or organizations, and how these interactions are shaped by institutions. The author emphasizes the importance of knowledge transfer between firms and non-firms, which results in transformation and evolution within the system. Many other taxonomies do not take the dynamic nature of the sectoral system of innovation into consideration.

One of the limitations of Pavitt's taxonomy is that he groups the categories at the industry, not firm level. The categorization considers the firm's output, not technology base. There is still a large degree of variance between firms within each category, because firms belonging to the same industry may have very different technological inputs (Archibugi, 2001). There is also variation in innovation and technology use depending on firm size. In recent years, there has been a movement towards extending Pavitt's taxonomy to account for firm size (De Jong and Marsili, 2006).

Small firms are often under-represented in innovation taxonomies. De Jong and Marsili conducted a study of over 1000 small manufacturing firm in the Netherlands to develop an empirical taxonomy of innovative small firms (De Jong and Marsili, 2006). The authors extend Pavitt's taxonomy, by suggesting that innovation patterns in small firms are more diverse than previously believed. Small firms differ in their innovative activities, business practices and strategies. SMEs are much more sensitive and responsive to changes in their environment. They tend to be highly specialized in their activities, which increases the importance of efficient interaction with other firms and public research institutions for R&D and exchange of knowledge (OECD, 2005). According to De Jong and Marsili, "small firms that do innovate successfully increase their chances of survival and growth" (De Jong and Marsili, 2006, P. 213). Firm behaviour is shaped and constrained by the nature of technologies they use, or their technological regime.

De Jong and Marsili's taxonomy of innovative small firms is similar to Pavitt's taxonomy, but does not differentiate between manufacturing and service firms. Instead of focusing on the industry level, they use firm level data, which allowed them to test the assumption that all firms within an industry have similar innovative patterns (Archibugi, 2001). The taxonomy was developed through cluster analysis techniques, looking at variables such as innovative input, innovative output, sources of innovation, managerial attitude, innovation planning and external orientation (De Jong and Marsili, 2006). Based on the cluster analysis, the authors identified four different types of innovative small firms. Small firms with a low level of innovativeness, mainly responding to proposals from suppliers, are classified as "supplier-dominated". They are relatively open and consult with more than three external parties (De Jong and Marsili, 2006). Firms producing product innovations driven by their customers are categorized as "specialised suppliers". "Specialised suppliers" have a low level of openness and will rarely consult external sources. "Science-based" firms have high levels of innovation in both products and processes. They employ innovation specialists and collaborate with universities and research institutes (De Jong and Marsili, 2006). "Resource-intensive" generate both product and process innovations. These firms have the largest budgets for investing in innovation out of all four categories. However, their external orientation is low, as they rarely engage in formal partnership or seek the help of consultants.

The level of innovation in SMEs is influenced by their ability to access funding. SMEs often lack internal funds and may have more difficulty obtaining external funding than large firms, which can inhibit their innovation efforts (OECD, 2005). This is a problem for Canadian forest sector firms, particularly logging firms. Due to the nature of the terrain, they may need to have smaller plants in multiple locations and may not have the funding to invest in new technologies for each facility (Binkley, 1995). De Jong and Marsili's findings are consistent with Pavitt's; some of the patterns of technological change in large firms are also found in small firms (De Jong and Marsili, 2006). However, they also extend Pavitt's taxonomy by including differences in business strategies and practices in their study. These variables are particularly important for understanding the patterns of innovation in small firms, because they capture informal aspects of innovation, which cannot be measured by traditional indicators of input and output (De Jong and Marsili, 2006). Empirical taxonomies have proven to be a useful tool for understanding the diversity of innovative behaviour that can be observed across firms. These new frameworks have implications for policy makers, who need to address the various sectors differently, as they cannot apply a generic scheme of R&D support to all industrial sectors.

2.2 High and Low-tech Interdependencies

An important factor to consider when developing innovation policies is that high-tech and LMT sectors are significantly heterogeneous. Knowledge and information do not only flow from high-tech to low-tech, but the low-tech sector plays a critical role in the diffusion of high-tech innovations (Hirsch-Kreinsen, 2008b). In developed economies, old and new technologies co-exist. Mature industries such as tobacco, food and textiles are adopting advanced technologies to remain competitive and prevent further decline (Hirsch-Kreinsen, 2008b). Even industries classified as "low-tech" based on their R&D levels conduct some activities involving high technology (Mendonça, 2009). In order to derive benefits for the whole economy and not just particular industries, policy makers must consider the complementarities between the technologies (Robertson and Patel, 2007). Therefore, authors such as Hirsch-Kreinsen (2008b) advocate a more holistic view of the innovation process, taking the inter-sectoral connections into account. Hirsch-Kreinsen (2008b) describes low-tech firms as knowledge carriers and disseminators of knowledge. LMT industries have a strong practical knowledge base, but they are also able to integrate scientific knowledge from high-tech industries. For example, beer producers have R&D labs specialising in chemistry and physiology, however they are classified as low-tech due to the ratio of production volume to R&D expenditure (Hansen and Serin, 1997). In food processing, and many other large-scale productions such as forestry, the R&D share is low when measured in relation to turnover. Although some low-tech firms do engage in internal

R&D, external knowledge sources are the main sources of knowledge for LMT firms. They obtain knowledge from the market, customers, suppliers and manufacturers of technical equipment and systems, design companies, research institutes and consultants (Hirsch-Kreinsen, 2008b). Linkages and relationships with external knowledge providers are therefore crucial to the innovation process.

Radical technological change produced by high-tech industries will have widespread effects on the economy as a whole. For example, the diffusion of information and communications technologies (ICT) has had a huge impact on production processes and productivity levels in both high and low-tech sectors (Robertson and Patel, 2007). Innovation in high-tech and low-tech is complementary (Hirsch-Kreinsen, 2008). LMT firms innovate incrementally, through adaptation and recombination of existing technology components in novel ways (Hirsch-Kreinsen, 2008). Adaptation of the product to market needs can have a greater commercial impact than more fundamental R&D (Hansen and Serin, 1997). The LMT sector is a "carrier industry," incorporating new technologies from the high-tech sector into the making of new products or implementation of new manufacturing processes (Hirsch-Kreinsen, 2008). This suggests that LMT and high-tech sectors are linked. Productivity in LMT depends on high-tech, but "the innovative capability of high-tech depends on their narrow relationship with LMT industries" (Hirsch-Kreinsen, 2008b, P.18). The success of high-tech sectors is highly dependent on their ability to sell their outputs to low-tech sectors (Robertson and Patel, 2007). The LMT industry is the main buyer of high-tech products and therefore encourages greater investment in R&D. LMT firms can request new products or alterations to existing products, which creates an innovation impulse in the high-tech sector (Hirsch-Kreinsen, 2008b). High-tech firms will innovate in response to their customers' needs.

The LMT sector provides revenues and sales to high-tech sectors, which helps cover the high fixed costs of innovation. The higher the rate of uptake by low-tech industries, the sooner the high tech producers can realize economies of scale, which will reduce the price of the innovative products (Robertson and Patel, 2007). Lead users of high-tech products will often provide feedback to their suppliers, which, in-turn, allows them to make improvements for their next customers. High-tech and low-tech firms are increasingly engaging in joint projects, as innovation projects often require a combination of both Science, Technology and Innovation

(STI) and Doing, Using and Interacting (DUI) innovation modes (Hansen and Winther, 2011). STI innovation involves the use of an analytical knowledge base, such as codified scientific knowledge from universities and research institutions. The results of STI innovation are often radical and are codified through patents and documents (Hansen and Winther, 2011). The DUI mode of innovation relies on a synthetic knowledge base, rather than creating new knowledge. As codified knowledge becomes more easily accessible within the global economy, tacit knowledge becomes increasingly important in generating a sustainable competitive advantage (Asheim and Gertler, 2005).

Employee skills, learning-by-doing, learning-by-using and tacit knowledge play an important role in DUI innovation. Hansen and Winther (2011) have noted that firms which combine both modes of innovation are usually more innovative than firms who focus on just one type of knowledge base. STI and DUI innovation are complementary, practical knowledge and experience are crucial for scientists in R&D departments and scientific knowledge can provide solutions to problems arising on the shop floor (Hansen and Winther, 2011). At the same time, scientific knowledge is also used within firms that typically focus on incremental innovation. Tacit knowledge is embedded within people, and therefore much more difficult to transfer than codified knowledge. “Learning through interacting” is becoming an important concept for knowledge acquisition – innovation is reliant on social interaction and knowledge flows between firms, research organizations and public agencies (Asheim and Gertler, 2005). Hansen and Winther (2011) describe LMT firms as “translators” between end customers and high-tech suppliers, because they are able to collect information about customers and help develop products based on the user’s needs.

Spatial proximity will play an important role in a firm’s ability to access knowledge. Information and technology will flow not just from high-tech to low-tech, but also in the reverse direction, as LMTs play a strategic role in high-tech innovation. High-tech firms may not have the same type of access to their end users as low-tech firms. Since high-tech firms are the suppliers of technology, they are usually found at the beginning of the production chain. Low-tech firms facilitate the information transfer between high-tech and their customers (Hansen and Winther, 2011). At the same time, the use of advanced technologies has been identified as a major source of innovation for low-tech firms (Hansen and Winther, 2011). The knowledge transfer occurs in both directions. Technology users will provide technology suppliers with tacit and codifiable knowledge on how they can better address the needs of their customers (Asheim and Gertler, 2005).

In Pavitt's (1984) taxonomy, low-tech firms are classified as "supplier dominated," which suggests that they derive technical change from their high-tech suppliers. However, low-tech firms are not only the purchasers of high-tech products, but they are also diversifying into high-tech and patenting in these areas (Hansen and Winther, 2011).

Although patents are a good measure of innovation within some industries, non-formalised methods of innovation also need to be considered by policy makers. Innovation policy has often seemed to be overly influenced by a simplistic view of innovation stemming from the idea that economic growth is a result of high R&D investment. These policies follow a "linear model of innovation," according to which scientific research is the first stage of innovation (Hansen and Winther, 2011). High levels of R&D investment are an important component of the US's innovation policy. Following the example of the US, there has been a strong emphasis on the "science-push" in European and Canadian policymaking. However, this type of policy fails to recognize the interdependence between high and low-tech sectors, which could have a detrimental impact on economic growth, particularly in less technology-intensive regions (Hansen and Winther, 2011). Innovation is not always supply-side driven, but can be a response to the demand in low-tech sectors. Nevertheless, priority is given to high-tech sectors with high R&D investment levels.

In addition to this, it is increasingly difficult for low-tech firms, such as those in the Canadian forest sector, to withstand competition from low-wage countries. Trade liberalization and improved infrastructure in industrialized countries have led to an increase in competition faced by LMT firms (Hansen and Winther, 2011). Upgrading their technologies is one method of differentiating themselves from their competitors. Sourcing technology from high-tech sectors can therefore be of great importance. Developments in information and communication technologies have allowed firms in both developed and developing nations to access new knowledge sources. However, according to Vernon (1966), equal access to scientific knowledge does not mean that all firms will be able to apply this knowledge in the creation of new products.

Firms need to develop their absorptive capacities in order to successfully acquire and assimilate external knowledge (Cohen and Levinthal, 1990). This requires entrepreneurs, who are able to search for knowledge, identify opportunities and are willing to take a risk (Vernon, 1966). Managerial capabilities and decision making will influence the firm's ability to absorb knowledge (Penrose, 1959; Cohen & Levinthal, 1990).

One of the problems associated with an innovation policy based on R&D intensity, is that it exacerbates regional differences and inequalities (Hansen and Winther, 2011). High-tech firms are usually found in large city-regions, therefore most resources are concentrated there as well (Hansen and Winther, 2011). The main factors influencing the location of firms are transport-costs and labour-costs (Vernon, 1966). Access to skilled labour is important, as high-tech firms require workers with the appropriate scientific knowledge for their R&D departments. The need for quick and efficient communication with suppliers and customers also helps explain the clustering of high-tech firms. This makes it more difficult for peripheral regions to compete, pushing them into further decline. Hansen and Winther (2011) make the argument that if regions want to remain prosperous, they should diversify, not focus only on high-tech. The authors note that geographic proximity of high and low-tech firms can play an important role in innovation, as it influences the level of collaboration. Spatial proximity is important for supplier and customer relations (Hirsch-Kreinsen, 2008). Large distances between firms can make it more difficult to collaborate, as they can slow down the diffusion of knowledge and information. Since many forest sector firms, particularly logging firms, are based in rural areas, access to skilled labour and resources is limited. This high level of interdependency highlights the importance of diversification in regional and national economies.

Therefore, innovation policy must also support low-tech industries, as they are crucial to the success of high-tech industries and economic prosperity. Policy makers should adopt a more holistic view of industrial innovation, taking into account the inter-sectoral connections. Policies need to encourage not only the generation of knowledge, but also knowledge diffusion and absorption. Technology adoption is an inherently risky process, the government can play a role in facilitating the sharing or creation of knowledge. By acting as an information broker, the government can "provide firms with information about new technologies, identify complementarities or quantify expected benefits", which will reduce some of the uncertainty associated with technology adoption (Van Biesebroeck, 2007, P.3). Governments should also promote upgrading in low-tech sectors through policies, which encourage smooth and speedy knowledge diffusion (Robertson and Patel, 2007; Hirsch-Kreinsen, 2008b).

2.3 Open Innovation and Absorptive Capacity

Much of the literature has focused on explaining the role of absorptive capacity in open innovation in large R&D intensive firms, primarily on the acquisition and use of externally generated knowledge by firms engaged in product development (Chesbrough, 2006). However, the importance of open innovation in small firms and traditional mature industries, such as the forest sector, is not as well documented. Spithoven et al. (2010) seek to illuminate how these types of firms develop absorptive capacities in order to successfully engage in open innovation. Firms in low-tech sectors may not dispose of their own in-house R&D facilities and rely on external sources of knowledge and technology. Much of the knowledge they acquire is embodied in the technology they purchase from high-tech sectors. In order for firms to benefit from this external knowledge, they need to develop an absorptive capacity, which was defined by Cohen and Levinthal (1990) as “the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to a commercial ends” (Cohen and Levinthal, 1990, P.28). Absorptive capacity is a pre-condition to open innovation (Spithoven et al., 2010). The ability to absorb information, technology and knowledge from outside sources is an essential aspect of an effective innovation-management system (Mockler and Robichaud, 2011).

There are numerous methods of developing absorptive capacities, such as performing internal R&D or through employee training. An increase in absorptive capacities may also be a side effect of production (Cohen and Levinthal, 1990). A firm’s incentive to learn will influence its investment in R&D. The incentive to learn is affected by the amount of available knowledge and the difficulty of learning. Firms need to not only identify new knowledge, but also assimilate it and use it within their production process. Therefore, they depend on their absorptive capacity to benefit from open innovation (Spithoven et al., 2010). Cohen and Levinthal (1990) argue that “the ability to evaluate and utilize outside knowledge is largely a function of the level of prior related knowledge” (Cohen and Levinthal, 1990, P.128) The influence of prior knowledge on the ability to assimilate new knowledge is based on the concept that learning is cumulative, and learning will be more successful if the information is associated with something that is already known (Cohen and Levinthal, 1990). The development of absorptive capacity is therefore path dependant. Accordingly, it is more difficult for firms to diversify their learning into new areas. The absorptive capacity of an organization will be influenced by the individual absorptive capacities of its employees (Cohen and Levinthal, 1990). Training is essential in ensuring that employees have the necessary skill set to adopt the new technology (Santamaria et al., 2009). The value of the acquired knowledge will depend on the employee's ability to apply the knowledge to accomplish organizational goals and mobilise it when and where it is needed (Robertson et al., 2012).

Chesbrough and Crowther (2006) identify two types of open innovation. With inbound open innovation, firms will scan their external environment for new technology and knowledge to complement their in-house research activities (Chesbrough and Crowther, 2006; Spithoven et al, 2010). With outbound open innovation, firms seek external paths to the market by commercializing technologies through other organizations. The original literature on open innovation was based on case studies of large R&D intensive firms representative of the high-tech sector (Chesbrough, 2003). Traditional LMT industries are typically composed of SMEs with little or no R&D capabilities (Chesbrough, 2003). Smaller companies often have less formalised IP, in the form of patents, to buy or sell, so open innovation requires collaborations and sharing of technology. According to Chesbrough (2006) a firm can be "too open", as there is a risk of sharing information with the wrong people, especially because small firms may not have the resources for formal legal protection. Such firms face the issue of attracting customers, capital and employees, while preserving their IP (Chesbrough, 2006). Therefore, they may have to rely on third parties to help them develop absorptive capacities. External knowledge comes from suppliers, customers or other organizations (Spithoven et al., 2010).

Chesbrough and Crowther (2006) explore open innovation outside of the high-tech sector, focusing on early adopters of the concept. The authors suggest that companies do not have to conduct their own R&D to achieve a competitive advantage, but can instead leverage the R&D of other firms. SMEs will often become members of collective research centres, which aid firms in finding the right technology, developing the capacities to absorb it and also perform R&D activities required by the firm (Chesbrough and Crowther, 2006). Another option is to employ technological consultants and acquire the absorptive capacity externally, through a process called "learning-by-hiring," rather than build it from within (Santamaria et al., 2009). A study conducted by Santamaria et al. (2009) found that consultants, hiring of personnel and external R&D are a significant source of external innovation for LMT firms. Consultants are important particularly in product innovations within the LMT sector, but are not a significant factor in high tech firms. One of the limitations in relying on external sources of innovation, is that they are also available to competitors and therefore are unlikely to provide a sustained competitive advantage, as other firms can adopt the same innovations.

In a recent paper, Robertson et al. (2012) argue that literature on absorptive capacity does not adequately address "distributed knowledge and learning or the application of innovative knowledge" (Robertson et al., 2012, P.822). The authors find that open innovation has more commonly been associated with process innovations rather than product innovations (Robertson et al., 2012). Pavitt (1984) has classified firms relying mainly on external sources for their technology as "supplier-dominated". Producers of commodity products, primarily low-tech firms also fit into this classification. These types of firms achieve a competitive advantage by maintaining low costs. Since their products are homogenous, the only way to produce at a lower cost than their competitors is through more efficient production processes (Pavitt, 1984). Therefore, the incentive to innovate processes is high (Robertson et al., 2012). However, process innovation is closely linked to product innovation, because new products may require changes in processes.

Firms in the "supplier-dominated" sector do not invest heavily in R&D, but instead rely on technology suppliers as a source of innovation. Cohen and Levinthal's (1990) seminal paper *"Absorptive capacity: a new perspective on learning and innovation"* focuses on developing absorptive capacity through R&D, which may not be a viable strategy for low-tech firms engaging in non-R&D innovation. The authors use R&D intensity as a proxy for absorptive capacity, however Spithoven et al. (2010) argue that there are better ways to operationalize the concept. Cohen and Levinthal's explanation of developing absorptive capacities is applicable to high-tech firms, however, in low-tech the application of new knowledge is related to capabilities other than R&D.

Many authors have since recognised that absorptive capacity is a multidimensional concept and should also include measures that proxy qualified personnel, for example the use of skilled labour (Robertson et al., 2012; Spithoven et al., 2010). Absorptive capacity needs to be combined with other skills, such as those of non-scientific and non-technical workers, to solve the problems involved in open process innovation (Robertson et al., 2012). These employees possess tacit knowledge and physical skills, which may be necessary in implementing a new technology. Tacit knowledge is developed over time and cannot be easily transferred; therefore, the role that employees play in technology adoption should not be overlooked. The perceived level of risk in R&D projects may influence employees' acceptance of the new technology (Chesbrough, 2006). External technology comes from a variety of sources and therefore has a higher perceived risk than internal technology. Firms may not be able to adequately evaluate the technology due to bounded rationality (Chesbrough, 2006). Firms can minimize the risk of adopting a new technology, by investing in a technology that has already been proven in other uses (Chesbrough and Crowther, 2006). If they are able to negotiate exclusive rights from their supplier, then they will obtain a competitive advantage over other firms in the industry.

Robertson et al. (2012) extend the original model presented by Cohen and Levinthal (1990) to include the capacities needed in knowledge application. Process innovation will often require tacit knowledge, which emphasizes the need for skilled workers in technology adoption. Firms must possess the necessary "innovative capacities" to gain access to and assimilate new knowledge (Robertson et al., 2012). These "innovative capacities" include accessive capacity, adaptive capacity and integrative capacity.

Accessive capacity refers to the knowledge generation and accumulation conducted both internally and externally (Robertson et al., 2012). Building tacit knowledge through learning-by-doing is a part of a firm's accessive capacity. The efficient transfer of knowledge across the organization is essential (Cohen and Levinthal, 1990). Gate-keepers can play an important role in translating the information and disseminating it across the organization. A firm's ability to establish relationships and create networks with other firms is also crucial to gaining access to new knowledge. It is important for process innovators to scan the environment for new technologies and remain informed about what is available to them. In addition to identifying new technologies, they must understand how to install and use them. Firms cannot integrate external knowledge passively (Cohen and Levinthal, 1990).

Adaptive capacity is described as a firm's ability to integrate the technology into their production process (Robertson et al., 2012). This adaptation represents a form of incremental innovation. Oftentimes, firms will use the technology for a purpose for which it was not originally designed, therefore they must adapt it to fit the organization's needs. Low-tech firms have adopted various technologies originally designed for high-tech uses. Robertson and Patel (2007) studied the adoption of advanced technology in food processing and the textile industry and its effects on international patterns of production and trade. Technology adoption will have effects on the production process as a whole that extended beyond a single piece of equipment. It will require changes in the organization's operations, which involve all the actors within the firm.

Robertson et al. (2012) have termed the firm's ability to ensure that the technology is compatible with their existing process as the firm's "integrative capacity." There is no inherent value in a technology itself, the value of a new technology is determined by the business model used to bring it to the market (Chesbrough, 2006). Firms need to be able to effectively assimilate the new technology, or they will not realize the full benefits offered by the technology.

2.4 Canada's Innovation Performance and Policy

Governments can assist in improving the innovative performance of firms by developing policies which facilitate the adoption and diffusion of advanced technologies (Van Biesebroeck, 2007). Small firms and firms with little experience in adopting advanced technologies may lack the absorptive capacities to assimilate it effectively. According to Van Biesebroeck, governments can implement policies to help firms use existing information more effectively, for example it can "provide expert information on available technological options, provide information on internal reorganizations that have proven to be necessary for successful adoption, or identify foreign information sources of new technologies" (Van Biesebroeck, 2007, P.3). Policy makers must consider why these firms have failed to grow, because removing some of the impediments to adoption does not mean that the adoption will be successful.

A firm belonging to a low-tech industry is not necessarily low-tech itself. Most of the innovation taxonomies, such as the one proposed by the OECD (2005) and by Pavitt (1984), look at innovation at the industry level rather than the firm level, which has led to the misconception that low-tech firms are not innovative. On an industry level, low-tech firms do not invest as much into R&D as high-tech firms do (OECD, 2005). However, an increasing number of firms from the low-tech sector, including forest sector firms, are using advanced technologies, such as biotechnology and nanotechnology in their production processes. Therefore, they are not as disconnected from the science base as it may appear. One of the reasons for the misconception, is that firms are classified based on the output produced, rather than the inputs going into the production. Even in low-tech industries, these inputs may involve high-tech products. The roles of high technology and LMT sectors cannot be analysed in isolation, because it is their interaction that drives economic growth and development.

Research on mature industries challenges the idea that they are not innovative (Mendonça, 2009). Many industries classified as low and medium-tech by the OECD are in fact involved in technology diversification and high-tech patenting. LMT firms do have the ability to learn and actively contribute. Although widely used, the OECD classification based on R&D expenditure, may not provide the most accurate representation of levels of innovation in different sectors. There is a trend towards technology diversification; new technologies are not replacing the old ones, but are being combined as inputs into new or improved products. Research in the past has not focused on the role of multi-technology firms in innovation and knowledge creation. Many large firms are diversifying their innovative activities into new areas, combining even three different types of advanced technologies in their production process (Mendonça, 2009). The existing classification systems may need to be expanded to account for these types of firms.

Pavitt's taxonomy has been used as a framework by other researchers (De Jong and Marsili, 2006; Castellacci, 2007), who have expanded it to include services as well as small firms. There may be some issues associated with designing policy at the industry level. Integrating the firm level of analysis with the industry level could help policy makers and managers understand how innovations within specific sub-sectors influence the industry as a whole. By extending the original framework, the rates, sources and direction of innovation may be used to explain the differences in business practices and strategies. These variables account for the informal aspects of innovation in small firms or low-tech firms, as they do not focus solely on R&D intensity. Certain firms belonging to a low-tech industry may be involved in R&D and have a scientific base. These types of firms should not be overlooked, as they play an important role within the industry.

2.4.1 Canada's Innovation Performance

The lack of innovation has been a problem for the Canadian economy as a whole. During the 1990s, Canadian firms were more focused on the local market and the US, rather than competing on a global level (Porter and Martin, 2000). The strategy they were pursuing was based on raw materials and labour cost savings instead of innovation. Over the past 20 years, it has become apparent that in order to be competitive on an international level, firms must produce distinctive and differentiated products and services, rather than replicate those of their competitors (Porter and Martin, 2000). Canada has for many years relied on its natural resource endowments to produce low cost commodities with standard technologies, particularly when it comes to the export industry. However, this will not result in a sustainable competitive advantage for Canadian firms. A recent study by the Conference Board of Canada (2012) found that Canada is near the bottom of its peer group on innovation. Out of 16 countries, Canada places thirteenth. This is a cause for concern, because "innovation is essential to a high-performing economy" (Conference Board of Canada, 2012, para.12). The countries scoring higher on innovation, are also performing better on measures such as income per capita, productivity and quality of social programs.

One of the reasons for the poor score is the fact that Canadian firms are behind on the adoption of innovative technologies (Conference Board of Canada, 2012). With increasingly shorter technology life-cycles, Canada, as a slow adopter, needs to catch up on many technologies, which is reflected in the country's low productivity level. As developing economies, such as Brazil and China, achieve productivity gains, Canada must focus on more innovation-related strategies based on knowledge-intensive, high-value-added goods and services (Conference Board of Canada, 2012).

The findings of the Conference Board are nothing new, Canada's productivity has been lagging behind the US and other developed countries since the 1980s (Mockler and Robichaud, 2011).

The country's abundant natural resources have resulted in it being primarily an "upstream" producer serving the same traditional markets with outdated production processes. The 2009 report by the Council of Canadian Academies points out that "despite a strong comparative advantage in resource endowment, Canada did not develop leading global firms in machinery for forest products, mining or fisheries" (Council of Canadian Academies, 2009, P.63). In regards to the forest sector, the industry has largely relied on primary products such as plywood and lumber, which are mainly exported to the US (Mockler and Robichaud, 2011). However, the growing demand for green products and the increasing intensity of competition has driven some forestry firms to innovate.

Canadian firms should differentiate themselves and develop unique production processes. Instead of exporting low value-added commodities, they should serve more demanding and sophisticated customers and export their technological and managerial expertise (Porter and Martin, 2000). Canadian firms are not sufficiently investing in cutting-edge technologies, such as ICT (Conference Board of Canada, 2012). However, there is currently no explanation for why this is the case, as comprehensive data on this issue is not available. The survey conducted by the Conference Board's Centre for Business Innovation revealed that 25% of firms find finance to be the primary challenge to innovation (Conference Board of Canada, 2012). Canadian firms rely on internal cash flow to finance innovation, a lack of finances can act as an obstacle to innovative activity. Seeking external sources of finance, both in Canada and abroad, could help firms overcome this problem. The analysis of the *2007 Survey of Advanced Technology* could provide some insights on this issue.

2.4.2 R&D Focus

Canada lacks a coherent Innovation Policy. Most innovation policy objectives are directed at specific industries or on the commercialization of technology, but fail to recognize that the true value of an innovation lies in its diffusion throughout industries (Hawkins, 2013). Canada was unable to meet its Innovation Strategy target, set in 2002, to become one of the top five countries in the world in R&D performance. With an R&D expenditure of 1.72% of its GDP in 2012, Canada is behind the OECD average of 2.4% (OECD, 2014).

The main focus of Canadian innovation policy has been on supporting R&D and technology start-ups. This techno-centric view is apparent in government reports, such as the report by the Council of Canadian Academies (2009) and the Jenkins Report (Industry Canada, 2011), which utilize input-based indicators, such as R&D, patents or technology. However, these indicators are biased in favour of high-tech firms (Hawkins, 2012). According to Hawkins (2012), this may not provide an appropriate representation of innovation in Canada because "the majority of our most economically significant sectors – basically our natural resource and financial services sectors – are for the most part capital-intensive technology adopters, rather than R&D-intensive technology producers" (Hawkins, 2012, P.13). Although their R&D intensity is low, this does not mean that firms in the natural resources or service sectors do not innovate, nor are they necessarily technologically behind other sectors.

For firms to extract economic value out of R&D, its results must be integrated into products and processes that become adopted throughout the market (Huang et al., 2010). The OECD has been using gross domestic expenditure on R&D as a percentage of GDP (GERD) to compare countries' R&D intensity. In a study of the third European Community Innovation Survey, Huang et al. note that the emphasis on R&D is "reflected in the structure of innovation support programmes" (Huang et al., 2010, P.5). They also found that almost half of innovative firms did not perform R&D. In addition to this, Gu and Tang observed that for wood products, expenditure on R&D is not correlated with innovation. Instead, the main source of innovation is investment in new equipment and skilled workers (Gu and Tang, 2004). These findings provide support for the idea that firms do not have to perform R&D to innovate. R&D is a risky activity, many firms, particularly small ones, may not be willing to take the economic and information risks involved. Technology adoption is perceived to be less risky than R&D, because firms are able to research the technology prior to adoption (Huang et al., 2010).

The standard classification system is focused on the inputs to innovation, rather than the outcomes. It does not account for the results of innovation, such as the creation of globally competitive firms or the impact on society (Hawkins, 2013). Other non-R&D forms of innovation include adaptation and learning by doing, imitation and adopting innovations developed by others, and combining existing knowledge in new ways (Huang et al., 2010). The OECD classification scheme is based on one input into the innovation process, R&D; however it does not take other factors, such as advanced processes or the skill level of the workforce into consideration (Baldwin and Gellatly, 1998). Indicators such as GERD are more commonly used in innovation scoreboards, because monetary investments in R&D are easier to measure than innovation outcomes (Godin, 2004). We must also distinguish between the outputs and impacts of R&D investment. Outputs are the direct outcomes of R&D activities, such as knowledge or innovation, which are measured by the number of papers produced, patents, product and process innovations (Godin, 2004). In contrast, "impacts are indirect and long-term outcomes, like economic growth, productivity and social welfare" (Godin, 2004, P.4).

Firms in the forest sector are more likely to engage in process innovation and informal R&D, which are not accounted for in traditional R&D measures. This may give the false impression that the forest sector is not innovative at all, when in fact certain firms, particularly in the pulp & paper industry, are very innovative (Schaan and Anderson, 2002). Innovation is a very complex process, and there is no evidence to suggest that the more a firm invests in technology, the better the outcome will be (Hawkins, 2012). Baldwin highlights the importance of recognizing innovation in LMT industries by stating that "focusing on highly visible industries, such as computers, can lead to the mistaken impression that innovation is only found in high-tech industries. In reality, innovation is occurring in many industries. And within these industries, firms that are innovative are the ones more likely to be growing" (Baldwin, 1999, P.1).

From a policy perspective, the implications of misclassifying industries could have detrimental impacts on society, particularly if resource allocation through government programs is based on these classifications (Baldwin and Gellatly, 1998). When an industry is classified as low-tech, it is seen as low-knowledge and part of the "old economy", whereas a high-tech industry is perceived to be innovative and desirable (Baldwin and Gellatly, 1998). The negative connotations applied to a low-tech industry could have adverse consequences for firms in these industries, as their access to government funding may be limited. This type of classification also gives the mistaken impression that all firms in low-tech industry are technologically inferior, which is not always the case. Baldwin and Gellatly emphasize that "low-tech industries are not devoid of high-tech firms, nor are high-tech industries comprised exclusively of high-tech firms" (Baldwin and Gellatly, 1998, P.6). The authors recommend a competency-based approach for firm classification based on new small firms, because they are often at the forefront of product development and technology use. This would also eliminate some of the bias in favour of large firm characteristics, which often occurs in classifications based on the industry level (Baldwin and Gellatly, 1998).

2.4.3 Canadian Policy Interventions

In Canada, the Investments in Forest Industry Transformation (IFIT) program, provides funding for firms implementing highly innovative technologies, which allows them to develop value-added forest products and bio-energy (Natural Resources Canada, 2014). Although the forest sector is considered to be low-tech, firms in this industry use many high-tech products in their production processes and also conduct research in collaboration with research institutes, such as FPInnovations. FPInnovations is "the world's largest public-private partnership in research and development" (Benoit, 2008, P.24). Its goal is "leadership in forest sector R&D and innovation in order to strengthen the Canadian forest sector's global competitiveness through research, knowledge transfer and implementation" (Benoit, 2008, P.24). Public-private partnerships can provide access to scientific research, as smaller firms may not have the resources to conduct the research themselves, but they are capable of applying it in innovative ways. The high cost and perceived risk associated with technology adoption could be preventing managers from implementing new technologies. Government projects, such as those in the Canadian Forest sector, can help reduce some of these costs and risks and allow firms to adopt innovative technologies. While these projects only support a small number of firms, other firms can learn from them, especially when it comes to world-first or Canada-first innovations.

Policies investing purely in high-tech may not result in economic growth and development, since the sectors are highly interdependent. Policy makers need to support both high and low-tech industries. Nevertheless, investments in R&D are often prioritized, as the effects of radical innovations are more readily apparent than that of incremental innovations. Firms that have been considered low-tech, are contributing to the development of high-tech products. When high-tech and low-tech firms collaborate on the development of new technologies, the contribution of the low-tech firm may be difficult to quantify in terms of R&D. Innovation cannot be studied as an isolated phenomenon, as it is a part of an Innovation System (Canadian Forest Service, 2014). The linkages between high and low-tech firms, such as collaboration, joint research, licensing or the flow of information and knowledge, are all a crucial part of the innovation system. The actors engaged in innovation activities all have linkages with other actors (Canadian Forest Service, 2014). Research into high and low-tech collaborations could provide some insight into the interdependencies between these sectors. This research could also help explain why policies supporting only the R&D side of innovation and not the diffusion of knowledge may not have much influence on firm success. Firms must also be able to access the knowledge created in R&D labs and assimilate it into their production processes (Cohen and Levinthal, 1990). One of the difficulties in developing innovation policies for the forest sector, is the fact that R&D is a federal responsibility, while forest management is provincial (Binkley, 1995).

The linear model of innovation focuses on formal R&D as a source of innovation and does not take into consideration the important role of other activities such as design, training and use of advanced machinery. Improved firm performance can be accomplished through the development and use of superior products and production processes. Gaining and retaining access to knowledge will only be of use if firms can effectively apply the knowledge. Policy therefore needs to support the commercialization of new knowledge and technology, as its value can only be realized in use. In addition, the absorptive capacities of firms are influenced by the absorptive capacities of the individuals within the organization (Cohen and Levinthal, 1990). Firms would benefit from policies directed toward training and skill building. Improved policy design would involve developing a new system of innovation indicators for non-R&D innovation activities, including design, technological intensity and skill intensity. These indicators could help provide a better understanding of innovation in low-tech firms.

Developing a National Innovation Policy requires a deeper understanding of innovation in Canada’s key industries, including the forest sector. This study will contribute to the growing body of knowledge on innovation in the forest sector, by examining how and why forest sector firms adopt advanced technologies and the outcomes of adoption in terms of performance improvement.

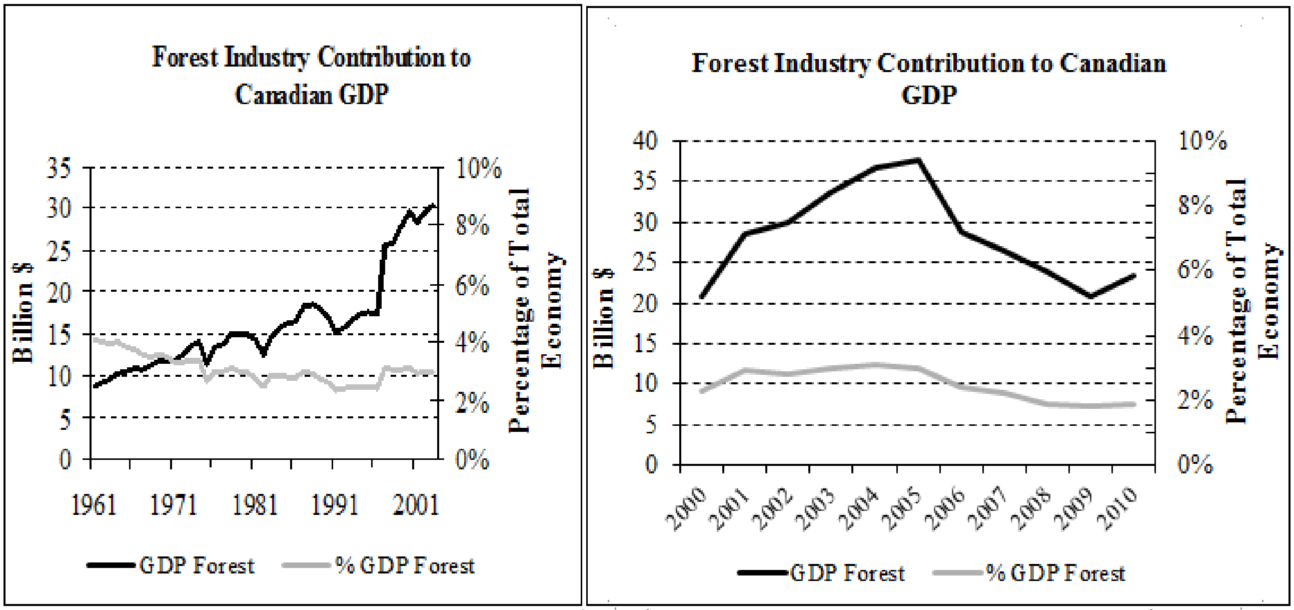
2.5 The Canadian Forest Sector

The forest sector is traditionally viewed as stagnant and non-innovative in comparison to higher-value added industries in the knowledge economy (Baldwin, 1999). Historically a driving force for the Canadian economy, the forest sector represented on average 3.4% of Canadian GDP between the years 1975 and 1991 (Madore and Bourdages, 1992). The average annual wage in the forest products sector in the year 2011 was $52,673, which is 16% higher than the national average (FPAC, 2012). The forest industry has also generated a large number of indirect jobs and stimulated economic development in other industries downstream by supplying sectors such as construction, furniture making, printing and publishing; as well as creating demand for energy, machinery, chemicals and transportation services (Madore and Bourdages, 1992). Due to the interdependence of these sectors, the industry crisis has had a negative effect on the product and service suppliers of forestry firms.

Canada's forests represent the third-largest area of forested territory in the world. Canada has approximately 397.3 million hectares of forest and wooded land, and less than 0.2% of Canada's forests is harvested annually (Canadian Forest Service, 2012). The majority (93%) of forest land is managed by the government: 77% is in control of the provinces and 16% held by the federal government (Benoit, 2008). The remaining 7% are private woodlots controlled by over 450,000 individual owners. Provinces are responsible for managing the forests within their territory. They have the authority to "develop legislation, regulations and policies, issue logging permits, collect stumpage fees and compile forestry data" (Benoit, 2008, P.4). The federal government deals with "trade and international relations, Aboriginal affairs, the management of federal lands and environmental protection" (Benoit, 2008, P.4). Currently, the industry is characterized by falling exports, mill and plant closures and job loss. The future of the Canadian forest sector depends in-part on adoption of new technology, access to new markets and sustainable forest management (Canadian Forest Service, 2012).

In the face of these challenges, Canada has been able to maintain its position as the world's largest exporter of forest products, in terms of both value and quantity. Canada's timber exports are thought to account for over 16% of the global trade in forest products (Cockwell, 2012). In addition, “Canada is also the world’s largest wood pulp exporter and accounts for 15% of global pulp production and 26% of global pulp exports” (Cockwell, 2012, P.143).

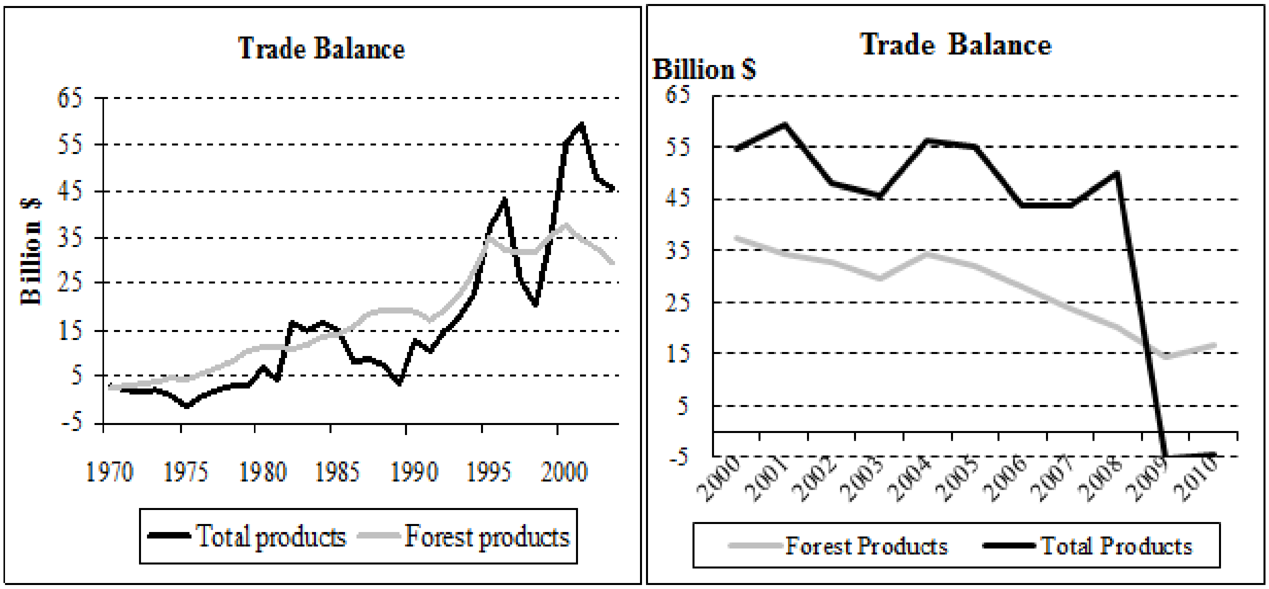
Figure 4: Forest Industry Contribution to Canadian GDP (1961 - 2010)



Source: Natural Resources Canada (2012)

Although the forest sector accounts for only around 2% of the Canadian economy, Canada is one of the largest exporters of forest products. About 70% of Canada’s GDP is represented by services, while natural resources (forest sector, minerals and metals, and energy) accounted for 11.5% in 2010 (Trading Economies, 2014). Between the years 2005-2009 the forest products sector’s contribution the total economy plummeted (Natural Resources Canada, 2013c). The logging and wood sub-sectors were severely impacted by the decrease in demand in the US construction market. Concurrently, consumers are switching from graphic paper to electronic media (Natural Resources Canada, 2013c). In 2011, the forest sector’s share of GDP improved from its record low in 2009 to 1.9% ($23.7 billion), primarily as a result strong domestic demand and increasing exports to Asia. Adopting and successfully implementing advanced manufacturing technologies could help the Canadian forest sector return to a position of greater contribution to the total GDP by improving its competitiveness in global markets.

Figure 5: Canadian Trade Balance (1970 – 2010)



Source: Natural Resources Canada (2012)

Canada is a leading exporter of natural resources and resource-based knowledge and technology (Natural Resources Canada, 2012). The contribution of the forest sector to Canada's trade balance grew steadily since the 1970s, until the year 2000, when it began to decline. However, the trade balance in forest products has remained positive over the years and has significantly contributed to Canada's trade surplus. In December 2008, Canada experienced its first monthly trade deficit since 1976, mainly due to weak demand from its main trade partner, the US, and falling oil prices (Trading Economics, 2009). The strengthening Canadian currency made exports more expensive, which further widened the trade deficit. In 2010, forest product exports picked up. Canada was the second largest forest product exporter and forest products made a major contribution, of $16.6 billion, to Canada's balance of trade (Natural Resources Canada, 2012). However, Canada was experiencing an aggregate $4.3 billion trade deficit. By the end of 2013, Canada's total trade balance declined to a deficit of $7.3 billion, partially influenced by a decrease in exports to the US (Statistics Canada, 2014).

Historically, the natural resource sectors have been an engine of job creation (Natural Resources Canada, 2012). However, many of the innovations in the forest sector have been labour-saving, resulting in labour productivity improvements, which contributed to the employment decline (FAO, 2012). Between the years 2003-2008, over 32,000 jobs were lost in the forest industry due to the closure of more than 300 plants (Benoit, 2008). The most significant impact was felt in

Quebec, where 11,329 people lost their jobs, representing one third of the total forestry jobs lost (Benoit, 2008). Forestry is a crucial component of many regional economies. Certain areas of Canada are primarily dependent on the forest sector. According to Cockwell, "British Columbia and the Maritimes, depend on forest-related activities for 15% or more of their economic activity." (Cockwell, 2012, P.77). The forest industry is concentrated in three provinces, British Columbia, Ontario and Quebec. The provinces are involved in different areas of the sector. Together, Ontario and Quebec account for 62% of the pulp and paper industry. While logging and the wood products industry are more active in British Columbia, each representing 51% and 45% of the activity respectively (Madore and Bourdages, 1992). This division is representative of the general trend in Canada, where value-added forest products are exported from the eastern provinces and the western provinces export non-value-added products, such as softwood lumber (Cockwell, 2012).

Further plant closures could have devastating effects on the forest-dependent communities, in particular on First Nations Individuals. The forest products industry is the largest employer of First Nations, in 2012 the industry employed over 17,000 (FPAC, 2012). The people in forest dependent communities need to be prepared to deal with the impending changes in the industry and adapt to the changes in skill requirements (National Forest Strategy Coalition, 2002). Many families are moving away from these areas to find employment elsewhere, which has significantly decreased school enrollment levels. The industry plays an important role in many rural economies, because it serves as "one of the major providers of high-quality, high-paying jobs for smaller communities" (Tulloch, 2008, P.3). Unlike in urban centres, where other job opportunities are available, retraining in these communities is often difficult, if not impossible.

2.5.1 Forest Sector Transformation

Transformation of the forest industry is one of the top priorities for the sector, as traditional forestry industries will continue to play a crucial role in the Canadian economy. The Canadian government has recognised that the sector needs to enhance its competitiveness and become more innovative (Mockler and Robichaud, 2011). The Council of Canadian Forest Ministers released the Sixth National Forest Strategy in December 2008 entitled *A Vision for Canada's Forests: 2008 and beyond.* The vision statement is "to be the best in the world in sustainable forest management and a global leader in forest sector innovation" (Mockler and Robichaud, 2011, P.35). The transformation of the forest sector relies heavily on the opportunities created through innovative products and technology. The forest sector is dependent on large capital investments in order to upgrade existing technologies or adopt new ones (FAO, 2012).

In recent years, the federal government has invested in many projects funding innovation and research in the forest sector. In August 2010, the federal government launched a $100 million initiative, the Investment in Forest Industry Transformation Program (IFIT). The goal of IFIT is to "support the introduction of leading-edge technologies in the forest sector through investment in innovative practices in forest work" (Mockler and Robichaud, 2011, P.36). The Economic Action Plan 2012 proposes $105 million over two years to support the continued transformation of the forestry sector (Forest Talk, 2012). An additional $92 million was allocated to the forest sector in Budget 2013 to fund programs in the forest sector, such as the Expanding Market Opportunities Program (EMO) and the Forest Innovation Program (FIP) (Natural Resources Canada, 2013b). The EMO is divided into two components: the off-shore markets component, the goal of which is to maintain and grow international forest product markets; and the North American component, which is focused on promoting the use of wood in North American non-residential construction in order to establish Canada as the world leader in sustainable forest management (Natural Resources Canada, 2013b). FIP supports pre-commercial research and development of innovative technologies conducted by FPInnovations as part of the Transformative Technologies Program (Natural Resources Canada, 2013b). In order to continue innovation in this sector, Canada's Economic Action Plan 2014 has renewed the IFIT program, providing $90.4 million to this project over the next four years (Natural Resources Canada, 2014).

However, investing in research and new technology will not necessarily result in improved firm performance; the full benefits of a new technology can only be realized when accompanied by changes in workplace organization, such as training (Boothby et al., 2010). The adoption of new technologies is often associated with increased skill requirements and changes in human resource practices (Co et al., 1998). Much innovation knowledge is embodied in people and their skills; innovation surveys provide limited information and ways of measuring the contribution of human capital to innovation have not been developed (OECD, 2005).

The forestry industry operates in a highly competitive, oversupplied commodity markets (Wright, 2002). The market is dominated by large global companies. A strategy focused on cost saving is not viable in the long run due to the downward pressure on commodity prices (Porter and Martin, 2000). Instead of competing through cost reductions, Canadian firms need to invest in new products and innovation. The development and diffusion of advanced technologies is crucial to sustaining a high level of productivity in the Canadian forest sector. For many years, Canada lacked a well-defined forest research strategy, both on a public and private level (Binkley, 1995). The forest sector's transformation is hindered by the comparatively lower levels of R&D expenditure in Canada. Canadian R&D investment lags behind that of our major competitors (Binkley, 1995). Forestry firms may be apprehensive when it comes to investing in new technologies, because they will not appropriate the benefits of their investment, as "the benefits of investing in the sector are often global, rather than national or local" (World Bank, 2008, P.2). Appropriability refers to "the ability to appropriate innovation investments through higher prices for new or improved products or through lower production costs" (Huang et al., 2010, P.16). The benefits of R&D and technology adoption will be passed on to customers in the form of lower prices. If one firm improves its technology and reduces its production costs, other firms in the sector are likely to follow suit. An increase in supply will lead to a reduction in price. Since most of the industry's customers are located outside of Canada, the benefits of R&D will flow out of the country.

2.5.2 Innovation in the Canadian Forest Sector

Schaan and Anderson (2002) examined the results of the *1999 Survey of Innovation* to determine if there are significant differences between innovative and non-innovative firms in the natural resources sector. They found that forest sector firms were more likely to introduce process rather than product innovations. This focus on process innovation might be explained by the main goals of innovation in the forest sector, which were to increase productivity and improve production flexibility (Schaan and Anderson, 2002). Some of the motivation behind forest sector firms adopting new technology is the desire to introduce more environmentally sustainable manufacturing practices while maintaining their competitive edge (Cockwell, 2012). The forest sector has been able to innovate by using wood resources more efficiently. The industry is a leader in using renewable sources of energy, especially in the pulp and paper industry, where energy consumption per unit output is declining (FAO, 2012).

According to data collected by the *1999 Survey of Innovation*, about 50% of innovative firms in the forest sector conducted R&D (Schaan and Anderson, 2002). However, there is great variation in the type of R&D based on the sub-sector. Firms in the paper industry are the most R&D intensive of the forest sub-sectors, about 63% of their R&D is conducted in-house in distinct R&D departments. On the other hand, innovative firms in logging will outsource 60% of their R&D (Schaan and Anderson, 2002). Most forestry firms are small and do not have research facilities of their own, therefore, they rely heavily on collaborative research efforts. The commitment of resources to R&D in public and private organizations in the forest sector and related industries will affect the possibilities for technological change in the sector (Rosenberg et al., 1990). When firms develop innovations in partnership, the cost for individual firms is reduced, as it is shared between them. The federal and provincial government are also involved in these research institutions, which provides further funding. Firms conducting R&D and using government support programs, such as R&D subsidies and tax credits, are more likely to innovate (Hanel, 2003). Public spending may be necessary where the long-run benefit to individual forestry firms is negative, but the overall social return is positive (Binkley, 1995; Hanel 2003).

2.5.3 The Forest Sector's Competitiveness

The Canadian forest industry is in danger of being overtaken on the international market by competitors who have been able to take advantage of new technology. While foreign mills are producing high value-added products, many "Canadian companies are still dependent on primary product markets with their shrinking profit margins" (Madore and Bourdages, 1992, P.2). Canada's businesses have not taken advantage of technological opportunities to increase their efficiency and diversify their production. The forest sector's productivity is affected by the forest tenure system, which inhibits the efficient use of forest resources by the private sector (Wang, 2009). This sets Canada behind its major competitors, such as Finland, Sweden and the US, where the majority of the forests are privately owned (Wang, 2009). The level of return on capital in Canadian forestry firms is lower than that in Nordic countries (Wright, 2002). These countries predominantly export value-added products, while 30% of the Canada's forest sector exports leave to the US as unprocessed timber (Cockwell, 2012). For too long, the industry has relied on a single market, which has contributed to the crisis it is dealing with today (Canadian

Forest Service, 2012). The sector will have to diversify if it is to remain competitive in the future.

Canada's forest sector is largely dependent on foreign technologies, as its investment in science and technology is much lower than that of its competitors (National Forest Strategy Coalition, 2002). Germany and Scandinavia have been the source of many important product innovations in the sector (Rosenberg et al., 1990). Many forestry firms rely on their suppliers for research and technology. If suppliers are the sole provider of research and technology, there is no competitive advantage between the firms, because competitors will have access to it as well (Wright, 2002). Therefore, this is a very risky strategy. As in-house R&D diminishes, forest sector firms will depend on universities and research institutes for new knowledge. Universities conduct fundamental research, however, they often lack the capabilities to commercialise their inventions. Research institutes are closer to the technology development and implementation and are better equipped to engage in proprietary research.

In 2009, The Natural Sciences and Engineering Research Council of Canada (NSERC) partnered with FPInnovations and NRCan to create the NSERC Forest Sector R&D Initiative (NSERC, 2009). The five year initiative represents a $34 million investment into university research in the area of forestry innovation and supports the commercialization of this research. The main goal of the initiative is forest sector transformation. The Forest Innovation by Research and Education (FIBRE) network was created in October 2011 as part of the Forest Sector R&D initiative in order to facilitate collaboration between the NSERC funded university networks (FPInnovations, 2013). FIBRE is tackling some of the skill shortages in the industry by training highly qualified professionals (FPInnovations, 2013). One of the universities greatly involved in forest research is the University of New Brunswick. The University has benefited from a federal government investment of $1 million as part of the Collaborative Research Partnership for Sustainable Forest Management (Industry Canada, 2010). The investment, provided through The Social Sciences and Humanities Research Council of Canada's (SSHRC) Community–University Research Alliances (CURA) program, will fund 20 large-scale research projects over a six year period, from 2010 to 2016 (Industry Canada, 2010). Collaborative efforts, such as this one, are a great example of industry, government and universities working together to transform the forest sector. Since forestry firms do not conduct much internal R&D, they need to develop absorptive capacities in order to assimilate external knowledge developed by universities, research centres or other firms.

Sweden's forest sector is facing similar challenges in terms of high labour and capital costs, so firms have adapted by producing high-value added goods in order to offset these costs. Many of the small firms have been joined together through mergers and acquisitions to form integrated pulp and paper companies, which has allowed them to reduce costs (Blömstorm and Kokko, 2007). There is a large emphasis on skill upgrading, through vocational education, and the firms benefit greatly from the knowledge clusters created as a result of the mergers. Swedish forest sector firms are investing in new technologies, such as drying kilns, in order to better serve the needs of their customers (Blömstorm and Kokko, 2007). Sweden and Finland have benefited greatly from applied research in the forest sector and are leading the market in the design and production of wood-processing equipment (Madore and Bourdages, 1992). Scandinavian research laboratories, comparable to Canada's cooperative research institutes, are conducting twice as much research as their Canadian counterparts (Madore and Bourdages, 1992).

Bowyer points out that "wood products manufacturing activity is beginning to shift from developed to developing regions. At the same time, industrial wood products consumption is growing in developing regions" (Bowyer, 2004, P.59). Production has transferred to countries with lower labour cost and lower costs of regulatory compliance (Bowyer, 2004; Canadian Council of Forest Ministries, 2008). Wood supply has also increased for a number of reasons: the development of fast-growing tree plantations, specifically in Asia and South America; the emergence of the Russian forest sector; and an increase in harvesting of rainforests (Luckert and Salkie, 1998; Bowyer, 2004).

Canada has been successful in selling its wood products on international markets due to the high quality of wood fibre in its forests. However, according to the National Forest Strategy Coalition, Canada is losing its advantage as other countries are "introducing new technology in the mills to produce high quality value added products from low-cost short-rotation fibre" (National Forest Strategy Coalition, 2002, P.8). Canada's forest firms are finding it difficult to compete with foreign low-cost producers. One of the key emerging players in the market for forest products is China, both on the production and consumption side. Chinese forest product manufacturers also pose a competitive threat to Canada. China is our second largest trading partner, after the US, with wood products being the largest Canadian export to China – representing 18.22% of the total exports to China (Wang, 2009; Canadian Forest Service, 2012).

However, rather than exporting value-added wood products, the majority of the exports consist of primary wood products, such as primary pulp, sawn lumber and logs. Chinese firms then turn the wood into finished products and sell them on the North American market at a cheap price (Wang, 2009). Instead of being able to capture the benefits of Canada's natural resource endowment, we are exporting primary goods, with little value-added, and buying back the resulting secondary goods. Domestic wood product firms struggle to compete with Chinese producers, who have much lower labour costs. To improve its competitiveness on global markets, Canada needs to promote small, flexible mills able to serve niche markets, not focus on short-term, market-oriented, profit-maximizing goals (Wang, 2009).

2.6 Advanced Technology Adoption

Empirical studies based on the "Survey of Innovation and Advanced Technology" by Statistics Canada have been conducted over the years to identify the benefits of advanced technology adoption and distinguish innovators from non-innovators (Baldwin, 1999; Baldwin and Sabourin, 2004). Advanced technology refers to "a new technology that performs a new function or improves some function significantly better than commonly used technologies" (Statistics Canada, 2008b, P.4). Investing in advanced manufacturing technology allows firms to serve their markets better, as it will enable them to design custom high-quality products and respond more rapidly to market changes (Tracey et. al 1999). Advanced technologies include design, engineering and virtual manufacturing technologies, such as computer-aided design or computer-aided manufacturing; processing, fabrication and assembly technologies; inspection systems; communications technologies; automated material handling and integration and control technologies (Appendix I, P.102-111). Studies on the adoption of advanced technology are usually concerned with the manufacturing industry as a whole, however not all manufacturing firms innovate in the same way. New technology may improve a plant's efficiency and allow firms to charge a lower price for their products, which should result in higher market shares

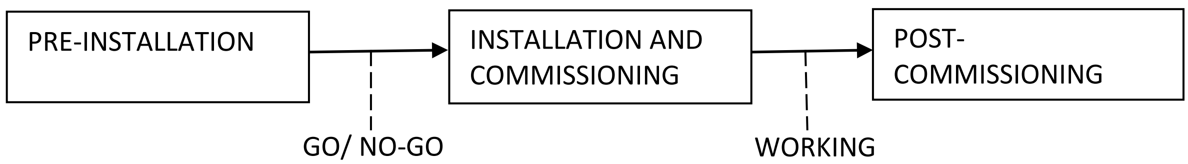
(Baldwin and Sabourin, 2004). Doms et al. (2005) found that capital-intensive plants employing advanced technologies have higher growth rates and are less likely to fail.

However, there is a gap in the innovation and technology adoption literature, as research on the Canadian forest sector has been limited to quantitative studies. As mentioned previously, innovation is a phenomenon that is difficult to measure. Looking at the firm level, rather than the aggregate level, can reveal more about the process of advanced technology adoption in forest sector firms. Instead of focusing only industry aggregates, this study will also include a qualitative component focused on individual firms and their behaviour.

Surveys focus on the outcomes, rather than the process of innovation. Innovation surveys are concerned with measuring the inputs and outputs of innovation within a firm, but do not really look at the dynamics, relationships and interactions that affect innovation (Salazar and Holbrook, 2004). Exploring the adoption process from a qualitative perspective can reveal the organizational changes that need to take place in the firm in order to adopt a new technology. For this reason, the *2007 Survey of Advanced Technology* data will be supplemented with interviews with forest sector firms adopting advanced technology.

Voss (1988) developed a life cycle model of the process of implementation (Figure 6 below), which will provide a conceptual framework for the qualitative study. The author defines implementation as “the user process that leads to the successful adoption of an innovation of new technology” (Voss, 1988, P.59). The implementation of advanced technology is a three-stage process; the first phase involves all the pre-installation factors that may influence the success of advanced technology implementation. The second phase involves the installation and commissioning of the technology, the goal of which is to meet technical and utilization targets. In the final, post-commissioning stage, further technical improvement takes place in order to derive business success from technical success (Voss, 1988).

Figure 6: Life Cycle Model of the Process of Implementation



Source: Voss (1988)

According to Voss (1988), the elements of the implementation strategy include organization, technical planning, business strategy and management. Support of top management is an important factor in the implementation of advanced technology (Co et al., 1998). Advanced technology adoption also has an impact on the employees working at the firm. Advanced technology can expand the technical complexity of forest sector jobs and changes the skill requirement, which means that technical retraining may be necessary (Co et al., 1998). This idea corresponds with the findings of Baldwin (1999), who suggests that firms which are successful in the implementation of innovations usually place an emphasis on their human resource strategy, in particular on training.

2.6.1 Factors Affecting Technology Adoption

"Adoption occurs when the benefits from adopting the new technology outweigh the costs. Adoption rates alone, are insufficient for attempting to understand the complex nature of technological change" (Sabourin and Beckstead, 1999, P.13).

The benefits of advanced technology use include a decrease in direct labour costs, more efficient use of machinery, decreased product development time and improved productivity (Co et al., 1998). According to Boothby et al. (2010) "firms that adopt new technologies and at the same time invest in skills are expected to realize greater productivity gains than those who do not" (Boothby et al., 2010, P.650). Internal expertise, organizational practices, training, R&D capabilities and linkages with external networks can facilitate the adoption of AMT.

Arundel and Sonntag analysed the results of the *1998 Survey of Advanced Technologies in Canadian Manufacturing* and found that the internal capabilities of the firm were a major determinant of the patterns of AMT use (Arundel and Sonntag, 1999). In fact, the internal capabilities within the plant had a greater influence on AMT use than environmental factors, such as obstacles to adoption. The 1998 Survey data indicated that prior AMT experience increased the likelihood of future adoption (Arundel and Sonntag, 1999). Existing technology is often cited as a determinant of successful AMT adoption (Voss, 1988). The authors also included other plant-level factors in their analysis. They found that plant size (measured by the size of employees) had an effect on the incidence of AMT use; larger plants were quicker to adopt advanced technologies than smaller plants (Bartelsman et al., 1996). Since Canadian firms are often smaller than those of our global competitors, it could be an indication of why they are less likely to adopt advanced technologies (Binkley, 1995). This adoption lag could also be explained by the greater availability in financial and technical resources within larger plants. Large firms are capable of generating internal funds, which they are able to invest in risky R&D activities (Huang et al., 2010).

On the other hand, small firms are less likely to be influenced by bureaucratic constraints or coordination problems, which may allow for speedier adoption than in large firms (Langley and Traux, 1994). Certain management-related factors also played an important role in determining the level of AMT adoption. Ownership status also has an effect on AMT use; foreign-owned plants use more AMTs than domestic plants (Zammuto and O'Connor 1992; Arundel and Sonntag, 1999). Foreign-owned plants are usually part of a multi-level enterprise, therefore are larger and more likely to adopt advanced technologies than standalone plants. Similarly, plants serving only the Canadian market will adopt fewer AMTs than exporting firms. The decision to adopt new technology may be influenced by the actions of the firm's competitors (Hoppe, 2002). If their rivals adopt a certain technology, other firms may have to adopt it simply to keep up and remain competitive in the market.

These results correspond with the results of the *1993 Survey of Innovation and Advanced Technology* based on which Baldwin and Lin concluded that "larger, younger, foreign-controlled plants are more likely to use any technology" (Baldwin and Lin, 2002, P.10).

2.6.2 Obstacles to Technology Adoption

Financial Constraints

The high cost of AMT can act as a significant barrier to adoption (Arundel and Sonntag, 1999; Huang et al., 2010). It can be difficult for a firm to justify an investment in AMT, because the strategic benefits resulting from adoption are hard to quantify (Small, 2006). Economic approaches using financial and accounting techniques, may not be suitable for measuring certain intangible outcomes of adoption, such as improvements in quality and flexibility. Instead, the results of AMT adoption should be examined from a strategic perspective by assessing the firm's position in relation to its competitors and taking the industry's future into consideration (Vrakkig, 1989; Small, 2006). Measuring the outcomes of an AMT investment is complicated even further if a firm adopts multiple technologies, because they may have system dynamics, making it difficult to distinguish the impacts of a certain technology. Different technology combinations will have varying effects on plant performance (Beede and Young, 1995; Small, 2006).

When it comes to the results of AMT adoption, the benefits are uncertain. Although most firms invest in AMT with the intention to improve performance, the findings of the *1998 Survey of Advanced Technologies in Canadian Manufacturing* are mixed. The data do not provide evidence to support that AMT adoption will lead to improved performance. In addition, the financial benefits of AMT adoption are not realized right after the introduction of the technology, but may take months or even years to be generated (Arundel and Sonntag, 1999). According to the survey data, firms rank increased profitability as the most important result of technology adoption; however, there is no indication that this increase in profitability actually occurs. Therefore, Arundel and Sonntag (1999) believe that firms were reporting on their expected results, rather than the actual outcomes of AMT use.

Organizational Barriers

The main barriers to effective use of technologies are related to the management process. Organizational changes are sometimes necessary in order to become compatible with the technology introduced (Da Costa and de Lima, 2009). The adoption of a new technology may be deemed a success by the firm in terms of the technical implementation, however studies conducted in the 1980s indicated that half of the firms, which adopted advanced manufacturing technology, did not achieve any strategic benefits, such as improved flexibility or reduced lead-times (Voss, 1988; Schroder and Sohal, 1999). Inadequate organizational preparation and planning may be the reason why firms do not fully reap all the benefits of AMT adoption (Small and Yasin, 1997).

Tracey et al. (1999) emphasize the importance of including manufacturing managers in advanced technology adoption, as it will provide better coordination between the various functional units of the firm and streamline the adoption process. Teamwork is believed to be a key component of technology adoption (Small, 2006). The involvement of managers in the technology adoption also "helps create a shared learning environment that increases the rate of information exchange" (Tracey et al., 1999, P.414). Top management support is crucial to the successful implementation of a new technology (Co et al., 1998). Training will be necessary throughout the adoption process, as employees need to be educated about the goals of the technology adoption (Mirvis et al., 1991; Co et al., 1998).

Skill Development

A shortage of skilled workers can slow down the process of innovation, as much innovation knowledge is embodied in people (OECD, 2005). However, methods from measuring the role of human capital in innovation are not well developed. Labour quality is not completely static; it also has a dynamic component, which makes it more difficult to measure (Freel, 2005).

Internal resources, including employees, are key to innovation in small and medium-sized firms, such as those in the forest sector, since they may not have designated R&D personnel. Employee contributions to innovation within the firm may not be captured using standard innovation metrics, such as R&D expenditure (Hansen and Winther, 2011). The skills necessary for innovation will vary by sector, therefore it is important to study the forest sector and its sub-sectors specifically, rather than, for example, the manufacturing industry as a whole (Freel, 2005).

Johnson et al. (1996) differentiate between labour-saving and labour-enhancing technologies and their effect on employee skill requirements. Labour-saving technologies assist employees on the work floor, while labour-enhancing ones will increase their range of abilities (Johnson et al., 1996). Rosenberg et al. (1990) found that most technological innovations in the forest sector have a labour-saving bias, which indicates that the industry "tends to increase its competitiveness through improvements in labour productivity" (Rosenberg et al. 1990, P.16). The type of training provided post technology adoption will likely be influenced by the nature of the technology adopted, that is: whether it has a labour-saving or labour-enhancing effect. Technologies that are labour-enhancing may require a higher skill set and thus more training than those which are labour-saving.

Although skill shortages are believed to be a major impediment to innovation, the *1998 Survey of Advanced Technology in Canadian Manufacturing* indicated that labour shortages did not prevent firms from adopting technology (Sabourin, 2001). Sabourin clarifies that "simply reporting an occupational shortage does not mean it has a dramatic effect on technology adoption" (Sabourin, 2001, P.14). The forest sector is competing with other sectors, such as oil and gas, for skilled labour, which has resulted in an industry wide skill shortage (FPAC, 2012). It is to be expected, that a period of radical technological change will result in a shortage for a certain type of skilled worker. As firms adopt new technologies, which require new skill sets, skill shortages will arise (Sabourin, 2001). The adoption of advanced technology will also result in an increase in skill requirements. AMT adopters are therefore more likely to implement a training program to account for the increase in job complexity (Baldwin, 1999).

It is anticipated that non-adopters face greater obstacles to technology adoption than adopters, however the results of the *1993 Survey of Innovation and Advanced Technology* demonstrate that this is not the case. AMT adopters are in fact more likely to report impediments (Baldwin and Lin, 2002). These firms were able to overcome the impediments and learn through innovation, as opposed to non-adopters, who may be faced with similar challenges, but do not possess the ability to overcome them. This differentiates successful and unsuccessful firms.

3. Research Objectives

This thesis seeks to understand the frequency, types of and obstacles to adoption of advanced technologies in the Canadian forest sector.

To increase our understanding, we will examine the main patterns of technology adoption across Canadian manufacturing industries, and within the sub-sectors of the Canadian forest sector (logging, wood and paper). So as to contextualize the results, a comparison within the Canadian forest sector and between the LMT forest sector and the predominantly high-tech ICT manufacturing sector will be made. The national innovation policy in the past has largely focused on the production and application of new technology. The ICT sector is characterized by low entry barriers and is attractive to venture capitalists due to high investment-to-earnings ratios (Hawkins, 2012). The OECD also benchmarks countries based on their levels of expansion of employment in the high-tech sector, which influences governments to evaluate the success of their innovation policies on these metrics (Baldwin and Gellatly, 1998). Therefore, the ICT sector is perceived as more desirable by investors and policy makers in comparison to the forest sector, as it is instrumental in the transition towards a knowledge economy (Baldwin and Gellatly, 1998). This has resulted in a techno-centric view of innovation with a bias toward high-tech firms. Many of the government policies in Canada have been aimed at increasing industrial R&D and stimulating the growth of tech start-ups (Hawkins, 2012). Although these policies may help ICT firms produce high-value added products, mature industries, such as the forest sector are also need in of investment in order to facilitate transformation (Conference Board of Canada, 2012). A comparison of the forest sector to the ICT manufacturing sector can help illustrate how a high-tech policy bias may have influenced technology adoption in both sectors.

The study will analyze not only involvement in R&D, but also other factors influencing innovation, such as advanced technology adoption, training or the use of advanced management practices. We will investigate the extent to which Canadian forest sector firms produce Canada first or world-first innovations and identify the differences between technology adopters and non-adopters. Interviewing firms involved in the IFIT program, which are considered to be leaders in forest sector innovation, allows us to gain a better understanding of the technology adoption process. The study also examines the obstacles to the adoption of advanced technologies. Finally, the study investigates potential outcomes from these activities, in terms of innovation, exports, and the impacts of advanced technology adoption on firm performance.

Specifically, we analyze:

- The percentage of **capital investment** in machinery and equipment spent on advanced technologies
- The percentage of business units involved in **R&D** and the type of R&D they are conducting
- The **type and number of advanced technologies** adopted
- The **business practices** regularly used (Product development, manufacturing and control management, quality management – including lean, supply chain/logistics management)
- The type of **training** provided by forest sector firms post adoption (Such as acquisition of fundamental competencies, computer literacy, technical skills, management skills;)
- The **obstacles** to adoption (in relation to financial justification, human resources, organizational obstacles, or external support services)
- The **novelty of product and process innovations** produced by forest sector firms (from new to firm to world-first)
- Forest sector **exports** as a percentage of revenue from sales to different countries

Previous surveys of advanced technology have demonstrated that firms in the Canadian manufacturing industry gain market share and increase efficiency in the form of increased labour productivity (Johnson et al., 1996; Baldwin and Sabourin, 2004; Sabourin and Beckstead, 1999). Firms will adopt advanced technologies with the expectation that they will improve performance.

The diffusion of technology can be measured by examining the incidence and intensity of technology usage. Based on the definitions from Sabourin and Beckstead's report on the *Survey of Advanced Technology in Canadian Manufacturing 1998:* "Incidence of use measures whether a technology is being used. Intensity of use measures the extent to which that technology is being used" (Sabourin and Beckstead, 1999, P.38). These two measures will be used in this study in order to evaluate the diffusion of advanced technologies in the Canadian Forest Sector.

It is less easy to hypothesize the type of technologies that are important to innovation in particular sub-sectors, such as logging compared to wood products manufacturing, due to the lack of previous research on the matter. Moreover, it is not clear the extent to which these activities will impact on firm performance and innovation.

Analysis of the *2007 Survey of Advanced Technology* will provide a better understanding innovation and advanced technology adoption in the forest sector and sub-sectors. The results of this project will be used to inform advice to industry on best practices in the adoption of advanced technologies for the purposes of improving firm-level innovation and performance. Results will also be useful in identifying public policy interventions both existing and potential for the purposes of encouraging innovation in the sector. The ability to measure innovation accurately is particularly important in evidence-based policymaking (Halkett, 2007).

The study will highlight the importance of advanced technology adoption in the forest sector and provide evidence to encourage the provision of government funding through programs such as IFIT, by demonstrating why continued investment in advanced technology in the forest sector is necessary by the government and private sector.

The existing professional networks and established working relationships between The Canadian Forest Service, The University of Ottawa and Statistics Canada provide a unique opportunity for research on innovation in the forest sector. There are limitations to the types of data that can be obtained by innovation surveys, at least as it pertains to the measurement of the impacts of innovation on firms individually and sectors collectively. The survey data was collected over five years ago, yet it has not been exploited to its full potential; this research study provides a great opportunity to explore the data in a new way and from the forest sector perspective. The investigation will require interviews for qualitative analysis, as data from surveys often needs to be combined with other sources of information (Salazar and Holbrook, 2004). The *20007 Survey of Advanced Technology* does not provide performance measures or measures of success, only self-reported “impacts of technology adoption.” The interviews will provide more information on the results of technology adoption and impacts on the firm.

4. Methodology

The study is based on a mixed methods approach, combining both quantitative and qualitative data. The main data source is the *2007 Survey of Advanced Technology* designed and administered by Statistics Canada. The survey results are supplemented by a qualitative study of two forest sector firms, which received IFIT funding in order to adopt advanced technology. The qualitative data was collected through semi-structured interviews with two forest sector firm managers who were involved in the adoption of advanced technology. Qualitative data will help us uncover any factors influencing the technology adoption process which may not have been addressed in the survey. It will also help us understand what occurs at the firm level during the technology adoption process, particularly how IFIT financing can benefit Canadian forest sector firms.

4.1 The Survey of Advanced Technology

The Survey of Advanced Technology is a part of the research efforts to create better measures of innovation (Statistics Canada, 2008). Statistics Canada has been at the forefront of developing comprehensive innovation surveys. The scale and magnitude of the *2007 Survey of Advanced Technology* make it one of a kind when it comes to the study of advanced technology use and innovation in manufacturing in Canada. Statistics Canada has developed some of the most sophisticated and large scale surveys of innovation in the world. The data analysis will draw on research papers based on previous Statistics Canada surveys of innovation and advanced manufacturing technology (Baldwin, 1999; Baldwin and Lin, 2002; Sabourin, 2001; Schaan and Anderson, 2002). Studies on innovation and advanced technology adoption in the manufacturing sector conducted in other countries, such as Australia and New Zealand (Schroeder and Sohal, 1999), Singapore (Co et al., 1998), the US (Beede and Young, 1995) or the CIS in Europe (Huang et al., 2010), can also provide some guidance in data analysis.

The *2007 Survey of Advanced Technology* was developed in partnership with many governmental institutions, such as Industry Canada and Natural Resources Canada (NRCan), as well as industry experts and researchers from universities. The final version of the questionnaire was developed based on the results of cognitive testing carried out with potential respondents (Statistics Canada, 2008).

The target population of the survey consists of all business units in the manufacturing sector and logging with at least 20 employees and revenues of at least $250,000 in order to minimize the response burden (Statistics Canada, 2008). The sampling unit was a single establishment. Data were collected directly from respondents through questionnaires in paper format. A copy of the survey questionnaire is attached in Appendix I on P. 102 of this document.

The survey sample was taken from the 2007 Business Register, which included a population of 16,590 manufacturing firms and 622 business units in the logging industry (Statistics Canada, 2008). A total of 9,814 firms fit the sampling criteria, which represents 57.9% of the population. The manufacturing sector was stratified into 49 different industries based on consultation with survey stakeholders. The logging industry was stratified by province and establishment size.

Data for this survey was collected between August 24th 2007 and March 31st 2008. The data covered a 3-year period. Response to the survey was mandatory. From a sample of 9,441, a total of 6,733 questionnaires were completed, resulting in a 72.8% response rate (Statistics Canada, 2008). The response rate was very high compared to similar surveys conducted in other countries, such as the CIS survey, which achieves a response rate of about 50% (Gov.uk, 2012). Many surveys are voluntary in nature, whereas the *Survey of Advanced Technology Use* is required by Canadian law, which may contribute to the relatively high response rate.

The forest industry sub-sectors surveyed include **wood product manufacturing** (NAICS 321), which is further classified into sawmills and wood preservation (NAICS 3211), veneer, plywood and engineered wood product manufacturing (NAICS 3212) and other wood product manufacturing (3219); and **paper manufacturing** (NAICS 322), including pulp, paper and paperboard mills (NAICS 3221) and converted paperboard manufacturing (NAICS 3222). The forest sector and associated manufacturing industries "were sampled with greater industry detail and with greater intensity with the expectation of reliable estimates at the provincial/territorial level" (Statistics Canada, 2008, para.18). The forest sector was very well represented in the survey, with a coverage of 76.3% of the total population (Appendix II Table 1A, P.128). A total of 1,003 wood product manufacturing establishments and 419 establishments from paper manufacturing were surveyed. The survey also covered the entire population of the **logging industry** (NAICS 1133), all 373 logging firms were part of the survey sample. Representative samples, such as these, provide reliable data from which to conduct analysis. The forest sector, combined with the logging industry, will be compared to a high-tech manufacturing industry, the **information and communication technology (ICT) manufacturing sector** (NAICS 3333, 3341, 33421, 33422, 3343, 3344, 3345 and 335920). This comparison will help us identify the differences between high-tech sectors, such as ICT, and sectors that are considered to be low-tech, such as the forest sector. The findings can also reveal where the forest sector may be lagging behind high-tech sectors and what it can do to improve.

The survey is divided into four sections. Section A is on advanced technologies, the type and number of technology used, the results of adoption and the obstacles to adoption. The questionnaire lists 39 advanced technologies in six different technology groupings (Found in Appendix I, P.102-111). Section B focuses on "advanced practices," such as the business and design practices within the firm. The following section, Section C, features questions on the use of emerging technologies, which include geomatics/geospatial technologies, biotechnologies and nanotechnologies. Questions about innovation and R&D are listed in the final section, Section D, of the survey.

The survey data was obtained through a partnership with the Canadian Forest Service (CFS). CFS has been involved in innovation research since 1999 and assisted in the development of the *2007 Survey of Advanced Technology Use in Manufacturing.* As a result of CFS's significant financial investment in the survey, the forest sector is the only sector in Canada's natural resource sector to have all of its activities covered as well as the only manufacturing sector to have all of its sub and sub-sub sectors covered in detail. The survey results produced over 3,000 Excel tables. In order to analyze such an extensive amount of data, Statistics Canada developed an analytical tool called Template for Analysis. The tool allows for a large volume of data to be measured against two mutually exclusive domains, such as adopters vs. non-adopters, as well as provides a reliability test and significance test against the compared data. The symbol convention used to report the reliability of the data is presented in Appendix II, Table 2A on P.128 of this document. The majority of the data used in this study is classified as level "A" or "B," deeming it "very reliable" or "reliable". Class "A" data has a coefficient of variation of ≤5.0% and a standard error of ≤ 2.5% (Statistics Canada, 2008). This type of data is reliable and can be used to inform policy decisions.

4.2 Qualitative Methodology

As a follow up to the *2007 Survey of Advanced Technology,* a qualitative study was conducted to provide new data and more insight into the adoption of advanced technology in forest sector firms by looking at some of the most innovative firms in the sector. Two firms, a sawmill and a pulp mill, which received funding from the IFIT program, were contacted for telephone interviews. The IFIT program covers up to 50% of the costs for forest sector firms' adoption of innovative technologies (including capital expenses, training, travel, overhead costs etc.). In 2010 the project received 107 applications, of which 14 projects were funded, and eight of these were world-first technologies (Natural Resources Canada, 2014). Although these firms are not representative of the forest sector as a whole, they are at the forefront of advanced technology adoption and can help us understand how leading-edge technologies are implemented in Canadian forest sector firms. Learning from other adopters has been found to be an important factor influencing technology adoption, which suggests that firms such as those involved in the IFIT program can act as an example to other firms in the forest sector (Van Biesebroeck, 2007).

Using interviews for data collection, allowed us to ask more in depth questions about the technology adoption processes and also provided us with up-to-date data about technology adoption within forest sector firms. Purposeful and convenience sampling was used to identify managers of Canadian forestry firms (Miles and Huberman, 1994). The sample of interviewees was limited to managers that were involved in the technology adoption process. The interviewees had to have a good understanding of why the technology was adopted and what the outcomes of the adoption were. Contact details for the interviewees were obtained through Natural Resources Canada. Both interviewees were from firms which obtained funding from the IFIT program. Their firms received the IFIT funding in order to introduce innovative technologies; this made them good candidates for the study.

The unit of analysis for the qualitative study was not just the firm itself, but it was bounded to the installation of a particular technology (Yin, 2009). The interviewees were therefore asked to focus on just one technology. A firm may have adopted more than one technology in the past, but for the purpose of these interviews the interviewees spoke about projects sponsored by the IFIT program.

Data was collected through semi-structured interviews, based on an interview protocol informed by the literature. Sequencing of questions was chronological; the interviews were divided into three sections pre-installation, installation and commissioning, and post-commissioning. The interviews were conducted over the telephone, as the interviewees were located on the west coast of Canada and it was not possible to meet with them in person. Names of the interviewees and firms were removed from the transcript, in order to protect the confidentiality of the interviewees pseudonyms were used.

The interviews were recorded using a digital recorder, there was a back-up copy of the interview in case one was distorted or accidentally deleted. Following the interviews, a contact summary form was written up, which captures some of the key points arising from each interview. The interviews were then transcribed and coded manually to identify common themes. Once the coding was completed, the main issues arising from each interview were identified in order to find the common themes that transcend the cases for a cross-case analysis (Creswell, 2013; Yin, 2009).

4.3 Qualitative Data Analysis Process

The data analysis process was iterative and involved going back and forth between the transcript, literature and code list, in order to identify the emergent themes. The interviews were coded manually, by coding lines or paragraphs to make sure the quotes did not lose their context. Coding was based on research questions, the conceptual framework, the literature, as well as the emergent themes in the data.

Some preliminary codes were based on the literature. One of the themes emphasized in the literature was the involvement of human capital in the adoption process. Many authors highlight the importance of employee training and skill upgrading (Voss, 1988; Co et al., 1998; Baldwin, 1999). The literature indicated that training would be influential in the success of advanced technology adoption; therefore led to the creation the code “Employee Training and Involvement.”

The code “High Performance Orientation,” also emerged from the literature. Voss (1988) emphasized that efficiency seeking did not occur only prior to the installation, but also in the post-commissioning phase. The installation of the technology motivates firms to improve their performance even further. The theme relates to the firm's high performance orientation AFTER the technology was adopted, NOT before.

After developing the preliminary list of codes, the interview transcript for interview #1 was used to conduct the first round of coding. The initial round of coding was grounded in the data (Charmaz, 2006). In Vivo codes were used, which means that the names for the descriptive codes came from the words of the interviewee (Creswell, 2013). When the interviewee said: *"That was probably one of the biggest challenges, just going through the negotiations of the power contract,"* the descriptive code attached to this quote was "contract negotiations were a challenge." The descriptive codes also suggested some important leads to pursue (Charmaz, 2006). For example, the "struggle to find qualified trades people" is not something that emerged from the literature. It is specific to the economic climate in Canada and is an important issue faced by Canadian forest sector firms.

After the second interview, a round of descriptive coding and inferential coding was conducted for interview #2, to see if any new themes emerge. The code list from interview #1 was used to see if these codes also fit with the second interview. Then interview #1 was re-coded based on the new codes from interview #2. The code list was then revised to include the new inferential codes. The frequency with which certain topics came up gave some indication of their importance to the topic of advanced technology adoption. For example, the themes of "Employee Training and Involvement" and "Employee Pride" reoccurred throughout the interviews.

The table of themes below is organized in chronological order to describe the step-by-step process of advanced technology adoption, starting from the decision to adopt a new technology to the outcomes of technology adoption. The table is based on the conceptual framework developed by Voss (1988), Figure 6 P.41 of this document. The themes have been divided into the three different phases of advanced technology adoption as suggested by Voss: pre-installation, installation and commissioning and post-commissioning. The themes reflect the factors that influence the success of advanced technology adoption. The description for each code and example quotes can be found in the revised code list (Appendix III, P.129).

Figure 7: Advanced Technology Adoption in the Forest Sector - Emergent Themes

<table>
<tr><th>Pre-installation</th><th>Installation and Commissioning</th><th>Post-Commissioning</th></tr>
<tr><td>Need Identification</td><td rowspan="2">Challenges: Regulations
Challenges: Financing
Challenges: Lack of qualified personnel</td><td rowspan="2">High Performance Orientation</td></tr>
<tr><td>Technology Background</td></tr>
<tr><td>Goals</td><td>Enablers: Financing
Enablers: Support from institutions</td><td>Improved Profile</td></tr>
<tr><td>Top management support</td><td>Diversification</td><td>Employee Pride</td></tr>
<tr><td>Employee Training and Involvement</td><td></td><td></td></tr>
</table>

Source: Developed based on interview data

One of the main goals of policy makers is identifying challenges faced by forestry firms in adopting advanced technology, in order to inform policy decisions. Identifying the challenges helps policy makers decide how to assist firms financially or with the permitting process. Therefore, it was important to include these themes in the analysis. A pattern code representing the challenges faced by forestry firms was created and split into “Regulations,” “Financing,” and “Lack of qualified personnel.” Based on the descriptive codes, it was found that these were the most common challenges for forestry firms when adopting new technology. When coding the second interview, the challenges of financing and a lack of qualified personnel also arose, therefore they were also included in the framework.

The following sections of the thesis provide an analysis of the findings. The survey data, in the form of graphs, and interviews are generally analysed in Section 5: Data Analysis. The results are explored in terms of implications and consequences for firm performance and government policy in Section 6. Tables with survey data are found in Appendix IV on P.132 for additional information.

5. Data Analysis

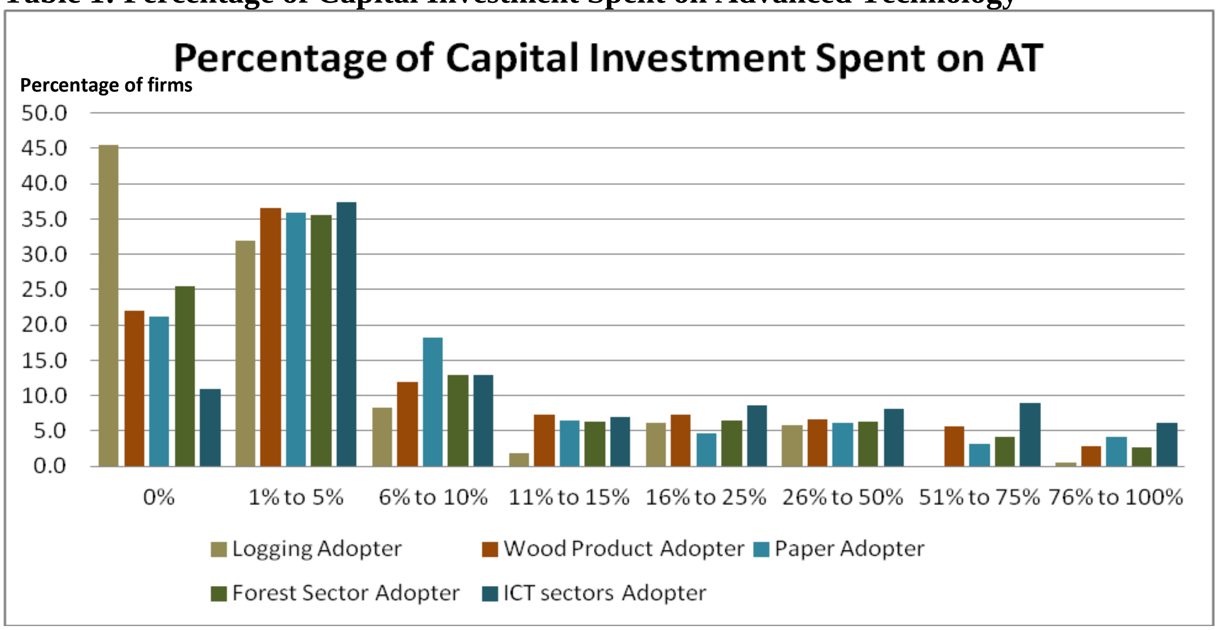
5.1 Survey Results

The following section presents the results of the *2007 Survey of Advanced Technology*. The results are displayed in tables developed with the use of the Template for Analysis. The template allowed for the comparison of two mutually exclusive domains, including Technology Adopters vs. Non-Adopters and Innovators vs. Non-Innovators. A comparison between the forest sector, ICT manufacturing sector and manufacturing sector average is made. The differences between the forest sector sub-sectors are also presented.

5.1.1 Capital Investment on Advanced Technology

The survey respondents were asked to specify what percentage of their total investment in capital and machinery, during the years 2005 to 2007, was spent on advanced technologies. They were provided with eight investment categories, the division of which can be seen in Table 1.

Table 1: Percentage of Capital Investment Spent on Advanced Technology



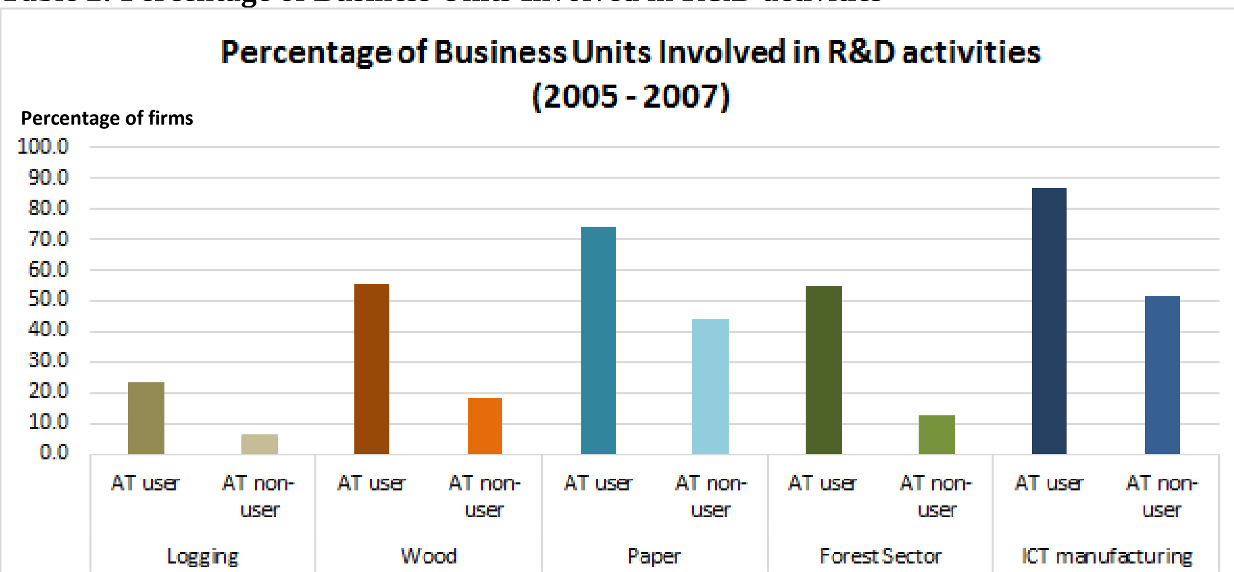
Source: Statistics Canada (2008)

A quarter of the forest sector technology adopters did not invest in advanced technology at all during this time period. This number is driven by the 45.5% of logging firms, which did not invest in advanced technology adoption. In contrast, only 10.9% of ICT manufacturers reported a 0% investment in AT. Very few plants spent more on advanced technologies than they did on conventional technology. Only 6.9% of forest sector technology users invested more than 50% of their capital spending into AT, while 16% of ICT manufacturers had more than a 50% investment in advanced technology. Over 30% of firms in the forest sector and in ICT manufacturing spend between 1-5% of their capital investment on ICT.

5.1.2 Research and Development

Research and Development (R&D) is considered to be an important input into innovation. The survey provides information on the percentage of firms involved in R&D activities and the type of R&D they are conducting.

Table 2: Percentage of Business Units Involved in R&D activities

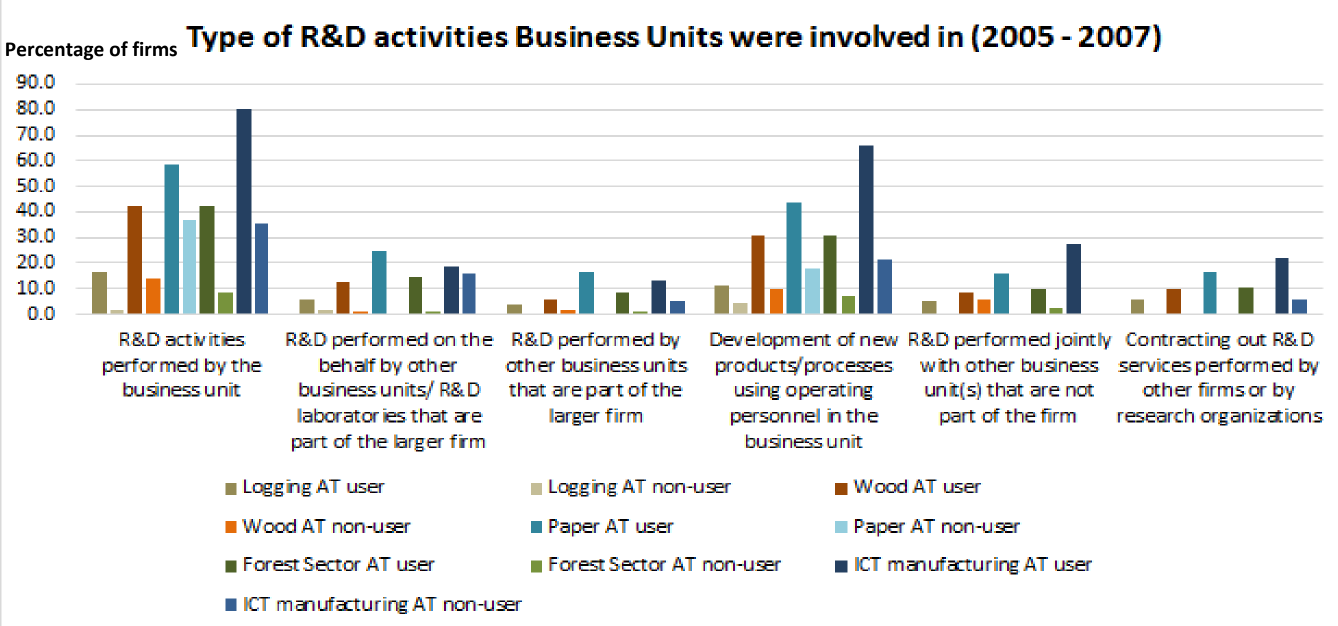


Source: Statistics Canada (2008)

According to the survey data, over half of forest sector AT users (58.4%) are involved in some type of R&D activity. However, there are great differences in R&D activity between the different forest sector sub-sectors. Almost three quarters of paper AT users are involved in R&D compared to 55% of wood AT users and only 23% of logging AT users. In comparison, 86.8% ICT AT users engage in R&D. The level of R&D activity for ICT AT non-users is also quite high, with over half of them being involved in R&D.

Across all sectors, there is a higher rate of involvement in R&D activity for AT users than there is for AT non-users.

Table 3: Type of R&D activities Business Units were involved in



Source: Statistics Canada (2008)

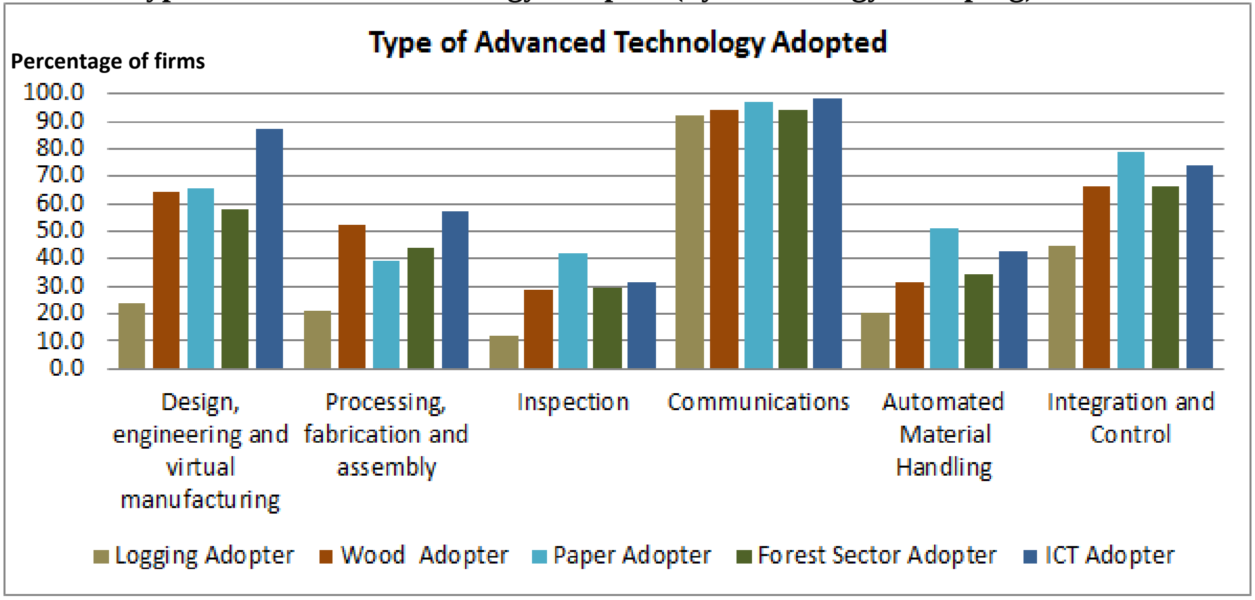
Firms can either conduct R&D in-house, in collaboration with others or contract it out to other firms or research organizations.

The survey results indicate that the preferred method of R&D is performing it in-house. About 80% of ICT AT users and 42.2% of forest sector AT users perform within their business unit. Firms which did not adopt advanced technologies are much less likely to perform R&D in-house. The second most popular method of R&D is developing new products and processes using operating personnel in the business unit. However, wood AT users and paper AT users engage in this type of R&D more frequently than logging firms. Very few firms in the forest sector perform joint R&D activities with other firms or contract out the R&D to others, only AT users are likely to do this.

5.1.3 Type and Amount of Technology Adopted

The survey addresses whether firms in the forest sector are using advanced technology and how many technologies they are using. The survey results, based on the three sub-sectors as well as the averages for the forest sector and ICT manufacturing sector are presented in Tables 4 and 5 below. A list of technology groupings used in the *2007 Survey of Advanced Technology* can be found in Appendix I on P.102.

Table 4: Type of Advanced Technology Adopted (by Technology Grouping)



Source: Statistics Canada (2008)

The graph represents the population of firms which have adopted advanced technologies. The figures denote the proportion of advanced technology users adopting a specific technology grouping, not the percentage of the entire forest sector population.

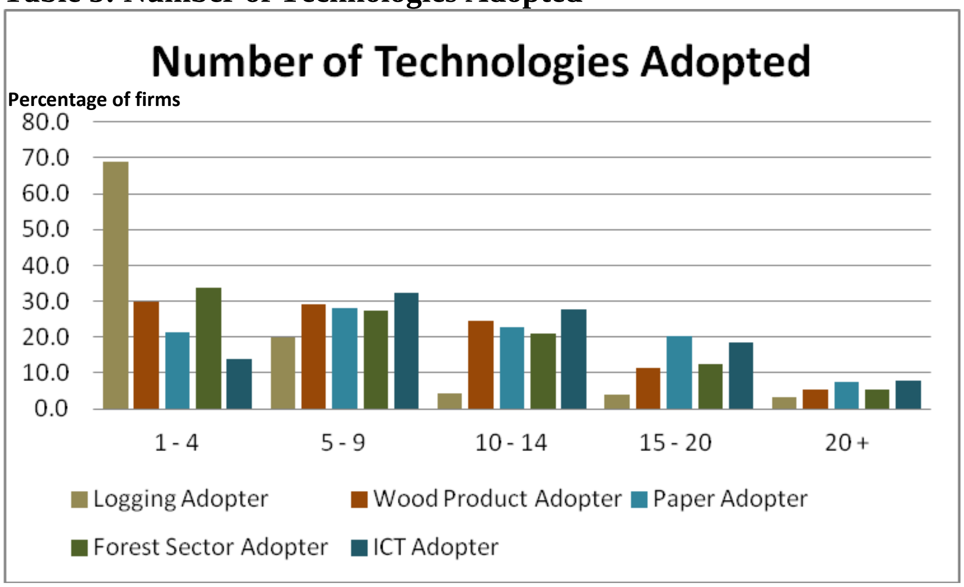
There is variation within the forest sector when it comes to the type of technology adopted. Paper and wood product firms adopt more technology than logging firms. The wood products sector is almost on par with the ICT sector in the adoption of processing, fabrication and assembly technology, with 52.5% of wood producers and 57% ICT manufacturers adopting these technologies.

ICT firms are much more likely to adopt design, engineering and virtual manufacturing (87.6% of AT adopters); and processing, fabrication and assembly technologies than forest sector firms (58.1%). However, when it comes to the adoption of inspection technologies, the forest sector (29.5% adopters) is not far behind the ICT manufacturing sector (31.2% adopters).

Paper sector firms tend to have the highest technology adoption rates out of all the forest sector sub-sectors; 41.9% of Paper AMT adopters have adopted inspection technologies. A greater percentage of firms in the paper sector adopted automated material handling and integration and control technologies than ICT firms.

Communication technologies are the most widely adopted advanced technologies, by 94.3% of forest sector adopters and 98.2% of ICT technology adopters. Other than communications technologies, the most widely adopted technology in the forest sector are computers used for control on the plant floor (a type of integration and control technology), adopted by 46.5% of forest sector technology users. Computer Aided Manufacturing (CAM) and Computer Aided Engineering (CAE), which is part of the design, engineering and virtual manufacturing technology group, was adopted by 43.2% of forest sector technology users.

Table 5: Number of Technologies Adopted



Source: Statistics Canada (2008)

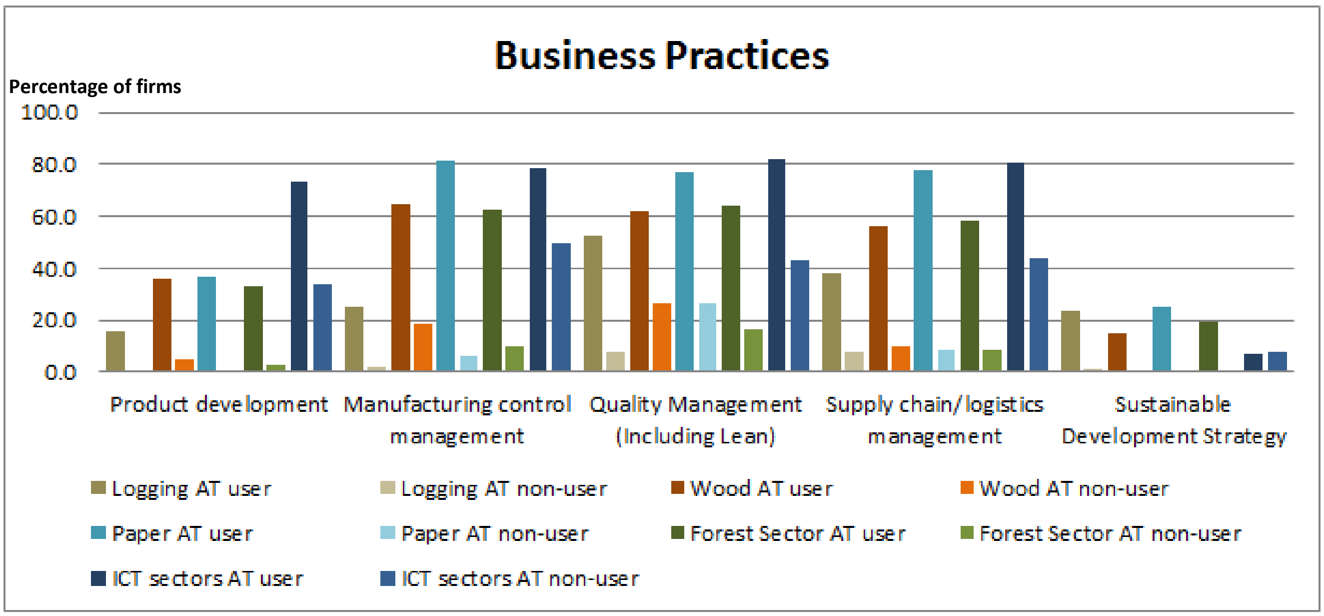
Overall, 66.2% of forest sector firms have adopted at least 5 of the technologies listed. Only 5.5% of forest sector technology adopters adopted 20 or more technologies, while 8% of ICT manufacturers adopted that amount. The average number of technologies adopted in the forest sector is 8.4, compared to an average of 10.8 advanced technologies adopted by the ICT sector. The three sub-sectors vary in technology adoption, logging firms adopt 4.5 AMTs on average, while wood product firms adopt 8.6 and paper firm adopt 10.3 advanced technologies.

The survey results indicate that paper and wood producers are not far behind ICT manufacturing in the incidence of technology adoption, however logging firms do not adopt as many advanced technologies.

5.1.4 Business Management Practices

Certain business practices and techniques are often associated with the use of advanced manufacturing technology. The graph below demonstrates the use of business practices by the forest sector sub-sectors and ICT manufacturing firms. The most commonly used business practices in the forest sector are quality management and manufacturing and control management. A Sustainable Development Strategy (or Environmental Stewardship Strategy) refers to "a strategy or plan to produce goods, function and grow while working within the means of their environment and resources and not deplete them to a point where they will sustain negative growth" (Statistics Canada, 2008b, P.17).

Table 6: Business Practices



Source: Statistics Canada (2008)

On average, ICT manufacturing AT users are more likely to use these business practices than forest sector AT users. However, paper AT users have a higher usage rate of manufacturing and control management practices than ICT and follow closely behind on the use of quality management and supply chain logistics. The most commonly adopted type of business practice for forest sector firms is continuous improvement, under the quality management category, which is implemented by 43.7% of forest sector AT users and 12.1% of non-users.

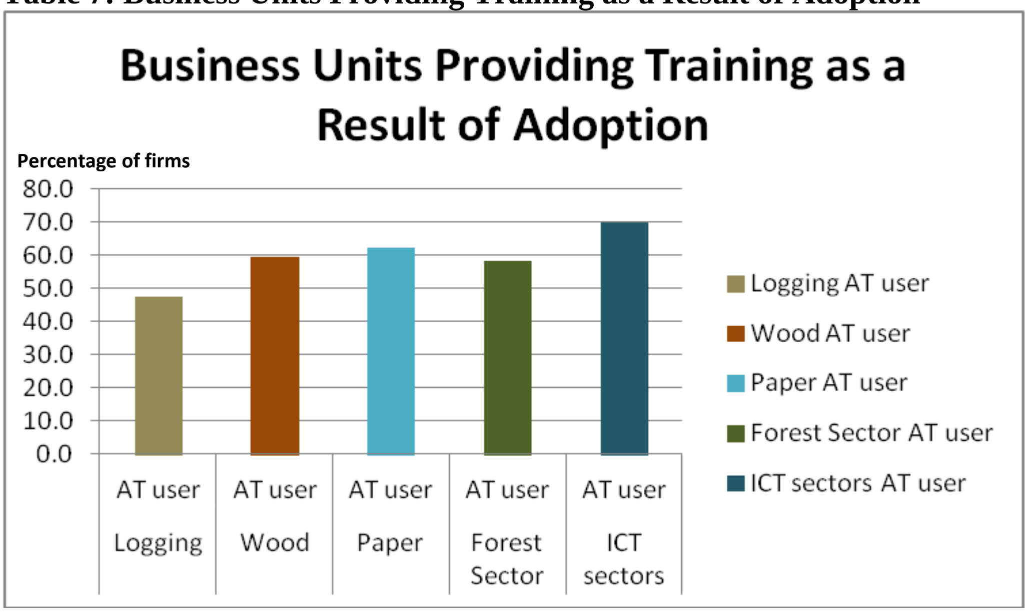
The survey findings indicate that advanced business practices are used much more frequently by AT users than by AT non-users across all sectors. ICT manufacturing firm that did not adopt advanced technology are more likely to use these business practices than forest sector AT non-users. For example, 58.6% of forest sector AT users use supply chain and logistics management practices, while only 8.6% of non-users do, and 80.7% of ICT AT users implement this business practice compared with 43.6% ICT AT non-users.

Forest sector firms are more likely to have a sustainable development strategy than ICT manufacturers. However, only technology adopters in the forest sector are likely to implement a sustainable development strategy, not non-adopters.

5.1.5 Training

The adoption of advanced technology will often result in a change in skill requirements for the firm's employees. If the current employees do not possess the skills required to operate and maintain the new technology, firms will have to compensate for the skill shortage by hiring new employees or training their existing ones.

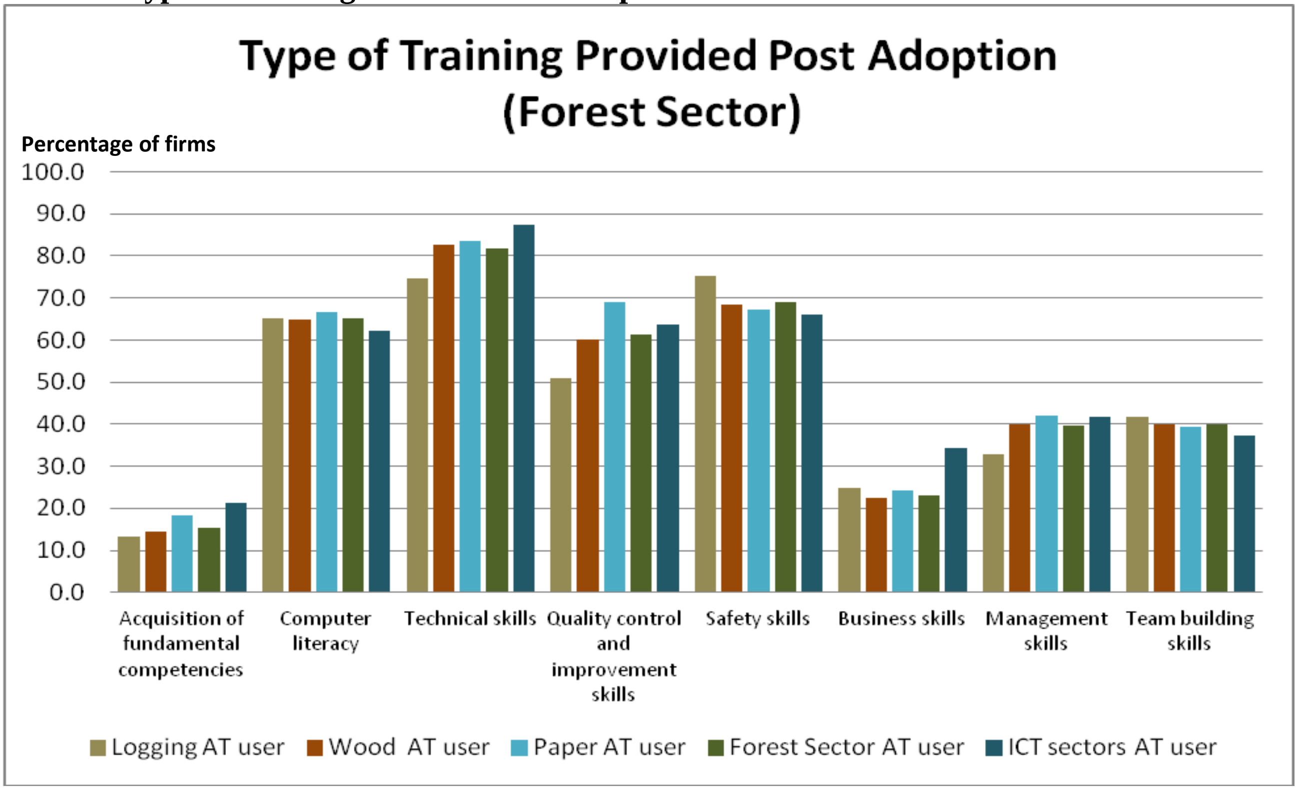
Table 7: Business Units Providing Training as a Result of Adoption



Source: Statistics Canada (2008)

Over half (58.2%) of the forest sector firms which adopted advanced technology provided training to their employees as a result of the adoption. Of those forest sector firms providing training post-adoption, firms in the paper sub-sector were the most likely to provide training (62.2%), while logging firms were the least likely (47.5%). ICT manufacturing firms rank highest in providing training as a result of adoption, with almost 70% of all ICT AT adopters providing training.

Table 8: Type of Training Provided Post Adoption



Source: Statistics Canada (2008)

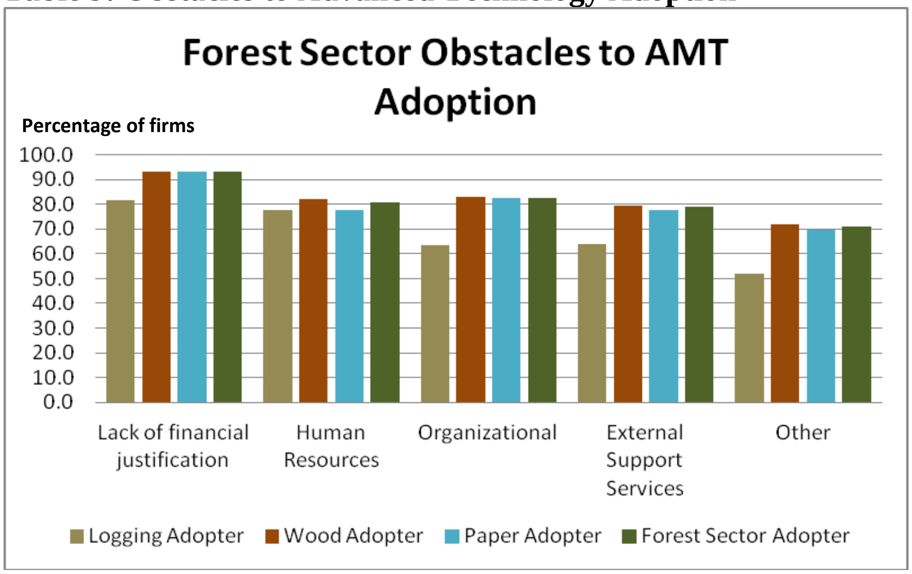
The most common type of training provided by firms in both the forest sector and ICT manufacturing as a result of technology adoption are technical skills. The majority of firms, 81.8% of forest sector adopters and 87.3% of ICT adopters, provide training in technical skills. Over half of forest sector firms also provide training in safety skills, quality control and improvement and computer literacy post adoption.

These types of skills may be more relevant to the adoption of advanced technology than business skills or management skills, as technical skills and safety are necessary for operating new machinery. Business skills appear to be more important for ICT firms than forest sector firms. On the other hand, forest sector firms, particularly those in logging, are more likely to provide training in safety skills and team building skills than ICT firms.

5.1.6 Obstacles to Adoption

Firms are likely to face a variety of challenges when adopting a new technology. These obstacles represent the factors that slowed down or caused problems to the firm during the process of advanced technology adoption. In this survey, the obstacles were divided into four categories: lack of financial justification, human resources, organizational and external support services. A detailed list of the obstacles can be found in Appendix IV, Table 10A on P.137.

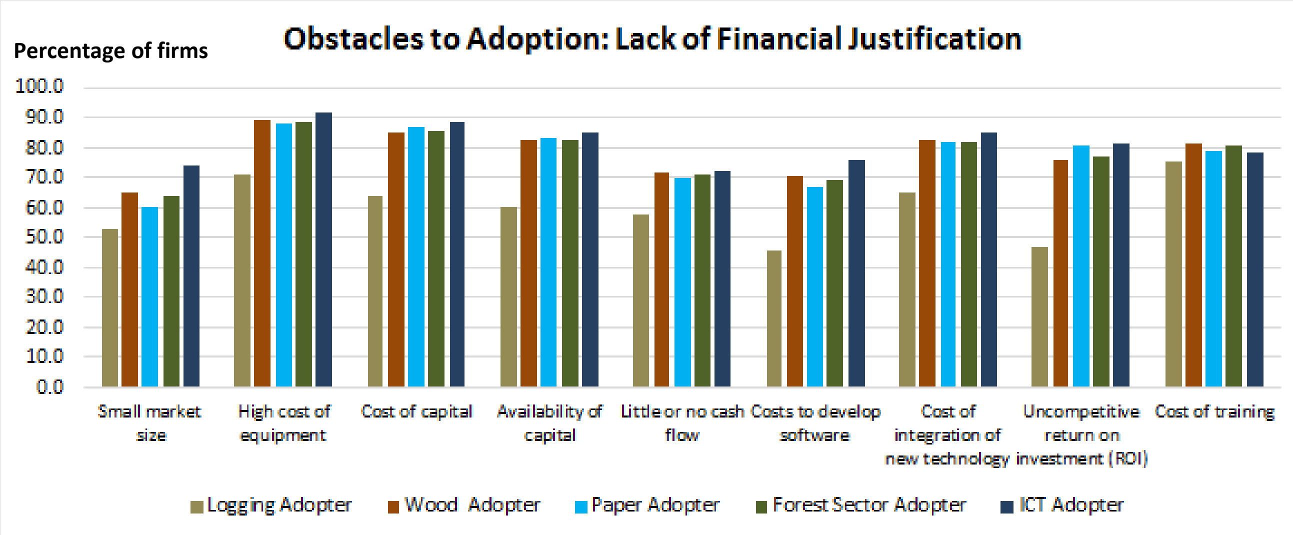
Table 9: Obstacles to Advanced Technology Adoption



Source: Statistics Canada (2008)

On average, forest sector firms reported to face 16 obstacles when adopting an advanced technology and 91.3% of forest sector firms face at least 5 obstacles to adoption. However, the majority of these were not of high importance. The most significant obstacle faced by forest sector firms was the lack of financial justification; 93% of forest sector firms reported to have encountered some type of financial constraints to advanced technology adoption. The breakdown of the "lack of financial justification" category is presented in Table 10 below. Human resource obstacles were not as widespread as financial ones, skill shortages posed a challenge to nearly 80% of forest sector firms, with 24.4% of technology adopters reporting this to be an obstacle of high importance. Organizational challenges were also faced by over 80% of forest sector firms, but ranked as lower importance than human resources. The majority of firms also dealt with obstacles related to external support services, nearly 70% of firms felt there was a lack of technical support services and 64% reported a lack of government support for training.

Table 10: Obstacles to Advanced Technology Adoption: Lack of Financial Justification



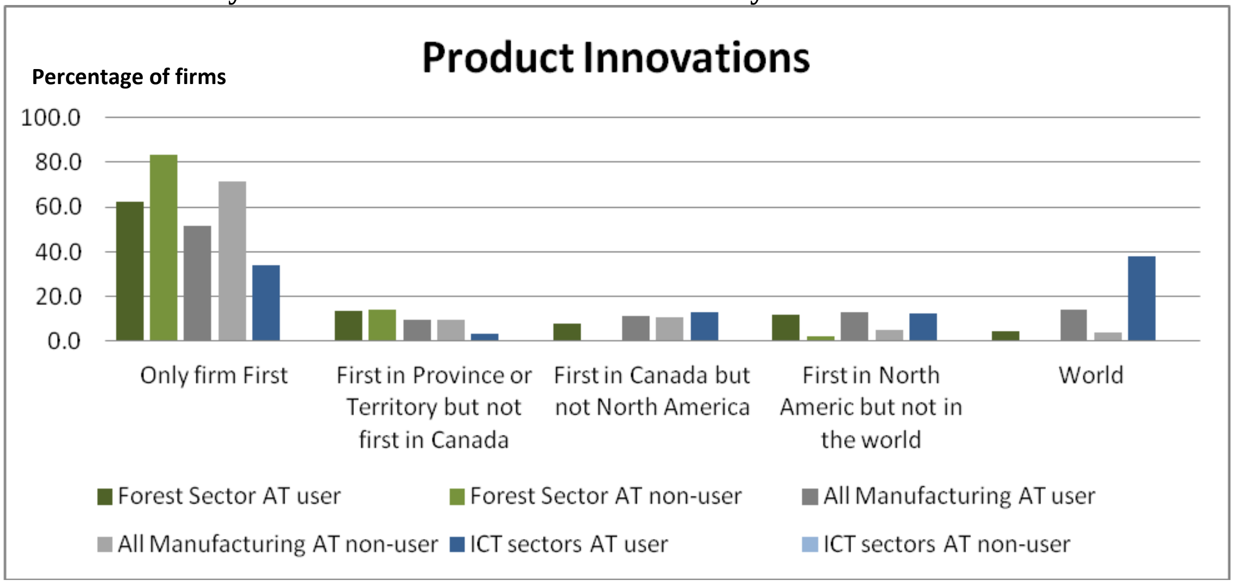
Source: Statistics Canada (2008)

According to the survey results, the greatest obstacle in adopting advanced technology is the high cost of equipment, faced by 88.8% of forest sector technology adopters. Over 90% of ICT manufacturing firms also struggled with this issue. Not all of the forest sector sub-sectors report the same obstacles. Logging sector adopters are the least likely to report financial obstacles to technology adoption. Small market size and costs to develop software are more of an obstacle to wood producers than paper manufacturers, on the other hand, paper technology adopters are more likely to struggle with the cost of integration of new technology than the other sub-sectors. ICT manufacturers are more likely to report obstacles to adoption relating to financial justification than any of the forest sector sub-sectors, except when it comes to the cost of training, which is more often an obstacle for forest sector firms than ICT firms.

5.1.7 Novelty of Product and Process Innovations

According to the OECD (2005) guidelines, the minimum requirement for an innovation is "new to firm." In the survey, an innovator is any firm that introduced an innovation during the period under review; the innovation did not have to be a commercial success (OECD, 2005). "A product innovation is the market introduction of a significantly improved good or service. A process innovation is the implementation of a new or significantly improved production process, distribution method or support activity for your good or services" (Statistics Canada, 2008b, P.21). On average, forest sector AMT adopters introduce more process innovations (48.0%) than product innovations (40.8%). There are significant differences between technology adopters and non-adopters in the amount and novelty of innovations introduced across all manufacturing sectors. Forest sector tech adopters introduce fewer world first innovations than the ICT sector[1].

Table 11: Novelty of Product Innovations introduced by Business Unit

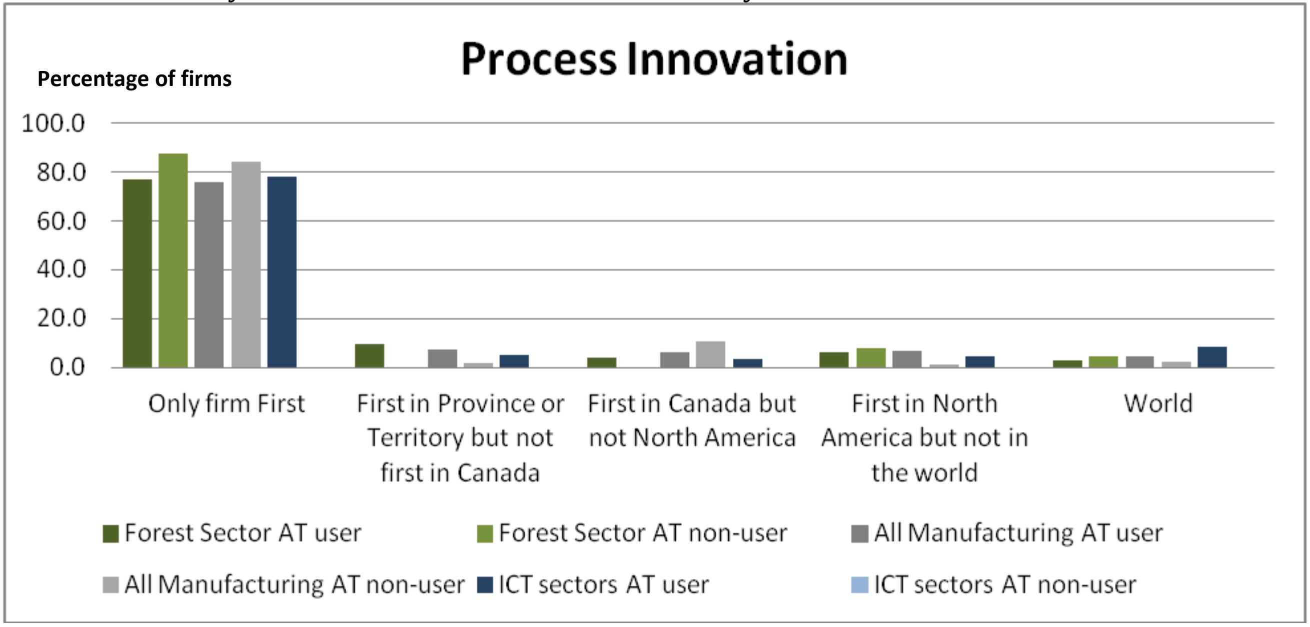


Source: Statistics Canada (2008)
Statistically Significant: Forest Sector: Only Firm First, First in Canada, First in North America, World First; Manufacturing: Only Firm First, First in North America, World First

The majority (80.0%) of ICT advanced tech users introduced product innovations, 37.7% of these firms introduced world first product innovations. Fewer ICT manufacturers, 52.2%, introduced significantly new or improved processes. The forest sector does not lag far behind on the introduction of innovations. Forest sector tech adopters are slightly more focused on introducing process innovations than product innovations. However, the percentage of world first product innovations (4.4%) and world first process innovations (3.0%) introduced by forest sector firms does not differ much.

[1] Data on the novelty of innovations by ICT manufacturing AT non-users was not available

Table 12: Novelty of Process Innovations introduced by Business Unit



Source: Statistics Canada (2008)

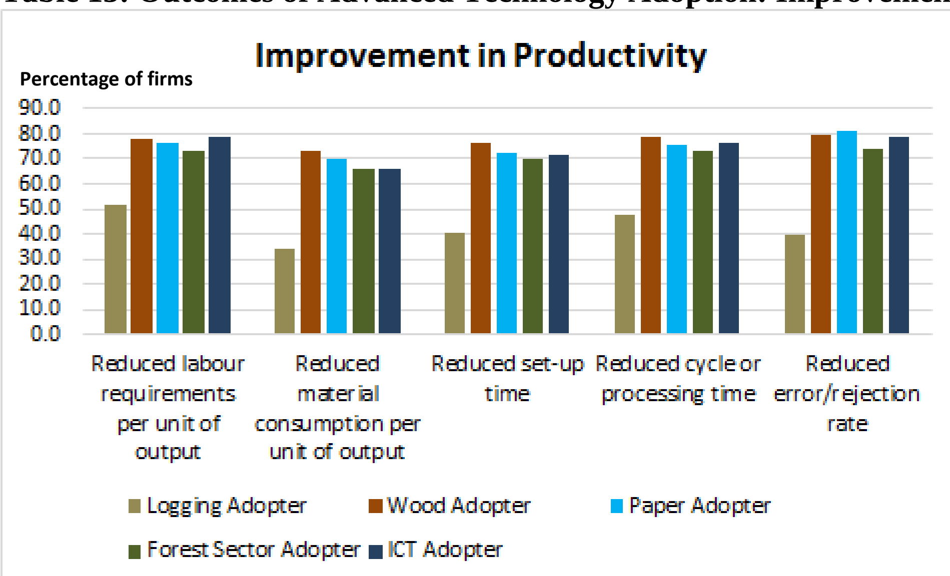
Statistically Significant: Forest Sector: First in Province, First in Canada; Manufacturing: Only Firm First, First in Province, First in North America, World First;

Although the graph may appear to show differences between AT users and non-users, not all of the data presented in this graph is statistically significant. This demonstrates the importance and value of using the Templates for Analysis – only by looking at the template data are we able to understand what the data represents. Forest sector AT adopters do in fact introduce more first in province/territory process innovations and first in Canada process innovations. Surprisingly, the difference between forest sector AT users and non-users in developing first in North America and World First innovations is not significant. Non-adopters do not introduce more World First process innovations than adopters. If you consider the statistically significant data for the manufacturing sector overall, AT adopters do introduce more First in North America and World First process innovations than AT non-adopters.

5.1.8 Outcomes of Advanced Technology Adoption

The surveyed firms were asked to report on the results of the technology adoption and to rate the impacts of the effects they experienced from the advanced technologies they adopted (Statistics Canada, 2008b). The results include improvement in productivity, product improvement, business unit organization changes, business unit efficiencies, market performance and reduction of environmental impacts. The tables below look at some of these in more detail. A breakdown of the impacts is presented in Table 16A in Appendix IV, P.142.

Table 13: Outcomes of Advanced Technology Adoption: Improvement in Productivity

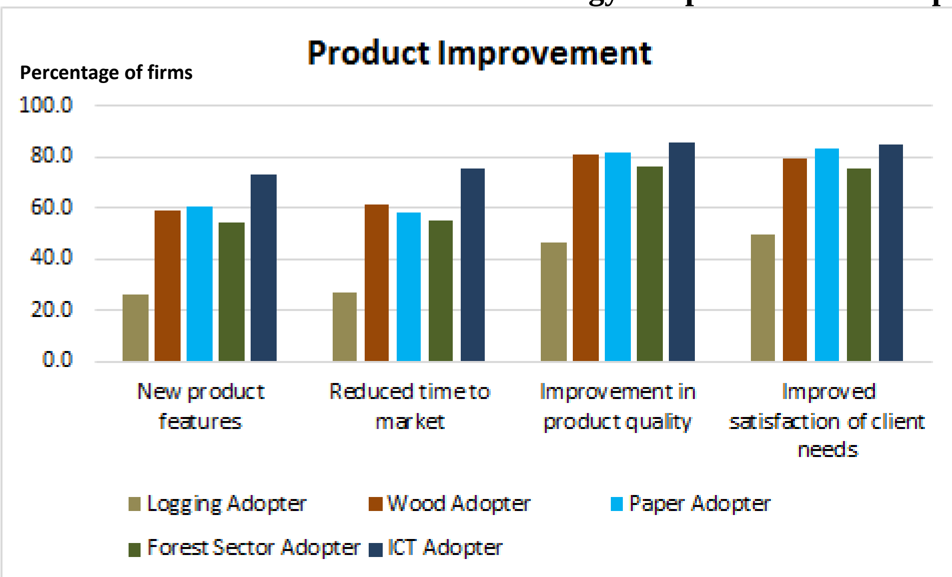


Source: Statistics Canada (2008)

The majority of forest sector firms reported an improvement in productivity as an outcome of advanced technology adoption. The most commonly experienced improvement in productivity was a reduction in error/rejection rate, reported by 73.7% of forest sector firms. The figures for the paper and wood tech adopters were significantly higher than those for the logging sub-sector, where only about 40% of firms experienced a reduction in error/rejection rate. Reduced labour requirements was the second most commonly experienced improvement in productivity, with 73.3% of forest sector firms reporting a reduction post adoption, followed by reduced cycle or processing time reported by 73.1%. ICT adopters were more likely to experience reduced labour requirements per unit of output after adopting advanced technology than forest sector firms, however on average the forest sector achieved similar results when it comes to productivity improvements.

The adoption of advanced technology also led to business unit organizational changes within forest sector firms; 69.6% of forest sector adopters reported increased flexibility, customization and/or specialization as a result of adopting technology and 74% experienced an increase in skill requirements.

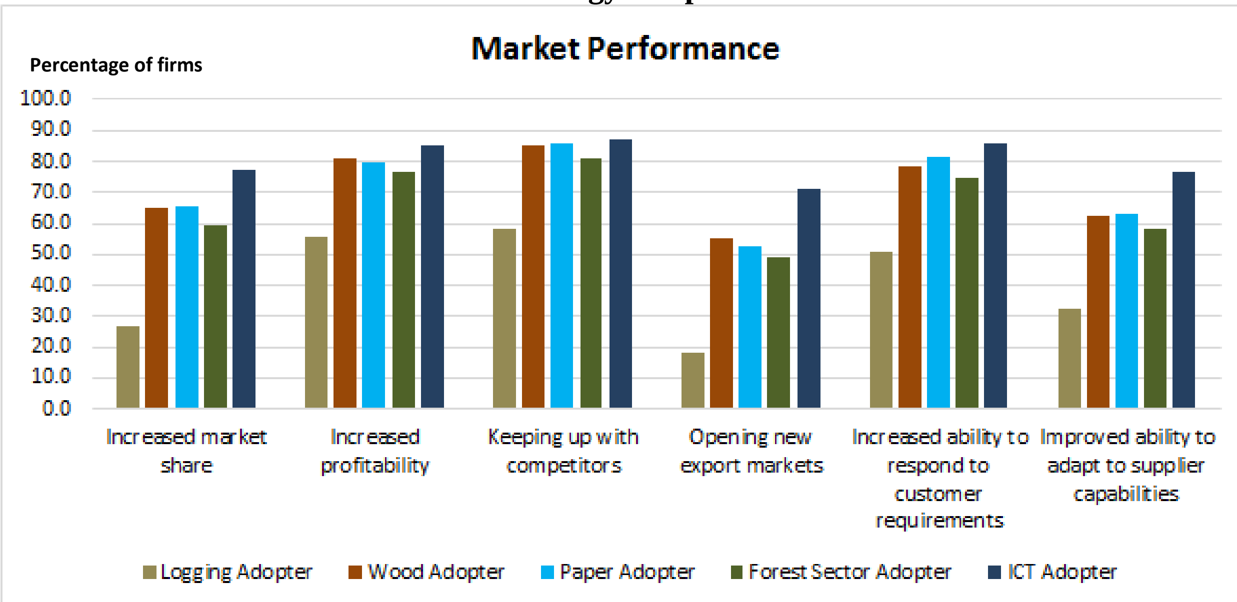
Table 14: Outcomes of Advanced Technology Adoption: Product Improvement



Source: Statistics Canada (2008)

When it comes to product improvements, ICT manufacturers are more likely (73.5%) to introduce new product features and reduce the time to market after adopting an advanced technology. However, more than three quarters of forest sector adopters experienced improvements in product quality and improved satisfaction of client needs. As with the previous table, logging firms were less likely to report product improvements than wood or paper adopters, indicating that wood and paper adopters are more likely to benefit from advanced technology than logging firms.

Table 15: Outcomes of Advanced Technology Adoption: Market Performance



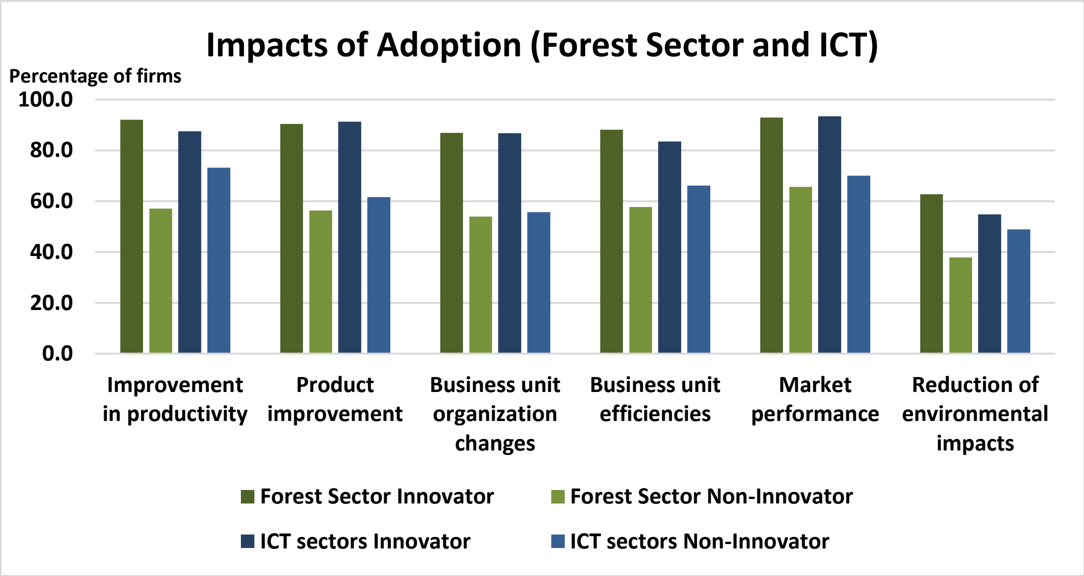
Source: Statistics Canada (2008)

Improved market performance is crucial to firms if they want to remain competitive on both local and global markets. Over 80% of forest sector adopters reported an improved ability to keep up with competitors and 76.8% have increased their profitability post adoption. However, less than 60% have experienced an increase in market share.

The majority (79.4%) of forest sector firms, particularly those in the paper sub-sector, have increased their ability to respond to customer requirements as a result of adopting advanced technology. Fewer forest sector adopters (58.1%) have experienced an improvement in their ability to adapt to supplier capabilities.

Forest sector firms are significantly less likely (48.9%) to open new export markets than ICT manufacturers (71.3%). In fact, less than 19% of logging firms reported to open new export markets after adopting advanced technology.

Table 16: Outcomes of Advanced Technology Adoption: Forest Sector and ICT Manufacturing Innovators vs. Non-Innovators

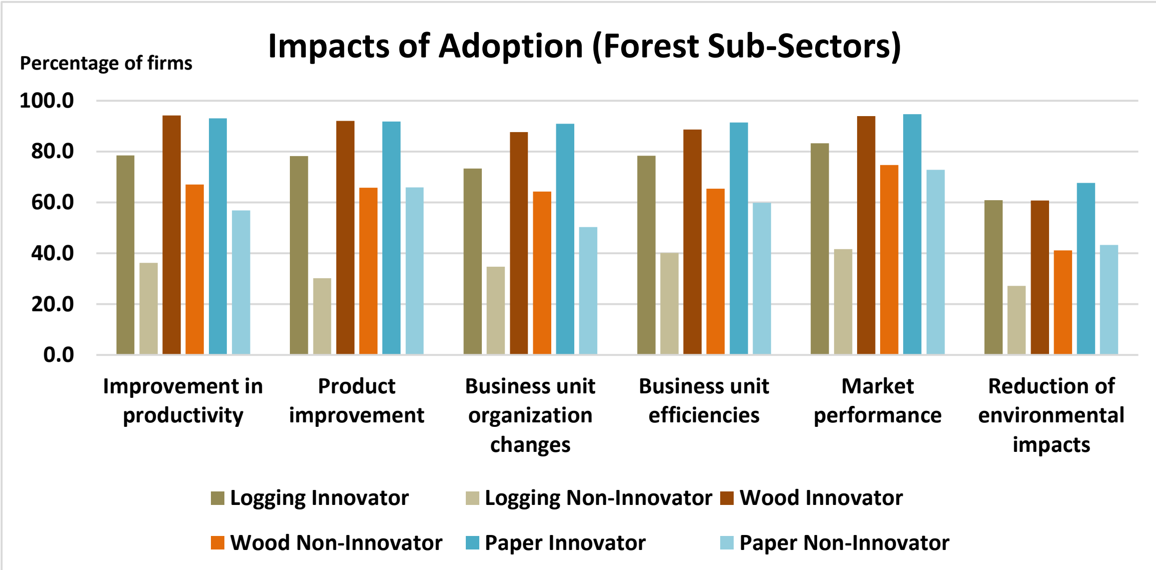


Source: Statistics Canada (2008)

Since the survey does not provide any data on performance for non-adopters, we are comparing innovators and non-innovators, all of which are also technology adopters, in order to determine the impact of innovation on firm performance. Innovators are firms which introduced a product, process, organizational or marketing innovation during the years 2005-2007.

Advanced technology adoption appears to have a positive impact on the majority of forest sector firms. In terms of productivity, business unit efficiencies and reduction of environmental impacts, an improvement is reported by more forest sector adopters, who also innovate, than ICT innovators. It is apparent that firms which adopt technology, but do not innovate, are less likely to report positive outcomes than innovative firms. There is a compounding effect between advanced technology adoption and innovation, which leads to a greater likelihood of experiencing positive impacts post adoption. According to the survey data, about 92% of forest sector innovators reported to experience an improvement in productivity after adopting technology (a greater increase than for ICT innovators), while only 57% of non-innovating forest sector firms reported improvements in productivity. Forest sector innovators were also more likely to experience a reduction in environmental impact post-adoption.

Table 17: Outcomes of Advanced Technology Adoption: Forest Sector Sub-Sectors Innovators vs. Non-Innovators



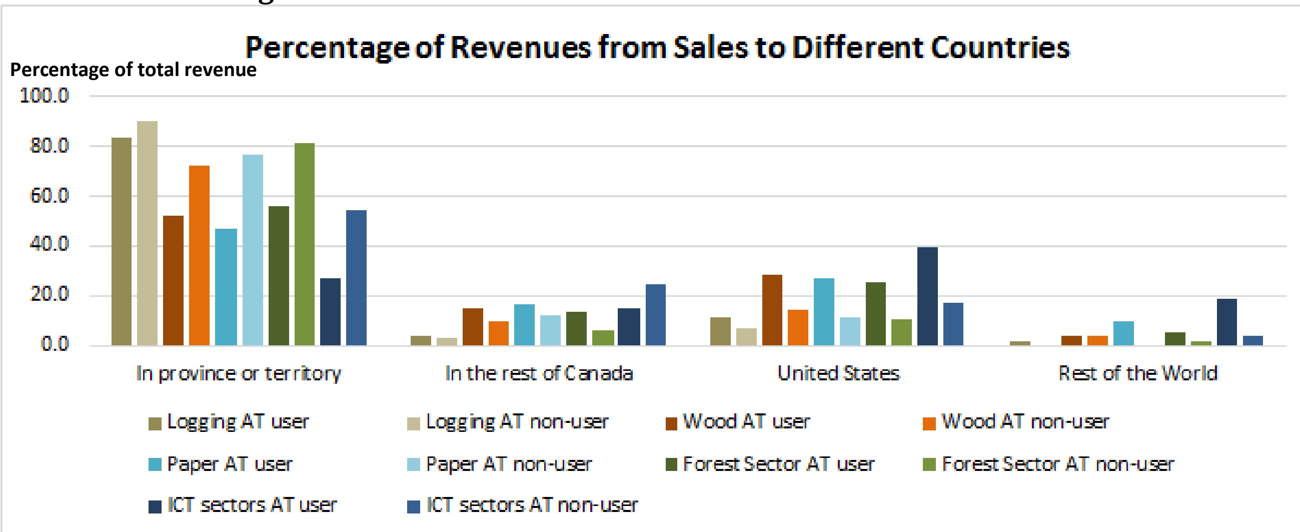
Source: Statistics Canada (2008)

By taking a closer look at the forest sector sub-sector we can identify clear differences in the outcomes of adoption. Fewer logging firms realize benefits from technology adoption than firms in the other sub-sectors. Over 90% of wood products and paper firms, which also innovate, experience an improvement in productivity, while only 78% of logging innovators do. The differences between non-innovators who adopt a technology are even greater. For example, when it comes to product improvement, nearly 80% of logging innovators experience improvements post-adoption, while only about 30% of non-innovators do. Out of all the sub-sectors, the paper product firms, which engage in innovation, are the most likely to benefit from technology adoption and improve their performance, except in productivity, where wood innovators perform slightly better.

5.1.9 Exports

In recent years, the forest sector's contribution to Canada's trade balance has dropped significantly, from $35 billion in 2004 to $16.6 billion in 2010. Since Canada is one of the world's largest forest product exporters, looking at the difference in percentage of revenue from sales to different countries between advanced technology users and non-users could provide some insight into this problem.

Table 18: Percentage of Revenue from Sales to Different Countries



Source: Statistics Canada (2008)

According to the survey findings, AT-non-users are a lot less likely to generate sales outside of their province or territory. Overall, in the forest sector, over 80% of the non-users sales revenue comes from within the province. On the other hand, for AT users it is just 56.1% sold within the province; 13.7% of Forest Sector AT users' revenue comes from sales to the rest of Canada and over 25% from sales to the US. In contrast, almost 40% of ICT AT users' revenue comes from sales to the US. ICT manufacturing firms are most likely to sell their products outside of North America; 18.9% to the Rest of the World, with 8.7% of that being to Europe.

Out of all the forest sector sub-sub sectors, logging firms, particularly the AT non-users, are least likely to sell their products outside of the province. Only 11% of their revenue comes from sales to the US. Sales to the US account for over 25% of revenue for paper and wood product AT users, for non-users it is less than 15%. Sales to Europe for the forest sector on average represent less than 2% of the total revenue (detailed figures can be found in Appendix IV, Table 19A, P.144).

5.2 Qualitative Study Results

The interviews conducted with two forest sector firm managers were used to supplement the data from the *2007 Survey of Advanced Technology* and allowed us to expand on the questions addressed in the survey. The interviews provide us with information that is specific to the forest sector and its sub-sectors, as the questions were tailored to the industry, rather than the manufacturing sector as a whole. This resulted in the generation of new themes, which were not observed in the literature or survey data. The interviews enabled us to study the sector within the current economic climate and evaluate the firms' experience with the IFIT program.

The case comparison in Table 19 below summarizes the two interviews and presents the differences and similarities between them.

Table 19: Cross-Case Comparison

	Firm X	Firm Y
Location	British Columbia	Alberta
Type of firm	Sawmill	Pulp mill
Sector	Wood	Paper
Technology Adopted	Organic Rankine Cycle Turbo generator	Methanol distillation
Goal	To turn heat waste into green energy	To produce commercial grade methanol (bio-fuel)
Supplier Location	Italy	Vancouver, British Columbia
Innovation Novelty	First in North America	World First
Funding Sources	IFIT and BC hydro	IFIT and Alberta government
Employee Training	Employees taken to Italy to see the technology in use and also received on-site training	Training conducted in phases on-site for all employees handling the technology
Challenges faced	Need for external financing Regulations Lack of skilled labour	Need for external financing Lack of skilled labour (Delay in engineering)
Enablers	Financial support from IFIT and BC hydro Administrative support from IFIT Employee involvement	Financial support from IFIT and Alberta government Administrative support from IFIT Employee involvement
Influence of Economic Climate	Increasing energy costs, firm had to adapt to this	Fall in demand for paper products, firm has to diversify
Collaboration w/ Research Institutions	Not for this project	FPInnovations
Diversification	Creation of a new company New revenue stream for the firm	New revenue stream for the firm
Outcomes	Surpassed goals in 3 days Improved efficiency Improved industry profile Employees take pride in technology	Have not yet achieved their goals, expect to by the end of the year
Future Perspectives	Producing their own power to combat high energy costs	Supply local businesses with commercial grade methanol

Source: Interview data

The interview findings support as well as expand on the survey results. The survey does not address the question of why firms choose to adopt a particular technology or the goals of the adoption. The interview data indicates that these forest sector firms are engaged in a process of continuous improvement which was part of their corporate strategy. The firms were constantly seeking ways to develop their business practices by improving efficiency and performance. The goal of these firms was to become more sustainable, diversifying into new areas by producing green energy. Waste reduction was an important factor in their adoption decision. The decision was also influenced by the economic climate. The sawmill was facing increasing energy costs and had to find a long term solution for this problem, while the pulp mill was experiencing a decrease in demand for paper products and needed to diversify its production.

During the adoption process, the influence of top management played an important role in guiding and motivating employees. They emphasized the importance of the transformation to their employees and provided training for them. However, a lack of skilled labour was one of the major obstacles faced by the adopting firms. In one case, a shortage of engineers caused a delay in the adoption of the technology. This was found to be a common problem in the region, as many engineers have left the forest sector to find employment in the oil industry. The firms also faced regulatory challenges. The adoption process was made more complicated by the bureaucracy and regulations in place, which are specific to each forestry sub-sector. In accordance with the survey findings, the qualitative study indicates that financial justification is an obstacle to adoption. Both interviewees stated that without the support of IFIT and the provincial governments, it would have been difficult for them to finance the new technology and they may not have been able to proceed with the technology adoption without it.

The outcomes of adoption varied by firm. The advanced technology adopted by the sawmill improved the firm’s efficiency within the production process and the firm was able to surpass its goals within three days. On the other hand, seven months after the technology was installed, the pulp mill was not seeing the results, in terms of the volume and quality of methanol produced, that it expected. The technology adoption did however result in other positive outcomes, which are more difficult to quantify and were not addressed in the survey. Namely, in the sawmill, the technology increased employee motivation and pride. The employees were proud to be using a new technology which improved the firm’s productivity and environmental sustainability. In addition to this, other firms are now looking to this firm as an example of a successful technology adoption and implementation, which has improved the firm's profile within the industry. The sawmill is perceived to be a technology leader providing both social benefits and value added to the economy by turning waste into green energy.

A detailed discussion of the qualitative results follows in Section 6.2 Qualitative Study Findings on P.87 of this report.

6. Discussion

6.1 Advanced Technology Survey Findings

6.1.1 Investment in Technology

The level of investment in advanced technology as a percentage of total investment in machinery and equipment provides a measure of the intensity of advanced technology use. This measure is an indication of "the relative importance of advanced technology to more conventional technology" (Sabourin and Beckstead, 1999, P. 38).

According to the survey data, the level of advanced technology investment as a percentage of total capital expenditure is relatively low. Nearly half of all logging firms do not invest in advanced technology at all, indicating that firms in this sector are more likely to invest in conventional technology than advanced technology (Sabourin and Beckstead, 1999). This may be due to the greater risks involved in adopting technology that has not yet been proven on the market; the logging sector is generally risk-adverse. Out of all the forest sector sub-sectors, paper manufacturers are more likely to invest a greater proportion of their capital investment into advanced technology. If transformation of the forest sector depends on the adoption of advanced technology, firms will have to begin to shift their investments towards advanced technology rather than conventional technology. Programs such as IFIT, which was renewed in February 2014, can help firms finance advanced technology, if they are unable to finance the project themselves (Natural Resources Canada, 2014).

6.1.2 R&D

The survey findings contradict the literature about LMT firms, which suggests that these firms do not have the internal capabilities to conduct R&D (Heidenreich, 2009, Spithoven et al., 2010). According to the data, the majority of wood product and paper firms are involved in some type of R&D. Advanced technology users are much more likely to engage in R&D activities than non-users. Out of the forest sector firms which are involved in R&D, most of them conduct R&D in-house rather than outsourcing it to other firms.

Nearly three quarters of paper technology adopters conduct R&D, about 60% of these firms conduct R&D within their firm and only 10% outsource their R&D. This suggests that forest sector firms, particularly those in the paper industry, are not as dependent on external sources of knowledge as they are perceived to be. LMT firms are believed to rely predominantly on external sources, consultants or collaborate research centres for R&D (Santamaria et al., 2009; Spithoven et al., 2010). However, the survey findings indicate that forest sector firms are mostly likely to perform their R&D activities within the business unit. They are less likely than ICT firms to perform joint R&D projects or contract R&D to other firms or research organizations. Considering that forest sector firms have access to FPInnovations, the world's largest public-private partnership in forest research and development, it is surprising that less than 30% of forest sector technology adopters engage in R&D through research institutions (Benoit, 2008). There is a link between advanced technology adoption and the outsourcing of R&D, as forest sector firms which do not use any advanced technologies also did not outsource their R&D, only technology adopters did. Forest sector firms could benefit from collaborating with FPInnovations, especially in the area of advanced technology adoption.

Although the majority of forest sector firms are involved in R&D, their share of R&D in relation to their turnover may be low, which is why they are classified as low-tech. This is not only a problem within the forest sector, but in Canada overall, as we lag behind the OECD average on investment in R&D. R&D is considered to be a risky activity, therefore many small firms, such as those in the logging sector, may not be willing to make the investment. Outsourcing R&D or collaborating with other firms could be beneficial to them.

6.1.3 Type of Advanced Technology Adopted

When it comes to incidence and intensity of technology, paper and wood product firms adopt more advanced technology than logging firms. The survey results indicate that there is variation within the forest sector when it comes to the type of technology adopted. Paper and wood product firms adopt more technology than logging firms, particularly design and processing technologies. When comparing the forest sector to the ICT sector, ICT firms are much more likely to adopt design, engineering and virtual manufacturing; and processing, fabrication and assembly technologies than forest sector firms as a whole. However, the forest sector is not far behind ICT sector in adoption of inspection and communications technologies.

Analysis at the individual sub-sector level reveals that the wood products sector is on par with the ICT sector in the adoption of processing, fabrication and assembly technology. In addition, a greater percentage of firms in the paper sector adopt inspection, automated material handling and integration and control technologies than ICT firms. Paper and wood are not far behind ICT, but logging firms do not adopt as many advanced technologies.

The data only provide information about the technology in use for more than two years or less than two years, but with the Template for Analysis, we are not able to discern the effect of the length of time used on productivity. Technological change is cumulative, which means past knowledge and adoption will influence future technology adoptions (Cohen and Levinthal, 1990). If these firms have adopted many similar technologies in the past, the adoption is more likely to be successful, because of the knowledge they have accumulated over time.

However, there is no inherent value in the technology itself (Chesbrough, 2006). There is no evidence to suggest that the more technologies a firm adopts, the greater the improvement in productivity will be. What is more important, is the firm's ability to assimilate the technology into its production process. This is why it is necessary for firms to develop strong absorptive capacities. The firm must have employees with adequate skills in place as well as adapt its organizational structure and culture to the new technology, otherwise it is unlikely to reap the full benefits of the technology adoption. We cannot understand technological change within the forest sector based on the adoption rates alone, there are many other factors influencing the process and they will be discussed in the upcoming sections.

6.1.4 Business Management Practices

The business practices addressed in the survey include: product development; manufacturing and control management; quality management (including lean); supply chain/logistics and sustainable development strategy (Appendix I, P.117). Advanced technology users across all sectors are more likely to use advanced business practices than non-users. Previous studies have found that advanced business practices can provide more successful plants with a comparative advantage (Gordon and Wiseman, 1995). These business management practices may be a necessary component to successfully managing the advanced technology. However, it is not clear from the survey data whether the firms were using these business management practices before they adopted the technology, or found it necessary to use these practices as a result of adopting advanced technology. This question could be addressed in future interviews with technology adopters. The two firms interviewed introduced Canada or World-first innovations and indicated that they are also involved in advanced business practices, particularly continuous improvement.

There are significant differences between technology adopters and non-adopters even within the forest sector when it comes to the use of advanced business practices. The aggregate figure for the forest sector does not provide an accurate representation of the sub-sectors. The paper sector is much more likely to adopt advanced business practices than the logging sector. The wood products sector also lags behind paper on most business practices. In addition to this, for manufacturing control management, advanced tech users in the paper sub-sector are more likely to use these practices than advanced tech users in the ICT sector.

When looking at the group of firms that have not adopted technology, AT non-users in the forest sector are less likely to use any business management practices than AT non-users from other manufacturing sectors, and they lag behind the manufacturing average. There is also a difference between adopters and innovators. Innovators across all manufacturing sectors are more likely to utilize advanced business practices than non-innovators. However, when comparing adopters and non-adopters it appears that there is a stronger link between AT use and the use of advanced business practices than innovation and the use of advanced business practices. Non-innovators are more likely to use advanced business practices than non-adopters. These results highlight the importance of advanced technology adoption when it comes to using advanced business practices. Further research is required to understand why AT adopters in the forest sector are more likely to utilize advanced business practices and the effects it has on firm performance. If advanced practices do in fact provide firms with a comparative advantage, and advanced technology adoption is correlated with the use of advanced business practices, it would be beneficial for firms to adopt advanced technologies as it could improve their competitiveness (Gordon and Wiseman, 1995).

Although the forest sector lags behind ICT on most business management practices, forest sector technology adopters are leaders in sustainable development strategy; 19% of forest sector AT adopters have a sustainable development strategy (sub-sector level: 25% of paper firms, 15% of wood producers and 24% of logging firms) compared with 7.4% of ICT manufacturers. This finding is in accordance with the Canadian government's goal to be a leader in sustainable forestry and position the sector as a green industry (Mockler and Robichaud, 2011). Sustainable forest management and forest products are some of the sectors main competitive advantages. These firms develop products in a more sustainable way, they continue to produce and grow within the means of their environment and resources. However, advanced technology non-adopters in the forest sector sub-sectors are unlikely to use a Sustainable Development Strategy, which could be a cause for concern. If these firms are to remain competitive as well sustainable, they will need to adopt Sustainable Development Strategies. For ICT manufacturing firms, the disparity between adopters and non-adopters in implementing a sustainable development strategy is not as large. Based on the data, it appears that advanced technology use and Sustainable Development Strategy in the forest sector are related. Further research should look into why non-adopters in the forest sector are not implementing Sustainable Development Strategies, as these firms could hinder Canada's goal to become a leader in sustainable forestry and innovation.

6.1.5 Training

Based on the literature and previous research on technology adoption, we expect there will be a positive relationship between investments in training and technology and firm performance, because the adoption of advanced technology leads to changes in skill requirements. Training will be necessary if a firm is to reap the full benefits of the technology, as employees require technical know-how to operate the new technology (Johnson et al., 1996, Sabourin, 2001). Highly skilled workers are instrumental to the innovation process (Baldwin, 1999). Firms investing in training as a part of technology adoption are expected to realize greater productivity gains than those that do not (Boothby et al., 2010).

Forest sector firms lag behind ICT in providing training post technology adoption (Table 8A, Appendix IV P.136). Only 58% of forest sector firms provide training compared to 69% of ICT firms. Within the forest sector, firms in the paper sub-sector are most likely to provide training after adopting technology; 62.2% of paper firms stated that they provide training as a result of adoption. The wood sub-sector is not far behind, 59.4% technology adopters provide training. The number of logging firms providing training post adoption is much lower, only 47.5%. The lower percentage of logging firms providing training after a technology is adopted could in part explain why fewer of them experience positive outcomes post-adoption compared to wood and paper firms. According to the literature, the absorptive capacity of a firm will be influenced by the individual absorptive capacities of its employees (Cohen and Levinthal, 1990). In order for employees to develop the necessary skill set to successfully implement and use the technology, training is likely needed (Santamaria et al., 2009).

Across all forest sub-sectors and in ICT manufacturing firms, technical and safety skills are most commonly trained for post adoption. Firms in the paper sub-sector are more likely to train for quality control and improvement skills than the other sub-sectors. Team building and safety skills appear to be more important for logging firms than for any other forest sector firms, quality control and management skills are less important. This is likely influenced by the type of technologies adopted in the logging sector and the nature of the work required by employees. However, the survey does not provide us with information about the skills the employees possessed prior to the technology adoption, perhaps the employees in logging firms already possessed the necessary skills to adopt the technology and did not require as much training as those in the other sub-sectors, which could also explain the lower training levels. Access to the survey micro data and tax data would allow for further analysis of the relationship between training and firm performance in forest sector firms.

6.1.6 Obstacles to Adoption

The technology adoption process is hindered by many obstacles, which not all firms are able to overcome. Financial justification is the most commonly reported obstacle for forest sector firms as well as ICT manufacturing firms. The financial obstacle faced by the majority of firms is the high cost of equipment. Purchasing equipment from an external source and integrating it into existing production processes can pose a large financial burden on firms and a lack of funding may even deter firms from adopting advanced technology. Successful firms are able to overcome this problem, for example, by receiving financial support from the government. It becomes clear that programs such as IFIT are instrumental in helping firms overcome financial barriers to adoption, the interviews provide more information of the importance of government funding.

Training costs were also reported as an obstacle for most forest sector firms, more so than for ICT firms. In western Canada, the forest sector is in competition for skilled employees with the oil industry. The forest sector is perceived to be in decline in comparison to the oil industry, which makes it difficult to attract skilled workers, especially engineers. Firms might find it necessary to re-train existing employees if they are not able to hire new ones. By promoting forestry research and engineering in universities, or providing scholarships within these areas, forestry could be seen as an attractive field to work in.

The risks of technology adoption could pose a major obstacle for firms, particularly if they are adopting a technology that has never been used before. The outcomes of adoption are uncertain, as firms find it difficult to evaluate the benefits due to bounded rationality (Chesbrough, 2006). One of the ways to minimize this risk is to adopt a technology that has already been proven elsewhere (Chesbrough and Crowther, 2006). The firms in the qualitative study received funding to introduce technologies that have not yet been used in Canadian forest sector firms and could be used as an example for other firms by providing guidance on adopting novel technology. This serves as an argument in favour of maintaining government programs, such as IFIT, which support firms in introducing advanced technology. Without these programs, the technologies may have never made it to the Canadian market. The new technology does not only impact the adopting firms, but can transform the whole sector if other firms follow suit. Specifically, the two firms introduced technologies that transform waste into bioenergy, which is an important new avenue for forest sector firms and has allowed them to diversify their production from traditional products.

Analysis of the *1993 Survey of Innovation and Advanced Technology* found that advanced technology adopters were more likely to report obstacles to adoption than non-adopters (Baldwin and Lin, 2002). However, in the 2007 survey, only adopters were asked the question about obstacles to adoption, therefore there is no data available about the barriers to adoption for non-adopters. This type of data would be useful in determining why the non-adopters did not adopt technology, and identifying the true obstacles to adopting technology rather than the difficulties the firms had to overcome. Since the survey was designed to cover the entire manufacturing industry, the obstacles were addressed on a very general level. The interviews were able to provide more insight into the specific obstacles forest sector firms in Canada face.

6.1.7 Novelty of Product and Process Innovations

Advanced technology use is also positively related to the novelty of innovations produced by the firms. Technology users are more likely to introduce North America first and World first innovations. Non-users introduce mostly firm first innovations. This suggests that technology users may be more competitive on an international level, by producing novel innovations, they are able to differentiate themselves from their competitors and be leaders in the industry. Introducing unique process innovations can provide firms with an increase in productivity and a reduction in cost allowing them to get ahead of their competitors.

There appears to be positive relationship between AT use and the novelty of product innovation introduced. The relationship between advanced technology use and the novelty of process innovation introduced is not as clear as with product innovations. In the forest sector, AT use is not necessarily related to the novelty of process innovation. In low-tech sectors, innovation is often a result of "learning by doing" in daily routines within the firm (Hirsch-Kreinsen, 2008). The firms interviewed provide a good example of firms introducing Canada first or World first innovations, by using technologies in a way they have never been used before.

Using the survey data, it is difficult to determine the cause and effect in technology adoption and novelty of innovation. It could be the case that these firms are "champions" in their sectors, therefore have better developed capabilities and are more inclined to adopt technologies as well as introduce innovations. Firms that are innovative might be more willing to adopt technologies than non-innovative firms. The data does not necessarily indicate that technology adoption will lead to more novel innovations, however there is a positive relationship between them, which could be explored further.

6.1.8 Outcomes of Advanced Technology Adoption

One of the main findings of this study is that technology adopters in the forest sector who innovate experience greater positive outcomes in performance in terms of productivity, product improvement, market share and efficiency resulting from adoption than non-innovators. According to the survey results, there is a compounding effect of innovation and advanced technology adoption that results in more positive outcomes for forest sector firms. Firms which are both innovative and technology adopters are more likely to experience positive impacts than firms that adopt a technology but do not innovate. This suggests that advanced technology adoption that is not accompanied by innovation will not have as many performance benefits for the firms.

The data demonstrate that the rewards of advanced technology adoption and innovation are not guaranteed - not all firms will experience improvements post-adoption. In order for firms to maximize the impacts of technology, such as gains in productivity or an increase in market share, they must innovate as well as adopt technology. This is particularly true for the forest sector. Policy should not only consider advanced technology adoption in isolation, but also needs to address the impacts of innovation in combination with AT adoption.

The effect of not innovating while adopting a new technology has a greater negative impact on forest sector firms than on firms in the ICT sector. The difference between the impacts of technology adoption on innovators and non-innovators is greatest in the forest sector. For example, 91.2% of forest sector innovators experience an improvement in productivity after adopting a new technology, while only 57.1% of non-innovators do. In ICT the non-innovators do not lag behind the innovators as much; 87.5% of ICT innovators reported an improvement in productivity, compared to 73.2% of non-innovators.

The survey data indicate that logging is a special case in the forest sector. Logging firms adopt significantly fewer advanced technologies, invest less in AT and are less likely to experience productivity and performance improvements as a result of adopting advanced technologies. This could be due to the structure of the sector and the type of products it produces. Logging firms are usually smaller and are part of the extraction industry, which means they produce primary products with little added value. Logging firms may be less motivated to adopt advanced technologies, because, based on the results of the survey, they do not expect to achieve the same benefits from technology adoption as wood product or paper firms. The Canadian forest land tenure system may also play a role in this, as the land is primarily government owned, logging firms will not appropriate the benefits of improving production process and may be less motivated to invest in a resource that they do not own themselves. It may also be more difficult for them to achieve improvements in their product, since they are dealing with a commodity, unlike the other forest sub-sectors or the ICT sector. However, logging firms do excel in the use of geomatics and geospatial technologies, which are listed under "emerging technologies" in the *2007 Survey of Advanced Technology*. Since these technologies are listed separately from the other advanced technologies, there is no data within the templates about the impacts of using these technologies on the logging sector. Further investigation is needed in order to understand the opportunities for improving productivity in the logging sector, a study on the use of emerging technologies could also provide some insight on advanced technology adoption in the logging sector.

The survey only captures the self-reported impacts of adoption, but does not provide information about the initial levels of productivity and performance. Performance for the logging sector may already be high and that is the reason it did not improve as much as in the other sectors. Previous studies of Canadian innovation surveys have not found any evidence to support that advanced technology adoption leads to an improvement in performance, perhaps this is because firms are reporting their expected outcomes, not the actual outcomes of adoption (Arundel and Sonntag, 1999). Business performance data, possibly from sources such as government tax data collected in the years prior to and after the technology adoption, would provide us with valuable information about the effects of technology adoption on performance.

6.1.9 Exports

One of the main problems with the Canadian forest sector, is that the majority of its exports are primary wood products, with little value added (Wang, 2009). By sending out commodity products and buying back the secondary products Canada is not capturing the benefits of the forest sector. The aim for Canadian forest sector firms should be to produce high-value added products in Canada, rather than exporting them in primary form (Hawkins, 2012). Not only does this foster innovation, it will also contribute to the trade balance.

According to the survey data, logging firms make the majority of their revenue from sales within the province or territory. Wood and paper firms also sell most of their products within the province, but are more likely to export than logging firms. The products of logging will often be an input into the wood and paper sector. These firms take the lumber and convert it into value-added products. The fact that logging firms export less than wood and paper firms could be positive, since this means that more products are being exported in value-added form, rather than as primary products.

Advanced technology adopters, are more likely to export their products outside of Canada than non-adopters. This indicates that technology adoption could play an important role in the competitiveness of the Canadian forest sector. An increase in technology adoption by forest sector firms could help Canada compete on international markets and improve its trade balance.

Although the forest sector is diversifying in exports, there still appears to be a great reliance on the US market, with a very small amount of sales being made outside of North America. In the future, the forest sector would benefit from diversifying its exports even further, as the overreliance on the US contributed to the crisis the sector faces today.

6.2 Qualitative Study Findings

The interviews provide information about the technology adoption process in two firms which have received IFIT funding for their projects. The interviews address all three phases of the adoption process as described in Voss's (1988) model: pre-installation, installation and commissioning, and post-commissioning. The analysis focuses on some of the main themes presented in Figure 7 on P.55 of this document and is supported by quotations from the interviewees.

6.2.1 Need Identification

The interviews suggest that the forest sector may be more innovative than it is perceived to be. Even with a limited sample size, we were able to identify firms which are champions in their sector. The IFIT program provides funding to some of the most innovative firms in the forest sector. Although only 14 firms received funding in the previous round of the project, the large number of applicants (over 100) suggests that many Canadian forest sector firms are interested in innovation and improving their production processes through the adoption of advanced technologies (Natural Resources Canada, 2014). The two firms interviewed for this study are involved in innovation in order to improve firm performance and remain sustainable in the long-run. A long-term outlook is important in the technology adoption process as it involves a substantial financial commitment and it takes time to adopt the changes; results are rarely instantaneous (Co et al., 1998). Both firms indicated that they engage in a process of "continuous improvement" to identify new technology needs and improve their production methods. They are taking a pro-active approach to innovation and advanced technology adoption, actively seeking ways to transform their firm. Firm X has an *"ongoing review process seeking efficiency."* The corporate culture in these firms is such that it promotes employee involvement and engagement. They are able to contribute their ideas. To illustrate, interviewee #2 described the corporate culture in the firm by saying:

"We really invest in our people and training and we really encourage them to complement the business through their ideas and their innovation. We have what we call continuous improvement process. People here are pretty free to come forward with their ideas. We have a system that allows them to do that and we can vet these ideas" (Interview #2, P.3).

However, some of their motivation to adopt new technologies might stem from the economic climate, and adaptation to the increasing energy costs. For Firm X, their decision to adopt a technology that produces energy, was influenced by the increase in the cost of power. Interviewee #1 described the situation by stating that:

"One of the things is that we had fairly low cost power up until now, up until say two years ago, we had quite a bit of... we had a surplus of low cost power in British Columbia. We no longer enjoy that surplus anymore" (Interview #1, P.9)

Since energy costs are very high in the forest sector, firms have had to find ways to decrease them, and producing their own energy is a good way to do so. In addition, they have connected to the electricity grid in British Columbia and can generate a revenue from selling off the excess energy they produce.

For both firms, the adoption of advanced technologies represented a diversification of their production. Firm X created a new company as a result of the advanced technology adoption. Interviewee #1 explained that: *"We were creating sort of a brand new direction for the company, for the production of energy, we had never done that before. And we were going to use that company to seek additional opportunities in energy creation."* (Interview #1, P.3).

Similarly, Firm Y has gone from being not only a pulp-mill, but also a bio-refinery producing green fuel. This diversification feeds into the idea of "long-term perspectives." Both interviewees realize that the forest sector is in decline and in need of a transformation, therefore they are pursuing methods of green energy production. Firm X is producing green power from waste, while Firm Y is producing a bio-fuel.

The process of need identification is therefore quite complex. Forestry firms seem to be predominantly looking for something that complements their core, a technology that will be a good fit for their business. Firm X identified a waste stream in their system and wanted to turn it into a revenue. Firm Y was already producing green power and was looking for ways to further diversify. In both cases, a feasibility study was conducted to identify the technology needs. The difference between the firms in the way they obtained the technology, was that Firm X put out a competitive tender, while Firm Y was approached by a specific supplier. As interviewee #2 put it the technologies are *"still in their infancy,"* therefore the pool of suppliers is very limited. Firm Y is the first pulp mill to ever use this technology, which may explain why their choice of suppliers was so limited. Firm X obtained its technology from Italy, and is the first North American firm to use this type of technology.

6.2.2 Challenges and Enablers

Obtaining the finances for advanced technology adoption was found to be one of the main obstacles to adoption for forest sector firms, however the interviewees identified other obstacles that were specific to the forest sector and the regions in which the firms operate.

The lack of skilled labour was identified as a major challenge by both firms. Due to the downturn in the industry, many engineers have left the sector to work in oil or mining. This lack of skilled labour could have a detrimental impact on innovation in the forest sector. Skilled engineers are needed to install new technologies, if they are not available it slows down the adoption process.

Team work is also perceived to be an important driver in successful technology adoption (Tracey et al., 1999). It is imperative for top management to show support for the technology implementation and to communicate the goals of adoption with their staff (Mirvis et al., 1991; Co et al., 1998). Firms which place an emphasis on their human resource strategy are more likely to successfully implement the technology (Baldwin 1999). The two firms involved in the qualitative interviews provided extensive training for the employees involved in the adoption. Firm X even took its employees to Italy, so they could see the technology in place before it was implemented in their firm. Both interviewees stressed the importance of employee involvement in the adoption of the technology and believed it to be instrumental to the successes of the technology implementation.

One of the challenges that was not documented in the survey, but arose in the interviews was bureaucracy and regulation. Firm X identified regulations as one of the challenges in the adoption process. Obtaining permits and negotiating power contracts posed a difficulty in implementing the new technology. The permitting process was influenced by the recent explosions in sawmills in British Columbia[2]. Firm Y, as a pulp mill, did not face these same challenges. This indicates that extent to which regulations pose a challenge to technology adoption will be influenced by the type of technology the firm wishes to install. Therefore, not all technology firms will face this challenge, but it can act as a major barrier to those who do.

The interview data show that the funding provided by external organizations is instrumental to the adoption of an advanced technology. In order to qualify for IFIT funding, firms must be willing to take a risk and invest in a technology that has not been proven before. Without the support of the IFIT program and provincial governments, these firms would most likely not have been able to adopt the technologies. Interviewee #1 explained that: "*I would say we probably wouldn't have been able to [adopt the technology] without the NRCan funding and Hydro funding."* (Interview #1, P.7).

Financing new technology is the most prevalent obstacle to adoption for forest sector firms. Lack of financial justification was reported to be an obstacle to adoption by 96.8% of technology adopters in the forest sector. They often have to turn to external sources to fund the new technology. In order to qualify for IFIT funding, firms must be willing to take a risk and invest in a technology that has not been proven before. It can be difficult for firm managers to convince

[2] After two deadly sawmill explosions took place in BC in early 2012, WorkSafeBC sent out officers to inspect sawmills and prevent the buildup of dangerous and potentially explosive wood dust (The Canadian Press, 2013). More information on: http://www.huffingtonpost.ca/2013/10/31/bc-sawmills-worksafe_n_4182177.html

their boards to invest in a new technology, having financial support for the project can help support the decision and minimize some of the potential losses for the firm.

6.2.3 Research and Collaboration

According to the literature, firms in the LMT sector are less likely to engage in in-house R&D and often collaborate with other firms or institutions in order to introduce a new technology (Spithoven et al., 2010). Both interviewees were very pleased with the support offered by the people with the IFIT program, which reduced some of the bureaucratic strain on the firms. Firm Y is also working with FPInnovations to overcome some of the challenges in implementing the technology. Firms which are members of FPInnovations can benefit from their services, by for example utilizing their research labs. Many forestry firms do not have R&D facilities of their own, therefore the help of research institutions, such as FPInnovations can be instrumental in the adoption of a new technology.

6.2.4 Outcomes of Technology Adoption

The data collected from the interviews suggest that improved productivity is only one of the outcomes of advanced technology adoption. Firm X was able to reach its productivity targets in only three days. This success has spurred on more innovation within the firm, as employees are now looking for even more ways to improve the production process. The organizational learning as a result of the successful technology adoption is an example of DUI innovation (Hansen and Winther, 2011). The employees have learned from the technology adoption and are continuing to improve production processes even further. Although Firm Y has not fully realized the benefits of the new technology yet, many pulping firms are waiting to see how it succeeds. Both firms have gained an improved profile in the forestry sector, as other firms are following their example in their technology adoption process. These firms are becoming well respected within the industry for being innovative. This could improve their future prospects, for example by attracting partnerships with other firms, or securing supplier/customer deals due to their improved reputation. It may also make it easier for them to attract skilled workers in the future. Another important outcome of the technology adoption is employee pride. Employees are very proud of the new technology, which has increased their motivation. As mentioned before, they are seeking ways to become even more efficient in their production methods, which is a very positive outcome for the firms.

6.2.5 Diversification and International Competitiveness

Since energy costs are very important to the forest sector, firms have had to find ways to decrease them, and producing their own energy is a good way to do so. As a result of adopting advanced technologies, some forest sector firms, like the sawmill interviewed for the qualitative study, have connected to the electricity grid and can generate a revenue from selling off the excess energy they produce. Reducing costs is only one of the options to improving competitiveness, as forest sector firms face competition from firms in developing nations with much lower costs. Canadian firms must develop some sort of competitive edge, in order to distinguish themselves from their competitors. Adopting advanced technologies can help them achieve these goals. Transformation in the forest sector through the production of these non-traditional products, such as bioenergy and biomaterials from wood fibre is expected to add to the contribution the forest sector makes to the Canadian economy (Natural Resources Canada, 2013c).

7. Conclusion

For many years academic scholars have emphasized the need for a forest sector innovation policy and the technological transformation of the sector (Rosenberg et al., 1990; Binkley, 1995; Madore and Bourdages, 1992). Even twenty years later, the forest sector is still suffering from the same problems outlined by these scholars (Mockler and Robichaud, 2011). However, the results of the *2007 Survey of Advanced Technology* suggest that the forest sector may not be as behind on technology adoption as originally believed, even when compared to a high-tech industry such as ICT manufacturing. Just because the sector is in the low-tech industry, does not mean it is not innovative. Although forest sector firms do not engage in as many R&D activities as ICT firms, they do innovate in different ways. For example through the adoption of advanced technology or by investing in the development of their human capital. Certain pioneering firms, such as those in the IFIT program, are adopting cutting-edge technologies in order to transform their firms into bioenergy producers and pave the way for the rest of the industry. The sector is also leading in the use of sustainable development strategies. This means that forest sector firms operate in a way that does not deplete environmental resources, which is crucial to the sustainability of Canada's economic growth.

The main findings from the study are:

- The forest sector sub-sectors are very diverse in technology adoption – it is imperative to study the forest sector at the sub-sector and sub-sub-sector level

- Technology adopters in the forest sector who innovate are more likely to experience positive impacts (productivity, market share, efficiency) from adoption than non-innovators

- Paper and wood product firms adopt more technology than logging firms, they also experience greater benefits resulting from adoption (not far behind ICT) – could be a result of the combination of type of technology, training provided, R&D investment, sector specific obstacles.

- Logging is a special case in the forest sector – further investigation is needed in order to understand why more firms in this sector are not experiencing positive impacts post technology adoption.

- Advanced technology users across all sectors are more likely to use advanced business practices than non-users. These business management practices may be a necessary component to successfully managing the advanced technology

- Technology users are more likely to introduce North America first and World first innovations. Non-users introduce mostly firm first innovations; suggesting that technology users are more competitive on an international level.

Both the survey results and the interview data revealed that the forest sector sub-sectors are very diverse in technology adoption, particularly in the types of obstacles they face and the outcomes of adoption, which suggests that researchers and policy makers need to study the forest sector at the sub-sector level or even the sub-sub-sector level. Policies designed at the sector level may not benefit all the sub-sectors.

Adoption of technology in the forest sector is influenced by various factors including the economic climate, geographical location, access to finance, support from other institutions and employee involvement. In light of these findings, innovation support programs should not only focus on R&D performers, but also firms engaging in non-R&D innovative activities, such as advanced technology adoption (Huang et al., 2010). Policy makers need to recognize the importance of the transformation of the forestry sector, due to the role the industry plays in the Canadian economy. Although policy makers cannot influence all the factors that affect advanced technology adoption, they can create policies that will help them overcome some of the challenges. For example by encouraging knowledge generation and transfer through institutions such as FPInnovations and continuing to provide funding for technology adoption. If the decline in demand for forest sector products persists, diversification and technological upgrading may be the only options left for Canadian forestry firms. The firms interviewed were both able to diversify their production as a result of adopting advanced technology by turning waste into energy.

The interviews provided some insight on the influence of advanced technology adoption on employees. According to the literature employees may be resistant to new technology, as it changes the nature of their work and can even make their position obsolete (Chesbrough, 2006; Co et al., 1998; Sabourin and Beckstead, 1999). The interviewees indicated that employees were apprehensive about adopting new technology, however adequate training and employee involvement in the adoption process resulted in positive outcomes. The employees were trained how to use the new technology prior to its adoption and subsequently felt a sense of pride in the business, as they were able to understand the benefits of using advanced technology. Employee pride was identified as an important outcome of advanced technology adoption, as it motivated the employees to seek new ways to improve production processes and innovate.

Statistics Canada is in the process of developing a *Survey of Advanced Technology* for 2014. The results of the 2007 Survey should be analysed thoroughly before the next one is launched, to identify any changes that need to be made to the survey design. This research can provide insight on how the survey instrument can be improved to provide us the information we are looking for. Analysis of the *2007 Survey of Advanced Technology* can inform survey design for the future by enabling us to identify which indicators are missing. It can also assist in developing an Innovation Scoreboard for the Canadian forest sector, as it provides some insight into the role of technology adoption in forest sector performance. The government has made significant investments into innovation and advanced technology surveys, however the results are not always fully exploited or communicated back to policy makers and industry. This thesis can help, at least in part, to bridge that gap.

Combining survey data and qualitative data, provided us with firsthand information about the adoption process and the challenges faced by Canadian forest sector firms. The amount and type of information that can be collected by surveys is limited. Supplementing survey data with interviews allowed us to tailor the questions to technology adopters in the forest sector and provided us with valuable information about the firms, which would not have been able to collect without these two information tools. Although the firms interviewed are not representative of the forest sector as a whole, they provide valuable information about what it is like for Canadian forest sector firms to adopt advanced technologies that have never been used in Canada before. The study gives managers some indication of the challenges they may face during the adoption process and what they can do to overcome them. These two firms can act as examples for other firms in the industry that wish to diversify or apply for government funding in the future. This can also help reduce the risk of adoption for other firms in the forest sector.

By analyzing the differences between adopters and non-adopters of advanced technology, we are able to highlight the benefits of technology adoption within the forest sector and the positive impact advanced technology adoption has on productivity, product improvement, market performance and even sustainable development, especially when combined with innovation. Since financing is a major obstacle for innovative firms, government programs such as IFIT are crucial for forest sector firms and need to continue in order for the Canadian forest sector to transform. Particularly in a time when environmental and sustainability concerns are rising, advanced technologies, such as those adopted by the two firms interviewed, can help Canada become a leader in sustainable forestry.

Policy makers should also look for ways to decrease the bureaucratic and regulatory challenges for firms in order to facilitate the technology adoption process. Obtaining permits and negotiating power contracts posed a difficulty for the sawmill studied. The permitting process was influenced by the recent explosions in sawmills in British Columbia, which increased the regulatory burden for firms. Having the right people in place for the procedures, particularly within the IFIT program, can help speed up the process, as they can provide support to firms in obtaining the right paper work.

The results of this study indicate that R&D spending is not necessarily the most accurate measure of innovation, especially for the LMT sector. These indicators are often used, because monetary outcomes are easier to measure. Firms are classified based on the output produced, rather than the inputs going into the production. Even in low-tech industries, these inputs may involve high-tech products. The roles of high technology and LMT sectors cannot be analysed in isolation, because it is their interaction that drives economic growth and development. For example, the number technologies adopted by the paper sub-sector, as well as the level of investment and the outcomes in terms of productivity and performance are more similar to the ICT manufacturing sector than the logging industry. By considering other inputs to innovation, such as technology use or training, we can get a more accurate picture of innovation within a sector, particularly if we examine technology use and the outcomes of technology on a sub-sector level. Forest sector firms innovate by using technology in novel ways. They are knowledge carriers and disseminators, they take technology used in other sectors and apply them in their own production processes, which can inspire other firms to adopt these technologies as well. When evaluating advanced technology use in the forest sector, logging drives the average figures down, but wood and paper firms are high intensity users of advanced technology. From the qualitative study, it becomes clear that certain firms in these two sub-sectors are very innovative, some introducing world first innovations, by using technologies that have never been applied to the forest sector before. It is important that these types of firms continue to receive support from the government, as they play a key role in the transformation and future success of the Canadian forest sector.

7.1 Limitations and Future Studies

There are some limitations when using a survey conducted in the past rather than designing one specific to this study. Surveys of Innovation and Advanced Technology are usually designed for the manufacturing sector as a whole, when it is comprised of many different industries, therefore the questions may be suited for some industries better than others. There is also no longitudinal, or panel, data available, because the survey is conducted only on an occasional basis and the questions change from year to year. This makes it difficult to track the performance of firms over time. However, the main benefits of using survey data from Statistics Canada is that the survey is mandatory and has a large sample size. The data collection process is very rigorous and provides users with reliable data. It would be difficult and costly to administer our own survey, even if the questions were better tailored to the forest sector. The survey does not provide enough detail or depth for the forest sector, thus the interviews were administered to better identify some of the problems specific to the Canadian forest sector. The interview data provides us with contextual depth rather than statistical generalizations. Making use of multiple data sources, such as past survey results, the *2007 Survey of Advanced Technology* and the interviews allowed for data triangulation. The interviews were used to expand on the data found in the survey. Access to the micro data from the 2007 Survey would be necessary in order to conduct a regression analysis and determine the correlation between advanced technology use and measures of firm performance (sales, profitability, return on capital investment etc.).

The survey design also imposed some limitations on the study. The definition of an “adopter” in the *2007 Survey of Advanced Technology* is a firm which has adopted any of the 39 technologies listed in the survey. Since the survey covers all manufacturing industries, the list of technologies may apply better to some than to others. Technologies relating to extraction industries, such as mining, logging or oil and gas, may not be as well covered. Technologies which have become mainstream in one sector may be considered advanced in other sectors. Since ICT technology is now very widely adopted among firms, most firms in the sample fell under the “adopter” category. That is why the list of technologies is revised with each iteration of the survey. Certain technologies were considered to be “emerging technologies,” which includes geomatics/geospatial technologies, biotechnology and nanotechnology. Firms using these technologies were not considered to be “adopters” in the Template for Analysis, which may have affected the results, especially for logging firms, which may be more likely to use geomatics/geospatial technologies than the technologies from the original list. Also, it may be difficult to identify and isolate the outcomes of a particular technology if a firm adopted more than one or adopted other technologies in the past. The positive impact on performance could a result of the combination of various technologies (Beede and Young, 1995). Firms that have adopted technology in the past may have more experience with the adoption process which would give them an advantage over first time adopters.

Another limitation in the survey design is that the *2007 Survey of Advanced Technology* did not include many performance or outcome measures. The outcomes of technology adoption were self-reported and based on a scale for the degree of impact (low, medium or high). There was no way for respondents to quantify the results. When asking for financial information, there is a risk of non-response, as firms do not want to disclose this information in a survey. This may be the reason the question was formulated this way. Also, since it can take many years for firms to realize the benefits of adopting the technology, if the technology has been in use for less than 2 years, it may not be sufficient enough for firms to report on. By linking the results of this survey to firm performance data, such as those captured in the tax filings of firms, we would be able to analyze the impact of AT adoption on performance through an econometric analysis. The tax data, which has been linked backward and forward until 2012 would provide more information on the outcomes of adoption, particularly how capital investment and technology adoption relate to performance improvements.

In addition, many of the questions were only addressed to adopters and not the non-adopters, which made comparison between these two groups more difficult. For example, the question about obstacles to adoption was only answered by adopters. It would be beneficial to also have the answers from non-adopters, particularly asking why the non-adopters are not using any advanced technologies. It could simply mean that these firms did not find it necessary to adopt advanced technologies, or there could be other reasons, such as lack of finances. Future surveys should include this question, since the data indicates that technology users improve their productivity post adoption and they are more likely to adopt a sustainable development strategy. If adopters faced obstacles to adoption, it suggests that they were able to overcome them somehow. By conducting additional interviews with firm managers, we could gain more insight into how adopters are able to overcome these obstacles, which could serve as an example to other firms. Moreover, examining the tax data for firms which did not adopt technology would allow us to determine how their performance has improved over the years in comparison to the adopters of technology and understand if there really is a competitive advantage to adopting advanced technology. This information would be useful for evidence-based policy making as it would allow policy makers to understand why certain firms are not adopting advanced technologies and how to address this issue.

Using the Templates for Analysis as a tool for analysing the 2007 Survey data allowed us to make comparisons between different groups of firms, for example Adopters v. Non-Adopters and Innovators v. Non-Innovators. Nevertheless, there were still some limitations imposed by using this tool rather than the micro data. The templates limited this study to the use of descriptive statistics based on percentage comparisons, which cannot be used for econometric analysis. Due to this limitation to domain comparisons, we cannot determine the overall percentage of technology adopters within the sectors, only the percentage of total adopters using a particular technology. It is also difficult to determine cause and effect using this type of survey. For example, we do not know if firms using advanced business practices are more likely to adopt advanced technologies or if they use these business practices as a result of the technology adoption.

Using the templates, we cannot determine how many technologies an individual firm adopted or the type of technology, we can only look at the sector and sub-sector level. There may be effects due to adopting multiple technologies or certain technology combinations that the templates are not able to capture. Some of the data in the templates is compressed or unavailable, such as the innovation novelty for ICT non-adopters, which would have provided a useful comparison to forest sector non-adopters.

We also cannot distinguish the effects of being a Non-Innovator AND Non-Adopter, as the templates only allow us to look at each group separately. It would be interesting to investigate the combined effect of not adopting new technology and not innovating on the performance of forest sector firms.

The qualitative portion of this research study could be expanded to include more firms, for example, looking at firms which did not receive IFIT funding when adopting advanced technology, since the pool of firms receiving IFIT funding is very small. These firms benefited from IFIT funding, because they were introducing novel technologies. To expand on this research, a comparison could be made between IFIT firms and those which funded the technology adoption in other ways. Do firms which are following in the footsteps of pioneering firms face different challenges? It would also be beneficial to interview managers from logging firms to gain some insight into this sub-sector and understand why they are not adopting as much technology or reaping the benefits of adoption like the firms in the wood or paper sub-sectors.

One of the factors that was not addressed in this study was the effect of firm size on technology adoption. The literature indicates that large firms are more likely to adopt advanced technology than small firms. Future studies could stratify the sample based on firm size in order to provide insight on the implications firm size has for the forest sector, especially logging, where the majority of firms are small. However, firms with less than 20 employees or revenues lower than $250,000 are excluded from the survey. Only about 58% of Canadian manufacturing firms fit the sampling criteria, which means that we do not have data on a large proportion of the industry, particularly small firms. This raises the issue of collecting data from small firms without creating too much of a response burden.

Another factor believed to influence technology adoption is the location of Head Office. The Head Office of forest sector firms is usually located within the province. According to the 2007 survey results, the Head Offices of technology adopting firms are more likely to be located outside of the province or country than those of non-adopters. This suggests that foreign firms are more likely to invest in AT than Canadian ones. Future studies could focus on this phenomenon in order to understand why Canadian owned firms are less likely to invest in advanced technology than those controlled outside of the country and the effect on forest sector firms.

8. Appendix

8.1 Appendix I: 2007 Survey of Advanced Technology Questionnaire

Science Innovation and Electronic Information Division

Survey of Advanced Technology - 2007

Confidential when completed

Si vous préférez ce questionnaire en français, veuillez nous appeler au 1-866-297-3138

Correct as required

Company name

Establishment name

C/O

Address

City

Province/Territory

Postal code

INTRODUCTION

Survey Purpose

The information you provide is essential to assure the availability of pertinent information on the technological capabilities of business units in the manufacturing and logging industries. The information compiled from the survey can be used by businesses for market analysis, by trade associations to study performance and other characteristics of their industries and by government to develop national and regional economic policies and technology strategies.

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 your continued co-operation and goodwill.

Confidentiality

Statistics Canada is prohibited by law from publishing any statistics which would divulge information obtained from this survey that relates to any identifiable business or individual without the previous consent of that business or individual. The data reported in this questionnaire will be treated in strict confidence, used for statistical purposes and published in aggregate form only. The confidentiality provisions of the *Statistics Act* are not affected by either the *Access to Information Act* or any other legislation.

Authority

This survey is conducted under the authority of the *Statistics Act, Revised Statutes of Canada*, 1985, Chapter S-19. Completion of this questionnaire is a legal requirement under the *Statistics Act*. Your participation is appreciated.

Record Linkage

In order to enhance the information you provide in this survey, Statistics Canada plans to combine the responses relating to your organization with the information previously provided on the Annual Survey of Manufactures. The combined information will be kept strictly confidential and used only for statistical purposes.

Federal-Provincial Agreement

In order to reduce respondent burden, to reduce the cost of collection and ensure uniform statistics, Statistics Canada has entered into an agreement with the Institut de la statistique du Québec, under Section 11 of the *Statistics Act*, where data on business units located or operating in Québec will be transmitted to the Institut de la statistique du Québec. The Institut de la statistique du Québec has the same provision for confidentiality and penalties for disclosure of information as the federal *Statistics Act* and has the legislative authority to collect this information on its own.

Survey Contact

Please indicate the name of the person completing this form so we know who to contact should we have questions about this report.

Name: 00001

Title: 00002

Telephone number: 00003 (   )   -

E-mail: 00004

5-5300-533.1: 2007-03-12 STC/SAT-465-75147

Statistics Canada Statistique Canada

Canada

Key Definition

In this questionnaire, we refer both to your "**business unit**" and to your "**firm**". By "**business unit**", we refer to your establishment or local operations (as described on the label on the first page of the questionnaire). By "**firm**", we refer to all business units and operations in Canada or in other countries that comprise your company.

Section A - Advanced Technologies

Advanced Technology Adoption

This question explores advanced technology adoption. It will provide important information on technological capabilities.

1. Please take your time to indicate (✓) if you are using (in use) or are not currently using (not in use) the following advanced technologies in your **business unit** (as described on the label on the first page of the questionnaire). If you are currently using the advanced technology, please indicate (✓) if it has been in use for more than 2 years in your **business unit** as well as the location of your suppliers of the technology (as indicated on the purchase order). If you are not currently using a given advanced technology please indicate (✓) if you plan to use it within 2 years in your **business unit**. **Please refer to the enclosed reporting guide** if you have questions or need a definition of the listed technologies.

Design, Engineering and Virtual Manufacturing

Technology	Status	Follow-up	Location of your supplier(s) of this technology *(Please check all that apply)*						
			Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
a. Computer Aided Design (CAD) including simulation technologies / Computer Aided Engineering (CAE) including modeling or simulation technologies	01011 In use 1 ○ →	In use for more than 2 years 01012 1 ○ Yes 3 ○ No	01014 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ →	Plan to use within 2 years	01013 1 ○ Yes 3 ○ No						
b. Computer Aided Design/ Computer Aided Manufacturing (CAD/CAM)	01021 In use 1 ○ →	In use for more than 2 years 01022 1 ○ Yes 3 ○ No	01024 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ →	Plan to use within 2 years	01023 1 ○ Yes 3 ○ No						
c. Virtual product development	01031 In use 1 ○ →	In use for more than 2 years 01032 1 ○ Yes 3 ○ No	01034 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ →	Plan to use within 2 years	01033 1 ○ Yes 3 ○ No						

			Location of your supplier(s) of this technology (Please check all that apply)						
			Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
d. Virtual manufacturing	01041 In use 1 ○ →	In use for more than 2 years 01042 1 ○ Yes 3 ○ No	01044 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ →	Plan to use within 2 years	01043 1 ○ Yes 3 ○ No						
e. Software technologies for systems engineering	01051 In use 1 ○ →	In use for more than 2 years 01052 1 ○ Yes 3 ○ No	01054 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ →	Plan to use within 2 years	01053 1 ○ Yes 3 ○ No						
f. Electronic exchange and management of CAD files	01061 In use 1 ○ →	In use for more than 2 years 01062 1 ○ Yes 3 ○ No	01064 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ →	Plan to use within 2 years	01063 1 ○ Yes 3 ○ No						
g. Rapid prototyping	01071 In use 1 ○ →	In use for more than 2 years 01072 1 ○ Yes 3 ○ No	01074 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ →	Plan to use within 2 years	01073 1 ○ Yes 3 ○ No						

Processing, Fabrication and Assembly

Location of your supplier(s) of this technology
(Please check all that apply)

h. Flexible Manufacturing Cells or Flexible Manufacturing Systems (FMC/FMS)

01081
In use 1 ○ →
In use for more than 2 years
01082
1 ○ Yes
3 ○ No

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
01084						
1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○

Not in use 3 ○ →
Plan to use within 2 years
01083
1 ○ Yes
3 ○ No

i. Reconfigurable systems

01091
In use 1 ○ →
In use for more than 2 years
01092
1 ○ Yes
3 ○ No

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
01094						
1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○

Not in use 3 ○ →
Plan to use within 2 years
01093
1 ○ Yes
3 ○ No

j. Lasers used in materials processing (including surface modification)

01101
In use 1 ○ →
In use for more than 2 years
01102
1 ○ Yes
3 ○ No

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
01104						
1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○

Not in use 3 ○ →
Plan to use within 2 years
01103
1 ○ Yes
3 ○ No

k. E-beam processes

01111
In use 1 ○ →
In use for more than 2 years
01112
1 ○ Yes
3 ○ No

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
01114						
1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○

Not in use 3 ○ →
Plan to use within 2 years
01113
1 ○ Yes
3 ○ No

l. Plasma sputtering

01121
In use 1 ○ →
In use for more than 2 years
01122
1 ○ Yes
3 ○ No

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
01124						
1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○

Not in use 3 ○ →
Plan to use within 2 years
01123
1 ○ Yes
3 ○ No

			Location of your supplier(s) of this technology *(Please check all that apply)*						
			Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
m. Robot(s) with sensing capabilities	01131 In use 1 ○ ➔	In use for more than 2 years 01132 1 ○ Yes 3 ○ No	01134 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ ➔	Plan to use within 2 years	01133 1 ○ Yes 3 ○ No						
n. Robot(s) without sensing capabilities	01141 In use 1 ○ ➔	In use for more than 2 years 01142 1 ○ Yes 3 ○ No	01144 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ ➔	Plan to use within 2 years	01143 1 ○ Yes 3 ○ No						
o. High speed machining	01151 In use 1 ○ ➔	In use for more than 2 years 01152 1 ○ Yes 3 ○ No	01154 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ ➔	Plan to use within 2 years	01153 1 ○ Yes 3 ○ No						
p. Near net shape technologies	01161 In use 1 ○ ➔	In use for more than 2 years 01162 1 ○ Yes 3 ○ No	01164 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ ➔	Plan to use within 2 years	01163 1 ○ Yes 3 ○ No						
q. Micro manufacturing (micro machining or micro moulding)	01171 In use 1 ○ ➔	In use for more than 2 years 01172 1 ○ Yes 3 ○ No	01174 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ ➔	Plan to use within 2 years	01173 1 ○ Yes 3 ○ No						

			Location of your supplier(s) of this technology *(Please check all that apply)*

r. Micro Electro Mechanical Systems (MEMS)

01181

- In use 1 ○ → In use for more than 2 years
  - 01182
  - 1 ○ Yes
  - 3 ○ No

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
01184 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○

- Not in use 3 ○ → Plan to use within 2 years
  - 01183
  - 1 ○ Yes
  - 3 ○ No

Inspection

Location of your supplier(s) of this technology *(Please check all that apply)*

s. Automated vision-based systems used for inspection/testing of inputs and/or final products

01191

- In use 1 ○ → In use for more than 2 years
  - 01192
  - 1 ○ Yes
  - 3 ○ No

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
01194 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○

- Not in use 3 ○ → Plan to use within 2 years
  - 01193
  - 1 ○ Yes
  - 3 ○ No

t. Other automated sensor-based systems used for inspection/testing of inputs and/or final products including e-beam inspection

01201

- In use 1 ○ → In use for more than 2 years
  - 01202
  - 1 ○ Yes
  - 3 ○ No

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
01204 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○

- Not in use 3 ○ → Plan to use within 2 years
  - 01203
  - 1 ○ Yes
  - 3 ○ No

Communications

Location of your supplier(s) of this technology
(Please check all that apply)

u. Local Area Network (LAN) to machines on the business unit (plant) floor

01211
- In use 1 → In use for more than 2 years
  - 01212
  - 1 Yes
  - 3 No

01214

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
1	2	3	4	5	6	7

- Not in use 3 → Plan to use within 2 years
  - 01213
  - 1 Yes
  - 3 No

v. Company-wide computer networks (including LAN, Intranet and WAN)

01221
- In use 1 → In use for more than 2 years
  - 01222
  - 1 Yes
  - 3 No

01224

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
1	2	3	4	5	6	7

- Not in use 3 → Plan to use within 2 years
  - 01223
  - 1 Yes
  - 3 No

w. Inter-company computer networks (including Extranet and EDI)

01231
- In use 1 → In use for more than 2 years
  - 01232
  - 1 Yes
  - 3 No

01234

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
1	2	3	4	5	6	7

- Not in use 3 → Plan to use within 2 years
  - 01233
  - 1 Yes
  - 3 No

x. Wireless communications for production

01241
- In use 1 → In use for more than 2 years
  - 01242
  - 1 Yes
  - 3 No

01244

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
1	2	3	4	5	6	7

- Not in use 3 → Plan to use within 2 years
  - 01243
  - 1 Yes
  - 3 No

y. Wireless communications for office operations and/or marketing/sales activities

01251
- In use 1 → In use for more than 2 years
  - 01252
  - 1 Yes
  - 3 No

01254

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
1	2	3	4	5	6	7

- Not in use 3 → Plan to use within 2 years
  - 01253
  - 1 Yes
  - 3 No

Automated Material Handling

Location of your supplier(s) of this technology
(Please check all that apply)

Technology	Status	Duration	Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
z. Part identification for manufacturing automation (e.g. bar coding)	01261 In use 1 ○ ➔	In use for more than 2 years 01262 1 ○ Yes 3 ○ No	01264 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ ➔	Plan to use within 2 years	01263 1 ○ Yes 3 ○ No						
aa. Part identification for tracking materials and components (e.g. Radio Frequency Identification, RFID)	01271 In use 1 ○ ➔	In use for more than 2 years 01272 1 ○ Yes 3 ○ No	01274 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ ➔	Plan to use within 2 years	01273 1 ○ Yes 3 ○ No						
bb. Post production tracking of products (e.g. Radio Frequency Identification, RFID)	01281 In use 1 ○ ➔	In use for more than 2 years 01282 1 ○ Yes 3 ○ No	01284 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ ➔	Plan to use within 2 years	01283 1 ○ Yes 3 ○ No						
cc. Automated Storage/ Retrieval System (AS/RS)	01291 In use 1 ○ ➔	In use for more than 2 years 01292 1 ○ Yes 3 ○ No	01294 1 ○	2 ○	3 ○	4 ○	5 ○	6 ○	7 ○
	Not in use 3 ○ ➔	Plan to use within 2 years	01293 1 ○ Yes 3 ○ No						

Integration and Control

Location of your supplier(s) of this technology
(Please check all that apply)

dd. Multi axis capability — 01301

- In use 1 → In use for more than 2 years — 01302: 1 Yes / 3 No
  - 01304

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
1	2	3	4	5	6	7

- Not in use 3 → Plan to use within 2 years — 01303: 1 Yes / 3 No

ee. Computer(s) used for control on the business unit (plant) floor — 01311

- In use 1 → In use for more than 2 years — 01312: 1 Yes / 3 No
  - 01314

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
1	2	3	4	5	6	7

- Not in use 3 → Plan to use within 2 years — 01313: 1 Yes / 3 No

ff. Adaptive machine control — 01321

- In use 1 → In use for more than 2 years — 01322: 1 Yes / 3 No
  - 01324

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
1	2	3	4	5	6	7

- Not in use 3 → Plan to use within 2 years — 01323: 1 Yes / 3 No

gg. Human Machine Interface (HMI) with coordinated motion control — 01331

- In use 1 → In use for more than 2 years — 01332: 1 Yes / 3 No
  - 01334

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
1	2	3	4	5	6	7

- Not in use 3 → Plan to use within 2 years — 01333: 1 Yes / 3 No

hh. Computer Integrated Manufacturing (CIM) — 01341

- In use 1 → In use for more than 2 years — 01342: 1 Yes / 3 No
  - 01344

Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
1	2	3	4	5	6	7

- Not in use 3 → Plan to use within 2 years — 01343: 1 Yes / 3 No

			Location of your supplier(s) of this technology (Please check all that apply)						
			Your province or territory	The rest of Canada	United States	Mexico	Europe	Asia Pacific	All other countries
ii. Supervisory Control and Data Acquisition (SCADA)	01351 In use 1 →	In use for more than 2 years 01352 1 Yes 3 No	01354 1	2	3	4	5	6	7
	Not in use 3 →	Plan to use within 2 years	01353 1 Yes 3 No						
jj. Process control software	01361 In use 1 →	In use for more than 2 years 01362 1 Yes 3 No	01364 1	2	3	4	5	6	7
	Not in use 3 →	Plan to use within 2 years	01363 1 Yes 3 No						
kk. Digital, remote controlled process plant control (e.g. Fieldbus or Total Process Control (TPC))	01371 In use 1 →	In use for more than 2 years 01372 1 Yes 3 No	01374 1	2	3	4	5	6	7
	Not in use 3 →	Plan to use within 2 years	01373 1 Yes 3 No						
ll. Predictive process control software and/or smart machines	01381 In use 1 →	In use for more than 2 years 01382 1 Yes 3 No	01384 1	2	3	4	5	6	7
	Not in use 3 →	Plan to use within 2 years	01383 1 Yes 3 No						
mm. Use of inspection data in manufacturing control	01391 In use 1 →	In use for more than 2 years 01392 1 Yes 3 No	01394 1	2	3	4	5	6	7
	Not in use 3 →	Plan to use within 2 years	01393 1 Yes 3 No						

If you do not use any of the advanced technologies listed in Question 1 → please go to Question 8.

Investment in Advanced Technologies

This question explores the intensity of investment in advanced technologies.

2. Over the **last three years, 2005 to 2007**, what percentage of your **business unit's** (as described on the label on the first page of the questionnaire) capital investment in machinery and equipment was spent on advanced technologies (as listed in Question 1)?

02010
- 1 ○ 0%
- 2 ○ 1% to 5%
- 3 ○ 6% to 10%
- 4 ○ 11% to 15%
- 5 ○ 16% to 25%
- 6 ○ 26% to 50%
- 7 ○ 51% to 75%
- 8 ○ 76% to 100%

Skill Requirements

The purpose of this question is to provide a general picture of the skills required as a result of advanced technology adoption and the effect of new technology on training needs.

3. Have your **business unit's** (as described on the label on the first page of the questionnaire) employees received any **training** pertaining to the adoption of advanced technologies in the **last three years, 2005 to 2007**?

03010 1 ○ Yes 3 ○ No ➔ ***Please go to Question 4***

If **YES**, please indicate in which of the following areas **training** was provided pertaining to the adoption of advanced technologies. Please include both on-site and off-site training.
Please check (✓) all that apply.

Please check all that apply

a. Acquisition of fundamental competencies (reading, writing, second language, counting, calculating)	03021	○
b. Computer literacy	03022	○
c. Technical skills	03023	○
d. Quality control and improvement skills	03024	○
e. Safety skills	03025	○
f. Business skills	03026	○
g. Management skills	03027	○
h. Team building skills	03028	○
i. Other, *please specify:* 03029txt ________	03029	○

Development and Implementation of Advanced Technologies

This question seeks information on the process of technological change, specifically, how advanced technologies are integrated into your **business unit**.

4. How does your **business unit** acquire or integrate advanced technologies (equipment and/or software)? *Please check (✓) all that apply.*

Please check all that apply

a. By purchasing off-the-shelf advanced technology (equipment and/or software) 04001 ○

b. By leasing off-the-shelf advanced technology (equipment and/or software) 04002 ○

c. By licensing advanced technology 04003 ○

d. By customizing or significantly modifying existing advanced technology 04004 ○

e. By developing new advanced technologies (either alone or in conjunction with others) 04005 ○

f. Through merger or acquisition of another firm with advanced technologies 04006 ○

Sources of Information or Assistance

This question seeks information on the process of technological change including the source of information or assistance for the adoption of advanced technologies.

5. Please indicate which of the following sources of information or assistance play an important role for the adoption of advanced technologies in your **business unit**. *Please check (✓) all that apply.*

		Please check all that apply
INTERNAL to your firm		
a. Research	05001	○
b. Experimental development	05002	○
c. Production engineering	05003	○
d. Corporate head office	05004	○
e. Related business units	05005	○
f. Technology watch program	05006	○
g. Production staff	05007	○
h. Design staff	05008	○
i. Sales and marketing services	05009	○
EXTERNAL to your firm		
j. Trade fairs	05010	○
k. Conferences	05011	○
l. Publications	05012	○
m. Patents	05013	○
n. Consultants	05014	○
o. Service firms	05015	○
p. Suppliers	05016	○
q. Customers	05017	○
r. Other firms in your industry	05018	○
s. Universities, technical institutes or colleges	05019	○
t. Government laboratories and programs	05020	○
u. Trade and industry associations	05021	○
v. Not-for-profit organizations (excluding trade and industry associations)	05022	○
w. Other source (internal or external), *please specify:* 05023txt ______	05023	○
x. None of the above	05024	○

Results/Outcome of Adoption

This question seeks information on the results of technology adoption.

6. Please rate the impact of the following **effects** following the adoption of advanced technology by your **business unit**.

EFFECTS		Degree of Impact			
		High	Medium	Low	Not applicable
Improvement in productivity due to:					
a. Reduced labour requirements per unit of output	06001	5	3	1	0
b. Reduced material consumption per unit of output	06002	5	3	1	0
c. Reduced set-up time	06003	5	3	1	0
d. Reduced cycle or processing time	06004	5	3	1	0
e. Reduced error/rejection rate	06005	5	3	1	0
Product improvement:					
f. New product features	06006	5	3	1	0
g. Reduced time to market	06007	5	3	1	0
h. Improvement in product quality	06008	5	3	1	0
i. Improved satisfaction of client needs	06009	5	3	1	0
Business unit organization changes:					
j. Increased flexibility, customization and/or specialization	06010	5	3	1	0
k. Increased skill requirements	06011	5	3	1	0
Business unit efficiencies:					
l. Increased overall equipment (OEE) utilization rate	06012	5	3	1	0
m. Reduced energy consumption	06013	5	3	1	0
n. Reduced energy costs	06014	5	3	1	0
o. Improved integration and coordination of activities with suppliers and/or customers	06015	5	3	1	0
Market performance:					
p. Increased market share	06016	5	3	1	0
q. Increased profitability	06017	5	3	1	0
r. Keeping up with competitors	06018	5	3	1	0
s. Opening new export markets	06019	5	3	1	0
t. Increased ability to respond to customer requirements	06020	5	3	1	0
u. Improved ability to adapt to supplier capabilities	06021	5	3	1	0
Other:					
v. Reduction of environmental impacts	06022	5	3	1	0
w. Other, *please specify:* 06023txt	06023	5	3	1	0

Obstacles to Adoption

This question explores the factors that slowed down or caused problems for your **business unit** during the process of advanced technology adoption.

7. Please rate the importance of the following **obstacles** to the adoption of advanced technologies by your **business unit**.

OBSTACLES		Degree of Importance			
		High	Medium	Low	Not an obstacle
Lack of financial justification due to:					
a. Small market size	07001	5	3	1	0
b. High cost of equipment	07002	5	3	1	0
c. Cost of capital	07003	5	3	1	0
d. Availability of capital	07004	5	3	1	0
e. Little or no cash flow	07005	5	3	1	0
f. Costs to develop software	07006	5	3	1	0
g. Cost of integration of new technology	07007	5	3	1	0
h. Uncompetitive return on investment (ROI)	07008	5	3	1	0
i. Cost of training	07009	5	3	1	0
Human resources:					
j. Shortage of skilled workers	07010	5	3	1	0
k. Worker resistance	07011	5	3	1	0
Organizational:					
l. Organizational rigidity of the firm	07012	5	3	1	0
m. The decision to adopt is made elsewhere in the firm and not in the business unit itself	07013	5	3	1	0
n. Resistance to introduction of new technology	07014	5	3	1	0
o. Inability to evaluate new technology	07015	5	3	1	0
p. Difficulty or inability to integrate new technology into existing system	07016	5	3	1	0
External support services:					
q. Lack of technical support or services (from service firms, consultants or vendors)	07017	5	3	1	0
r. Lack of private support (programs) for training	07018	5	3	1	0
s. Lack of government support for training	07019	5	3	1	0
t. Lack of government support services (including intelligence centres and networks)	07020	5	3	1	0
Other:					
u. Difficulty integrating technology across the supply chain (having technologies work concurrently)	07021	5	3	1	0
v. Equipment or technologies unequipped for small lot fabrication	07022	5	3	1	0
w. Insufficient flexibility of regulations or standards	07023	5	3	1	0
x. Other, *please specify*: 07024txt ______	07024	5	3	1	0

Section B - Advanced Practices

Business Practices

8. Please indicate which of the following **practices** are regularly used in your **business unit**.
Please check (✓) all that apply.

Please check all that apply

Product development

a. Concurrent engineering 08001
b. Cross-functional design teams 08002

Manufacturing and control management

c. Electronic work order management 08003
d. Distribution Resource Planning (DRP) 08004
e. Lean Manufacturing 08005
f. Manufacturing Resource Planning (MRPII)/ Enterprise Resource Planning (ERP) 08006
g. Just-in-time (JIT) control 08007

Quality management (including Lean)

h. Continuous improvement (including TQM) 08008
i. Business unit certification (e.g. ISO9000, ISO14000) 08009
j. Statistical Process Control (SPC) 08010
k. Quality Management System (QMS) 08011
l. Quality Function Deployment (QFD) 08012
m. Six sigma 08013

Supply chain/logistics management

n. Certification of suppliers 08014
o. E-sourcing (online sourcing)/E-procurement (online procurement) 08015
p. E-based (online) design/engineering 08016
q. On-line trading (bartering) 08017
r. Warehouse Management System (WMS) 08018
s. Customer Relationship Management (CRM) (includes order management) 08019
t. Use of forecasting/demand planning software 08020
u. Advanced Planning and Scheduling (APS) 08021
v. Transportation management system 08022

Others

w. Competitive Technological Intelligence (CTI) and benchmarking 08023
x. Sustainable development strategy/Environmental stewardship plan 08024
y. Product Data Management/Life Cycle Management (PDM/PLM) 08025
z. Outsourcing/offshoring 08026
aa. Collaboration(s)/strategic alliance(s) 08027

bb. None of the above 08028

Design Practices

DESIGN ACTIVITIES may include creative problem solving techniques in the development, engineering, testing and/or communication of designs for products, structures, and/or systems.

9. Do you carry out design activities in your **business unit**?

09010 1 ◯ Yes

3 ◯ No ➔ ***Please go to Question 11***

Design Practices Expenditures

10. What percentage of your **business unit's** total expenditures (dollar value) in 2007, were on design activities? *Please provide your best estimate.*

10001 ____ %

a. What proportion of these expenditures was in-house (in your business unit)?	10101	____ %
b. What proportion of these expenditures was by other business units or operations of your larger firm?	10102	____ %
c. What proportion of these expenditures was for externally acquired design services (not carried out by other business units or operations of your larger firm)?	10103	____ %

Section C - Emerging Technologies

Geomatics/Geospatial Technologies

Geomatics is the science and technology of gathering, analyzing, interpreting, distributing and using geographic information. Geomatics encompasses a broad range of disciplines that can be brought together to create a detailed but understandable picture of the physical world and our place in it. The disciplines include: surveying, mapping, remote sensing, geographic information systems, and global positioning systems.

Geospatial technologies refer to hardware and software systems that relate and display data of geographic, spatial or location nature. The technology helps to increase the speed of data interpretation and analysis for geomatic research.

11. Please indicate (✓) whether the following geomatics/geospatial technologies are in use in your **business unit**. If in use, please indicate if it has been in use for more than two years in your **business unit**. If not in use, please indicate if you plan to use it within two years in your **business unit**.

a. Geographic Information Systems (GIS)	11011 In use 1 ◯ ➔	In use for more than 2 years	11012 1 ◯ Yes 3 ◯ No
	Not in use 3 ◯ ➔	Plan to use within 2 years	11013 1 ◯ Yes 3 ◯ No
b. Global Positioning System (GPS)	11021 In use 1 ◯ ➔	In use for more than 2 years	11022 1 ◯ Yes 3 ◯ No
	Not in use 3 ◯ ➔	Plan to use within 2 years	11023 1 ◯ Yes 3 ◯ No
c. Remote Sensing (RS)	11031 In use 1 ◯ ➔	In use for more than 2 years	11032 1 ◯ Yes 3 ◯ No
	Not in use 3 ◯ ➔	Plan to use within 2 years	11033 1 ◯ Yes 3 ◯ No

If none of the above three geomatics/geospatial technologies are in use in your business unit ▶ *Please go to Question 13*

12. In reference to the geomatics/geospatial technologies which you indicated are in use in your **business unit** in Question 11, please indicate their purpose. *Please check (✓) all that apply.*

Please check all that apply

- a. Planning (visualization) — 12001 ◯
- b. Monitoring supply (including harvesting and extraction activities) — 12002 ◯
- c. Monitoring input or work in process materials in the business unit — 12003 ◯
- d. Monitoring distribution of outputs — 12004 ◯
- e. Other, *please specify:* 12005txt ________ — 12005 ◯

Biotechnologies

Biotechnology is defined as the application of science and engineering in the direct or indirect use of living organisms in their natural or modified forms in an innovative manner in the production of goods and services or to improve existing processes.

Biotechnologies can be grouped in the following types: DNA (the coding); proteins and molecules (the functional blocks); cell and tissue culture and engineering; process biotechnologies; sub-cellular organisms e.g. gene therapy, viral vectors; others (bioinformatics, nanobiotechnologies, environmental biotechnology, other). For the purpose of this survey, do not include fermentation for beer, bread, cheese or yogurt.

13. Please indicate (✓) whether you are using (in use) or are not currently using (not in use) biotechnologies in your **business unit**. If you are currently using biotechnology, please indicate (✓) if it has been in use for more than 2 years in your **business unit**. If you are not currently using biotechnologies please indicate (✓) if you plan to use it within 2 years in your **business unit**.

DNA, proteins and molecules, cell and tissue culture and engineering, process biotechnologies, sub-cellular organisms, and others (do not include fermentation for beer, bread, cheese or yogurt).	13011 In use 1 ○ →	In use for more than 2 years	13012 1 ○ Yes 3 ○ No
	Not in use 3 ○ →	Plan to use within 2 years	13013 1 ○ Yes 3 ○ No

Nanotechnologies

Nanotechnology is the manufacturing of devices and products from molecular or nano-scale components with extraordinary properties. One nanometre (1 nm) is one billionth of a metre (.000000001 m), 3 to 4 atoms wide. Examples of nanotechnology include: nanoparticles, nanomaterials, nanocoatings, nanostructures, nanosystems, nanophotonics, nanoelectronics, nanomedicine, nanobiotechnology.

14. Please indicate (✓) whether you are using (in use) or are not using (not in use) the following nanotechnologies in your **business unit**. If you are using the nanotechnology, please indicate if it has been in use for more than 2 years in your **business unit**. If you are not currently using the nanotechnology please indicate (✓) if you plan to use it within 2 years in your **business unit**.

a. Nanomaterials (includes both organic and inorganic nanocomposites, nanopowders, nanoparticles, nanocoatings, carbon nanotubes)	14011 In use 1 ○ →	In use for more than 2 years	14012 1 ○ Yes 3 ○ No
	Not in use 3 ○ →	Plan to use within 2 years	14013 1 ○ Yes 3 ○ No
b. Nano-devices, including sensors, NEMS, and nano-enabled MEMS	14021 In use 1 ○ →	In use for more than 2 years	14022 1 ○ Yes 3 ○ No
	Not in use 3 ○ →	Plan to use within 2 years	14023 1 ○ Yes 3 ○ No
c. Nanoelectronics, including photonics, nano-optical devices/sensors or light emitters	14031 In use 1 ○ →	In use for more than 2 years	14032 1 ○ Yes 3 ○ No
	Not in use 3 ○ →	Plan to use within 2 years	14033 1 ○ Yes 3 ○ No
d. Nano-enabled industrial processes (e.g. nano-enabled catalysts) including systems such as nanofabrication	14041 In use 1 ○ →	In use for more than 2 years	14042 1 ○ Yes 3 ○ No
	Not in use 3 ○ →	Plan to use within 2 years	14043 1 ○ Yes 3 ○ No
e. Nano-enabled industrial products	14051 In use 1 ○ →	In use for more than 2 years	14052 1 ○ Yes 3 ○ No
	Not in use 3 ○ →	Plan to use within 2 years	14053 1 ○ Yes 3 ○ No
f. Nano-enabled consumer products including cosmetics and health care products	14061 In use 1 ○ →	In use for more than 2 years	14062 1 ○ Yes 3 ○ No
	Not in use 3 ○ →	Plan to use within 2 years	14063 1 ○ Yes 3 ○ No
g. Nano-tools, hardware, instruments and software	14071 In use 1 ○ →	In use for more than 2 years	14072 1 ○ Yes 3 ○ No
	Not in use 3 ○ →	Plan to use within 2 years	14073 1 ○ Yes 3 ○ No

15. Please indicate (✓) whether you are **developing**, the following nanotechnologies (as listed in Question 14) in your **business unit**. *Please check (✓) all that apply.*

		Please check all that apply
a.	Nanomaterials (includes both organic and inorganic nanocomposites, nanopowders, nanoparticles, nanocoatings, carbon nanotubes)	15001 ○
b.	Nano-devices, including sensors, NEMS, and nano-enabled MEMS	15002 ○
c.	Nanoelectronics, including photonics, nano-optical devices/sensors or light emitters	15003 ○
d.	Nano-enabled industrial processes (e.g. nano-enabled catalysts) including systems such as nanofabrication	15004 ○
e.	Nano-enabled industrial products	15005 ○
f.	Nano-enabled consumer products including cosmetics and health care products	15006 ○
g.	Nano-tools, hardware, instruments and software	15007 ○
h.	None of the above	15008 ○

Section D - General Questions

Success Factors

This question collects information on business success factors.

16. Please rate the importance of the following factors for the success of your **business unit**.

SUCCESS FACTORS		Degree of Importance			
		High	Medium	Low	Not applicable
Products and marketing					
a. Developing new products (goods or services)	16001	5	3	1	0
b. Improving existing products (goods or services)	16002	5	3	1	0
c. Entering new markets	16003	5	3	1	0
Process					
d. Developing new methods of manufacturing or producing products	16004	5	3	1	0
e. Improving existing methods of manufacturing or producing products	16005	5	3	1	0
f. Introducing new logistics, delivery or distribution methods for your inputs or products (goods or services)	16006	5	3	1	0
g. Introducing significantly improved logistics, delivery or distribution methods for your inputs or products (goods or services)	16007	5	3	1	0
h. Introducing new supporting activities for processes such as maintenance systems or operations for purchasing, accounting or computing	16008	5	3	1	0
i. Introducing significantly improved supporting activities for processes such as maintenance systems or operations for purchasing, accounting or computing	16009	5	3	1	0
j. Reducing manufacturing costs	16010	5	3	1	0
k. Developing new manufacturing technology(ies)	16011	5	3	1	0
l. Using new materials	16012	5	3	1	0
m. Reducing cycle time for new product development and market introduction	16013	5	3	1	0
Human resources					
n. Using teams (e.g. cross-functional, quality improvement)	16014	5	3	1	0
o. Carrying out ongoing technical training	16015	5	3	1	0
p. Recruiting talent	16016	5	3	1	0
Financial resources					
q. Securing funding from conventional sources (i.e. banks)	16017	5	3	1	0
r. Securing support from venture capitalists	16018	5	3	1	0
s. Securing support from angel investors/family	16019	5	3	1	0
t. Securing government support funding	16020	5	3	1	0
Other					
u. Implementing new information and communications technologies (ICT)	16021	5	3	1	0

Innovation

Innovation is vital for economic growth and development. Responses to these questions will allow an exploration of the relationship between advanced technology use and innovation.

17. A **PRODUCT INNOVATION** is the market introduction of a **new** good or service or a **significantly improved** good or service. The innovation (new or improved) must be new to your business unit. Exclude the simple resale of new goods purchased from other business units and changes of a solely aesthetic nature (i.e. colour change, model change, label change, etc.).

During the last three years, ***2005 to 2007***, did your **business unit** introduce?

		Yes	No
a. New or significantly improved goods?	17001	1 ○	3 ○
b. New or significantly improved services?	17002	1 ○	3 ○

18. During the last three years, **2005 to 2007**, were **ANY** of your new or significantly improved products (goods or services) introduced by your **business unit**:

		Yes	No	Do not know
a. A first in your province/territory?	18001	1 ○	3 ○	0 ○
b. A first in Canada?	18002	1 ○	3 ○	0 ○
c. A first in North America?	18003	1 ○	3 ○	0 ○
d. A world first?	18004	1 ○	3 ○	0 ○

19. A **PROCESS INNOVATION** is the implementation of a **new** or **significantly improved** production process, distribution method, or support activity for your goods or services. The innovation (new or improved) must be new to your business unit.

During the last three years, **2005 to 2007**, did your **business unit** introduce?

		Yes	No
a. New or significantly improved methods of manufacturing or producing goods or services?	19001	1 ○	3 ○
b. New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services?	19002	1 ○	3 ○
c. New or significantly improved supporting activities for your processes, such as maintenance systems or operations for administration, purchasing, accounting, or computing?	19003	1 ○	3 ○

20. During the last three years, **2005 to 2007**, were **ANY** of your new or significantly improved processes introduced by your **business unit**:

		Yes	No	Do not know
a. A first in your province/territory?	20001	1	3	0
b. A first in Canada?	20002	1	3	0
c. A first in North America?	20003	1	3	0
d. A world first?	20004	1	3	0

21. An **ORGANIZATIONAL INNOVATION** is the implementation of new or significant changes in your firm or your business unit's structure or management methods that are intended to improve your business unit's use of knowledge, the quality of your goods or services, or the efficiency of work flows.

A **MARKETING INNOVATION** is the implementation of new or significantly improved designs or sales methods to increase the appeal of your goods or services or to enter new markets.

During the last three years, **2005 to 2007**, did your **business unit** introduce:

		Yes	No
ORGANIZATIONAL INNOVATION			
a. New or significantly improved knowledge management systems to better use or exchange information, knowledge and skills within your firm	21001	1	3
b. Major changes to the organization of work within your enterprise, such as changes in the management structure or integrating different departments or activities	21002	1	3
c. New or significant changes in external relations with other firms or public institutions, such as through alliances, partnerships, outsourcing or sub-contracting	21003	1	3
MARKETING INNOVATION			
d. Significant changes to the design or packaging of a good or service. Exclude routine/ seasonal changes such as clothing fashions	21101	1	3
e. New or significantly changed sales or distribution methods, such as internet sales, franchising, direct sales or distribution licenses	21102	1	3

Research and Development (R&D)

These questions will provide data on the type of involvement in R&D and intensity of R&D being carried out in the business unit.

22. Please indicate (✓) the categories below which describe your **business unit's** involvement in R&D activities during the last three years, **2005 to 2007**. Please **exclude** quality control, routine testing, style changes, minor adaptations and market research. Please include technological advances accomplished by operating personnel. *Please check (✓) all that apply.*

		Please check all that apply
a. Research and development (R&D) activities within your organization, performed by your business unit	22001	○
b. R&D performed on your behalf by other business units or R&D laboratories that are part of the larger firm to which your business unit belongs	22002	○
c. R&D performed by other business units that are part of your larger firm (exclude R&D performed on your behalf as described in option b above)	22003	○
d. Development of new products (goods or services) or processes using operating personnel in your business unit	22004	○
e. R&D performed by your business unit jointly with other business unit(s) that are not part of your larger firm	22005	○
f. Contracting out R&D services performed by other firms or by public or private research organizations and purchased by your business unit	22006	○
g. None of the above	22007	○

23. Please provide your best estimate of the percentage of the full-time employees in your **business unit** in **2007** who were involved in **research and development activities**. Please **exclude** employees involved in quality control, routine testing, style changes, minor adaptations and market research.

23001 ______ %

General Information

24. Please indicate (✓) the location of the head office of your **controlling firm** (all business units and operations in Canada or in other countries that comprise your company).
*Please check (✓) **one** option only.*

*Please check **one** option only*

a. In your province/territory	24001	○
b. In the rest of Canada	24002	○
c. United States	24003	○
d. Mexico	24004	○
e. Europe	24005	○
f. Asia Pacific	24006	○
g. All other countries	24007	○

25. Please provide your best estimate of the **percentage of your business unit's total revenue** that came from the sale of products (goods or services) to clients in the following geographical markets **in 2007**.

a. In your province/territory	25001		%
b. In the rest of Canada	25002		%
c. United States	25003		%
d. Mexico	25004		%
e. Europe	25005		%
f. Asia Pacific	25006		%
g. All other countries	25007		%
TOTAL		**100**	%

Please make a copy for your records which may be referenced if we need to follow-up with any specific issues. Thank you.

Please return the completed survey in the enclosed return-envelope. Thank you very much for your participation.

8.2 Appendix II: Survey Sample

Table 1A: Forest Sector Coverage in 2007 Survey of Advanced Manufacturing Technology by NAICS code							
NAICS 2007		**Industry**	**Population**	**Sample**	**Coverage**	**Response**	**Number of Firms**
		Forest Sector	**2,306**	**1,760**	**76.3%**	**75.5%**	**1,328**
1133		**Logging**	**373**	**373**	**100.0%**	**79.9%**	**248**
321		**Wood product manufacturing**	**1,423**	**1,003**	**70.5%**	**74.2%**	**745**
	3211	Sawmills and wood preservation	514	360	70.0%	68.9%	248
	3212	Veneer, plywood and engineered wood product manufacturing	249	224	90.0%	80.3%	180
	3219	Other wood product manufacturing	660	419	63.5%	75.4%	317
322		**Paper manufacturing**	**510**	**384**	**75.3%**	**74.5%**	**286**
	3221	Pulp, paper and paperboard mills	143	138	96.5%	69.9%	97
	3222	Converted paper product manufacturing	367	246	67.0%	77.0%	189
Source: Statistics Canada (2008)							

Table 2A: Survey of Advanced Technology 2007 - Estimation			
Symbol	**Meaning**	**Coefficient of variation**	**Standard Error**
A	Very reliable	≤5.0%	≤2.5%
B	Reliable	>5.0% and ≤15.0%	>2.5% and ≤7.5%
E	Use with caution	>15.0% and ≤30.0%	>7.5% and ≤15.0%
F	Too unreliable to be published	>30.0%	>15.0%
Source: Statistics Canada (2008)			

8.3 Appendix III: Interview Code List

Code	Description	Example Quotation
Pre-installation		
Need Identification	The factors that help forest sector firms identify new technology needs	"Basically what we do is we go through a feasibility study. We look at what's a good fit for our – geographically you gotta look at what is a good fit – what is something you can market and sell, and what is a good fit." (Interview #2, P.3)
Technology Background	Information about the type of technology the firm is adopting	"The technology is basically a distillation process that will take this unrefined methanol and upgrade it to what we call – you can just use the word I guess – 'commercial grade methanol' which we could then use." (#2, P.2)
Goals	The goals the firm wishes to achieve in adopting and using the new technology	"When you have built-in inefficiencies [in your process cycle], because you have a waste product, to make the process more efficient, you need to find something to do with that waste product. You always want to be increasing efficiency, you never want to have something in your production cycle where you are actually encouraging inefficiency because you have excess." (Interview #1, P.2)
Top Management Support	Managerial involvement in the implementation of a new technology	"With that particular project my role was right from the beginning to end. It began as an idea, and really, the beginning of the idea was, we saw a waste stream (…) my role there was all the way from the initial investigation of what we could do, what we could use that heat for. Right up to today, the investigation of the options, the hiring of a firm to do a feasibility study, the engineering, so I oversaw these things. Hiring an engineering firm to do all the engineering. The negotiation of hydro agreements and purchase agreements and funding agreements with NRCan and installation and I'm the President of the new company we set up. With

		that particular one, I have been completely involved right from the start." (#1, P.1)
Employee Training and Involvement	The training employee's receive before and during the implementation of the technology. The employees were involved in the technology adoption process	"We had budgeted and set up onsite training and we trained all of the individuals and the chemical recovery utilities folks that have to operate this. They were all trained at one point. Halfway through the project, when we were starting up one phase, the people in the area were trained and as we were getting closer to the start-up, we assigned key individuals from operations to be part of a team." (#2, P.5)
Installation and Commissioning		
Challenges: Regulations	The bureaucratic and regulatory challenges a firm faces when implementing a new technology	"Power generation in British Columbia is regulated by a public utility, a huge public utility. And, there was an enormous amount of…um…I don't want to call it bureaucracy or red tape…*(Laughs)*…design process, and rightly so. When you are looking at generating power onto the grid in British Columbia it's a very complicated thing." (#1, P.5)
Challenges: Financing	Lack of finance/ Difficulty in accessing finance to purchase and implement a new technology	"I would say we probably wouldn't have been able to [adopt the technology] without the NRCan funding and Hydro funding." (#1, P.7)
Challenges: Lack of qualified personnel	The challenges a firm faces in finding qualified personnel to implement the new technology	"Where there used to be lots of engineer that we would call upon, and trades people, they have in the last 5 years, because there haven't been many projects in the forestry industry, they have gone to the mines and oil and gas. So, when we actually went to get crews to do the installation, we found it very difficult." (#1, P.6)
Enabler: Financing	Financial support received from outside sources, such as the federal or provincial government	"The project is a $10 million project. We received half of that funding, $5 million, from the IFIT program. The Alberta government provided $1.5 million towards what they call "infrastructure" for any new green technology, they are trying to

		support…you know the risk with this, there's no guarantees. Without the IFIT support, in reality when you look at it, they helped us to take the next step." (#2, P.6)
Enabler: Support from institutions	The (non-financial) support received from outside sources, such as the federal or provincial government	"From the IFIT perspective, the people they hired are very professional and they were very supportive. From our perspective, I can't say enough about that. We received their support and they have the right people in place. The right people to evaluate and their support has been great." (#2, P.6)
Diversification	An expansion or change in the firm's operations as a result of the technology adoption	"We were creating a sort of a brand new direction for the company, for the production of energy, we had never done that before. And we were going to use that company to seek additional opportunities in energy creation." (#1, P.3)
Post-commissioning		
High Performance Orientation	The firm is seeking more innovation and efficiency as a result of the technology adoption	"We found that once we put the turbo generator in, not only did it up the excess heat, but our employees are now looking for more ways to be efficient in the delivery of the heat from the original system, so we are trying to be more efficient in how we deliver heat from the kilns, because that leaves more heat for the [power] generation." (#1, P.3)
Improved Profile	The firm gained a positive reputation in the industry as a result of the technology adoption. Other firms are trying to emulate its success	"We also received a lot of profile in our industry by being the first ones to do this. There are a number of other firms that are sort of copying it now." (#1, P.7).
Employee Pride	Employee pride in the new technology	"When you said the firm-wide initiative, that brings to mind the pride of the employees, because they had something new – proud of it." (#1, P.4)

8.4 Appendix IV: Survey Tables

Table 3A: Percentage of capital investment in machinery and equipment spent on advanced technologies during the three years 2005 to 2007					
	Logging Adopter	**Wood Product Adopter**	**Paper Adopter**	**Forest Sector Adopter**	**ICT Adopter**
0%	45.5	22.0	21.2	25.4	10.9
1% to 5%	32.0	36.5	35.9	35.6	37.3
6% to 10%	8.3	12.0	18.2	13.0	13.0
11% to 15%	1.9	7.3	6.5	6.3	6.9
16% to 25%	6.1	7.3	4.6	6.4	8.6
26% to 50%	5.8	6.6	6.2	6.3	8.2
51% to 75%	0.0	5.6	3.2	4.2	8.9
76% to 100%	0.5	2.8	4.1	2.7	6.1

Source: Statistics Canada (2008)

Table 4A: Percentage of business units involved in R&D activities during the three years, 2005 to 2007

	Logging		Wood		Paper		Forest Sector		ICT manufacturing	
	AT user	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**
Percentage of business units involved in R&D activities	23.0	6.3	55.0	18.0	74.2	43.7	54.8	12.9	86.8	51.8
Research and development (R&D) activities within the organization, performed by the business unit	16.6	1.5	42.1	13.6	58.3	37.0	42.2	8.2	80.3	35.7
R&D performed on the behalf by other business units or R&D laboratories that are part of the larger firm to which the business unit belongs	6.0	1.4	12.3	1.0	24.8	0.0	14.4	1.2	18.4	15.7
R&D performed by other business units that are part of the larger firm (exclude R&D performed on the behalf as described in option b above)	3.8	0.0	6.0	1.5	16.8	0.0	8.3	0.7	13.1	5.3
Development of new products (goods or services) or processes using operating personnel in the business unit	11.0	4.2	30.7	9.5	43.5	18.2	30.8	7.1	66.0	21.5
R&D performed by the business unit jointly with other business unit(s) that are not part of the larger firm	5.0	0.0	8.3	5.4	16.0	0.0	9.7	2.4	27.7	0.0
Contracting out R&D services performed by other firms or by public or private research organizations and purchased by the business unit	5.7	0.0	9.7	0.0	16.3	0.0	10.7	0.0	21.9	5.7
None of the above	77.0	93.7	45.0	82.0	25.8	56.3	45.2	87.1	13.2	48.2

Source: Statistics Canada (2008)

Table 5A: Type of Advanced Technology Adopted					
	Logging Adopter	**Wood Adopter**	**Paper Adopter**	**Forest Sector Adopter**	**ICT Adopter**
Design, engineering and virtual manufacturing	24.0	64.0	65.5	58.1	87.6
Processing, fabrication and assembly	21.1	52.5	39.1	44.3	57.0
Inspection	11.7	29.0	41.9	29.5	31.2
Communications	92.0	93.9	96.7	94.3	98.2
Automated Material Handling	20.2	31.4	51.2	34.5	42.6
Integration and Control	44.9	66.5	79.1	66.2	74.2

Source: Statistics Canada (2008)

Table 6A: Number of Technologies Adopted					
	Logging Adopter	**Wood Product Adopter**	**Paper Adopter**	**Forest Sector Adopter**	**ICT Adopter**
1 - 4	68.8	29.9	21.3	33.8	13.7
5 - 9	19.9	29.1	28.1	27.4	32.2
10 - 14	4.4	24.4	22.8	20.9	27.7
15 - 20	3.9	11.3	20.4	12.4	18.4
20 +	3.1	5.3	7.4	5.5	8.0

Source: Statistics Canada (2008)

Table 7A: Business Practices Employed (Advanced Tech Users vs. Advanced Tech Non-Users)						
	Forest Sector		**All Manufacturing**		**ICT Manufacturing**	
	AT user	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**
Product development	33.2	2.6	45.6	6.6	73.3	33.5
Concurrent engineering	17.7	0.4	29.6	3.5	60.0	33.5
Cross-functional design teams	25.1	2.6	35.9	4.9	59.7	28.6
Manufacturing and control management	62.8	9.8	73.5	22.3	78.7	49.4
Electronic work order management	38.2	3.6	48.0	10.5	60.6	49.4
Distribution Resource Planning (DRP)	10.4	0.4	12.5	1.9	15.3	7.6
Lean Manufacturing	29.8	3.5	35.5	5.7	39.4	19.2
Manufacturing Resource Planning/ Enterprise Resource Planning	20.7	0.4	32.2	3.4	52.3	30.0
Just-in-time (JIT) control	25.2	3.7	33.1	10.6	34.3	19.2
Quality management (including Lean)	64.4	16.8	69.7	25.4	82.1	43.0
Continuous improvement (including TQM)	43.7	12.1	49.5	14.1	59.4	23.7
Business unit certification	34.5	6.7	39.2	11.8	54.7	43.0
Statistical Process Control (SPC)	18.2	0.4	21.9	1.9	28.6	19.2
Quality Management System (QMS)	35.4	3.0	40.9	11.7	51.7	28.6
Quality Function Deployment (QFD)	8.2	0.4	10.6	1.0	12.0	7.6
Six Sigma	7.2	0.4	10.7	0.7	13.5	11.6
Supply chain/logistics management	58.6	8.6	69.0	20.8	80.7	43.6
Certification of suppliers	28.7	2.0	40.0	14.2	56.8	43.6
E-sourcing/ E-procurement						
E-based design/engineering	20.2	4.4	26.1	6.8	42.9	19.2
On-line trading (bartering)	5.4	0.4	8.0	0.7	11.3	7.6
Warehouse Management System (WMS)	3.2	0.4	3.2	0.8	3.8	7.6
Customer Relationship Management	19.4	1.2	19.1	1.6	20.2	17.4
Use of forecasting/demand planning	19.9	1.2	25.1	4.0	40.2	16.1
software	18.5	1.1	25.7	1.4	33.7	12.1
Advanced Planning and Scheduling	16.1	0.4	20.6	2.3	23.2	19.2
Transportation management system	19.8	0.8	15.6	2.3	8.0	7.6
Others	34.1	2.9	40.1	6.5	62.9	35.0
Competitive Technological Intelligence (CTI) and benchmarking	7.1	0.4	7.8	0.7	11.2	12.5
Sustainable development strategy/Environmental stewardship plan	19.2	0.8	9.9	1.4	7.2	7.6
Product Data Management/Life Cycle Management (PDM/PLM)	4.4	0.4	9.0	1.1	18.7	19.2
Outsourcing/Off shoring	12.3	1.6	24.5	4.7	46.3	18.4
Collaborations(s)/strategic alliance(s)	12.1	2.5	17.9	2.3	37.1	24.2

Source: Statistics Canada (2008)

Table 8A: Business Units Providing Training as a Result of Adoption					
	Logging Adopter	Wood Adopter	Paper Adopter	Forest Sector Adopter	ICT Adopter
Business Units Providing Training as a Result of Adoption	47.5	59.4	62.2	58.2	69.8

Source: Statistics Canada (2008)

Table 9A: Type of Training Provided					
	Logging Adopter	Wood Adopter	Paper Adopter	Forest Sector Adopter	ICT Adopter
Acquisition of fundamental competencies	13.2	14.6	18.2	15.3	21.4
Computer literacy	65.2	64.8	66.6	65.3	62.2
Technical skills	74.5	82.6	83.4	81.8	87.3
Quality control and improvement skills	50.9	60.0	69.1	61.3	63.8
Safety skills	75.3	68.3	67.3	68.9	66.0
Business skills	24.8	22.4	24.1	23.2	34.2
Management skills	32.9	40.1	42.1	39.7	41.8
Team building skills	41.8	40.0	39.5	40.1	37.4

Source: Statistics Canada (2008)

Table 10A: Importance of the following obstacles to the adoption of advanced technology (Advanced Technology Adopters)

	Forest Sector	All Manufacturing	ICT Manufacturing
Lack of financial justification	93.0	92.4	95.8
Small market size	63.9	68.2	74.2
High cost of equipment	88.8	87.4	91.7
Cost of capital	85.9	84.1	88.6
Availability of capital	82.8	80.1	85.0
Little or no cash flow	71.2	68.9	72.5
Cost to develop software	69.5	67.3	76.0
Cost of integration of new technology	82.3	81.7	85.4
Uncompetitive return on investment	77.5	78.1	81.2
Cost of training	80.6	78.5	78.7
Human resources	80.7	83.3	83.1
Shortage of skilled workers	79.6	81.0	80.8
Worker resistance	71.4	72.2	68.6
Organizational	82.7	82.5	84.3
Organizational rigidity of the firm	63.6	65.5	64.2
The decision to adopt is made elsewhere in the firm and not in the business unit itself	47.8	44.9	40.6
Resistance to introduction of new technology	59.0	60.6	59.2
Inability to evaluate new technology	62.9	63.7	63.4
Difficulty or inability to integrate new technology into existing system	71.0	71.6	73.7
External support services	78.9	76.5	78.5
Lack of technical support or services (from service firms, consultants or vendors)	69.7	68.8	70.6
Lack of private support (programs) for training	63.6	64.0	64.3
Lack of government support for training	64.0	63.8	65.4
Lack of government support services (including intelligence centres and networks)	62.4	61.7	64.4
Other	71.1	71.2	80.6
Difficulty integrating technology across the supply chain (having technologies work concurrently)	63.8	61.0	63.5
Equipment or technologies unequipped for small lot fabrication	56.9	61.4	72.9
Insufficient flexibility of regulations or standards	52.3	53.5	57.1
Other	0.9	1.3	0.7

Source: Statistics Canada (2008)

Table 11A: Obstacles to AMT Adoption Forest Sector				
	Logging Adopter	Wood Adopter	Paper Adopter	Forest Sector Adopter
Lack of financial justification	81.8	93.1	92.9	93.0
Human Resources	77.4	81.9	77.6	80.7
Organizational	63.5	82.9	82.4	82.7
External Support Services	63.8	79.6	77.5	78.9
Other	52.1	71.7	69.6	71.1

Source: Statistics Canada (2008)

Table 12A: Novelty of Innovation in Manufacturing Sectors (Advanced Tech Users vs. Advanced Tech Non-Users)						
	Forest Sector		**All Manufacturing**		**ICT Manufacturing**	
	AT user	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**
New or significantly improved products	40.8	11.6	59.7	24.1	80.0	14.3
Goods	35.2	6.2	54.4	20.8	76.3	7.6
Services	20.7	9.3	28.0	14.1	33.9	14.3
Novelty of new or significantly improved products (goods/services) introduced						
Only firm first	62.4	83.6	51.5	71.2	33.8	X
First in province but not first in Canada	13.5	14.3	9.7	9.5	3.2	X
First in Canada but not first in North America	7.7	0.0	11.5	10.5	12.9	X
First in North America but not first in world	12.1	2.1	12.9	5.1	12.5	X
World first	4.4	0.0	14.4	3.7	37.7	X
New or significantly improved processes	48.0	8.2	51.3	15.9	52.2	10.7
Manufacturing methods	37.7	6.2	42.9	14.4	41.4	5.7
Logistics, delivery or distribution methods	13.0	1.3	14.4	3.9	15.2	5.7
Support activities for processes	28.3	3.7	28.1	5.9	30.5	10.7
Novelty of new or significantly improved processes introduced						
Only firm first	77.2	87.5	75.7	84.1	78.2	X
First in province but not first in Canada	9.8	0.0	7.1	1.6	5.3	X
First in Canada but not first in North America	4.0	0.0	6.2	10.7	3.5	X
First in North America but not first in world	6.1	8.1	6.7	1.3	4.3	X
World first	3.0	4.4	4.3	2.3	8.6	X
Novelty of new or significantly improved products or processes introduced						
First in province	34.7	17.1	45.0	25.8	63.3	X
First in Canada	22.0	6.7	35.7	18.1	60.0	X
First in North America	15.1	6.7	24.9	8.0	47.4	X
World first	4.2	2.4	12.6	3.4	35.6	X
Organizational innovations	43.9	7.2	47.7	15.7	59.5	22.5
Knowledge management	26.1	3.1	28.3	9.1	35.8	17.4
Organization of work	33.4	5.4	35.2	11.0	43.0	17.4
External relations	16.7	3.4	21.6	6.6	33.6	5.0
Marketing innovations	17.3	2.9	23.1	8.9	33.4	5.0
Design or packaging	12.0	2.9	16.5	6.2	25.1	0.0
Sales or distribution methods	11.2	1.3	14.5	4.8	21.0	5.0

Source: Statistics Canada (2008)

Table 13A: Novelty of Innovation in Forest Sub-Sectors (Advanced Tech Users vs. Advanced Tech Non-Users)								
	Forest Sector		**Logging**		**Wood Product**		**Paper**	
	AT user	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**
New or significantly improved products	40.8	11.6	20.4	9.2	42.8	12.8	48.7	29.7
Goods	35.2	6.2	12.6	1.4	36.8	9.9	45.7	29.7
Services	20.7	9.3	16.9	9.2	21.8	8.6	20.5	44.5
Novelty of new or significantly improved products (goods/services) introduced								
Only firm first	62.4	83.6	69.5	91.5	70.0	78.3	44.3	X
First in province but not first in Canada	13.5	14.3	17.3	8.5	14.2	21.7	10.9	X
First in Canada but not first in North America	7.7	0.0	5.3	0.0	4.5	0.0	15.5	X
First in North America but not first in world	12.1	2.1	7.9	0.0	9.4	0.0	19.0	X
World first	4.4	0.0	0.0	0.0	1.9	0.0	10.7	X
New or significantly improved processes	48.0	8.2	27.5	7.0	50.3	8.7	55.5	18.2
Manufacturing methods	37.7	6.2	15.5	3.8	41.3	8.0	43.0	18.2
Logistics, delivery or distribution methods	13.0	1.3	6.6	0.5	14.2	1.7	14.2	6.7
Support activities for processes	28.3	3.7	18.4	3.7	30.2	2.5	29.9	18.2
Novelty of new or significantly improved processes introduced								
Only firm first	77.2	87.5	73.3	100.0	80.1	90.9	71.8	X
First in province but not first in Canada	9.8	0.0	13.0	0.0	9.6	0.0	9.2	X
First in Canada but not first in North America	4.0	0.0	0.0	0.0	3.2	0.0	7.0	X
First in North America but not first in world	6.1	8.1	9.0	0.0	5.1	0.0	7.5	X
World first	3.0	4.4	4.7	0.0	2.0	9.1*	4.6	X
Novelty of new or significantly improved products or processes introduced								
First in province	34.7	17.1	29.0	6.4	30.3	20.9	55.5	18.2
First in Canada	22.0	6.7	15.4	0.0	16.0	4.7	43.0	18.2
First in North America	15.1	6.7	12.2	0.0	11.2	4.7	14.2	6.7
World first	4.2	2.4	3.8	0.0	2.4	4.7	29.9	18.2

Source: Statistics Canada (2008)

Table 14A: Product Innovations Forest Sector (Advanced Tech User vs. Non-User)								
	Logging		**Wood**		**Paper**		**Forest Sector**	
	AT user	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**
Only firm First	69.5	91.5	70.0	78.3	44.3	X	**62.4**	**83.6**
First in Province or Territory but not first in Canada	17.3	8.5	14.2	21.7	10.9	X	13.5	14.3
First in Canada but not North America	5.3	0.0	4.5	0.0	15.1	X	**7.7**	**0.0**
First in North America but not in the world	7.9	0.0	9.4	0.0	19.0	X	**12.1**	**2.1**
World	0.0	0.0	1.9	0.0	10.7	X	**4.4**	**0.0**

Source: Statistics Canada (2008)

Table 15A: Process Innovations Forest Sector (Advanced Tech User vs. Non-User)								
	Logging		**Wood**		**Paper**		**Forest Sector**	
	AT user	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**	**AT user**	**AT non-user**
Only firm First	73.3	100.0	80.1	90.9	71.8	X	77.2	87.5
First in Province or Territory but not first in Canada	13.0	0.0	9.6	0.0	9.2	X	**9.8**	**0.0**
First in Canada but not North America	0.0	0.0	3.2	0.0	7.0	X	**4.0**	**0.0**
First in North America but not in the world	9.0	0.0	5.1	0.0	7.5	X	6.1	8.1
World	4.7	0.0	2.0	9.1	4.6	X	3.0	4.4

Source: Statistics Canada (2008)

Table 16A: Impacts of the effects following the adoption of advanced technology (Advanced Technology Users)

	Forest Sector	All Manufacturing	ICT Manufacturing
Improvement in Productivity	81.8	84.3	86.2
Reduced labour requirements per unit of output	73.3	76.8	78.4
Reduced material consumption per unit of output	66.2	68.1	65.7
Reduced set-up time	70.0	72.6	71.3
Reduced cycle or processing time	73.1	76.0	76.6
Reduced error/rejection rate	73.7	77.5	78.6
Product improvement	80.3	83.8	88.4
New product features	54.6	62.0	73.5
Reduced time to market	55.5	62.1	75.8
Improvement in product quality	76.2	79.2	86.0
Improved satisfaction of client needs	75.6	78.9	85.3
Business unit organization changes	77.2	81.3	83.9
Increased flexibility, customization and/or specialization	69.6	73.6	79.5
Increased skill requirements	74.0	78.6	81.1
Business unit efficiencies	79.2	81.4	81.8
Increased overall equipment (OEE) utilization rate	68.4	71.5	68.2
Reduced energy consumption	62.1	63.4	59.5
Reduced energy costs	61.6	62.7	57.7
Improved integration and coordination of activities with suppliers and/or customers	64.2	67.7	74.3
Market performance	84.8	87.2	91.2
Increased market share	59.1	68.2	77.4
Increased profitability	76.8	80.6	85.4
Keeping up with competitors	81.2	82.0	87.0
Opening new export markets	48.9	57.8	71.3
Increased ability to respond to customer requirements	74.9	80.0	86.1
Improved ability to adapt to supplier capabilities	58.1	65.8	76.6
Other	55.6	57.4	54.4
Reduction of environmental impacts	55.4	57.3	54.3
Other	1.0	0.5	0.1

Source: Statistics Canada (2008)

Table 17A: Impacts of Adoption (Forest Sector Innovator vs. Non-Innovator)								
	Logging		Wood		Paper		Forest Sector	
	Innovator	Non-Innovator	Innovator	Non-Innovator	Innovator	Non-Innovator	Innovator	Non-Innovator
Improvement in productivity	78.5	36.3	94.2	67.1	93.0	56.8	92.1	57.1
Product improvement	78.2	30.2	92.0	65.8	91.8	65.9	90.4	56.3
Business unit organization changes	73.3	34.7	87.6	64.3	90.9	50.3	86.9	54.0
Business unit efficiencies	78.3	40.2	88.6	65.4	91.4	59.9	88.2	57.8
Market performance	83.2	41.7	93.9	74.7	94.7	72.8	92.9	65.6
Reduction of environmental impacts	60.9	27.2	60.8	41.2	67.7	43.3	62.8	37.9

Source: Statistics Canada (2008)

Table 18A: Average percentage of business units' total revenue that came from the sale of products (goods or services) to clients in different countries								
	Forest Sector		Mining		All Manufacturing		ICT sectors	
	AT user	AT non-user	AT user	AT non-user	AT user	AT non-user	AT user	AT non-user
In province or territory	56.1	81.6	60.2	85.2	50.5	70.0	27.2	54.5
In the rest of Canada	13.7	6.3	13.0	6.4	17.3	14.8	14.8	24.5
United States	25.3	10.4	22.8	7.8	25.7	12.3	39.2	17.3
Mexico	0.3	0.0	0.6	0.0	0.9	0.0	1.2	0.0
Europe	1.7	1.4	0.9	0.0	2.3	1.1	8.7	1.2
Asia Pacific	2.0	0.2	1.0	0.0	1.8	1.4	5.4	2.3
All other countries	1.0	0.1	1.5	0.6	1.6	0.4	3.6	0.2

Source: Statistics Canada (2008)

Table 19A: Average percentage of business units' total revenue that came from the sale of products (goods or services) to clients in different countries (Forest Sector)								
	Logging		Wood		Paper		Forest Sector	
	AT user	AT non-user	AT user	AT non-user	AT user	AT non-user	AT user	AT non-user
In province or territory	83.8	90.0	52.4	72.4	47.3	76.6	56.1	81.6
In the rest of Canada	3.6	2.9	15.2	9.7	16.5	11.8	13.7	6.3
United States	11.0	7.1	28.4	14.0	26.7	11.6	25.3	10.4
Mexico	0.0	0.0	0.1	0.1	0.7	0.0	0.3	0.0
Europe	0.3	0.0	1.7	3.1	2.6	0.0	1.7	1.4
Asia Pacific	0.9	0.0	1.3	0.4	4.4	0.0	2.0	0.2
All other countries	0.4	0.0	0.8	0.2	1.7	0.0	1.0	0.1

Source: Statistics Canada (2008)

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